

# Impressum

## EDITOR-IN-CHIEF

Ivica Kuzmanić

## SENIOR EDITOR

Pero Vidan

## EXECUTIVE EDITORS

Research Integrity: Joško Šoda

Student ToMS: Igor Vujović

Electronic Publishing: Vedran Elez

Management: Nikola Račić

Language Editors: Bisera Plančić,

Adelija Čulić-Viskota

Book Reviews: Andrija Nenadić

Manuscript Editor: Branka Bedalov

## REGIONAL EDITORS

Andrej Dávid (Zilina, Slovakia)

Nebo Jovanović

(Stellenbosch, South Africa)

Mirsad Kulović

(Travnik, Bosnia and Herzegovina)

## ADVISORY BOARD

Sanja Bauk (Kotor, Montenegro)

Zlatimir Bičanić (Split, Croatia)

Rudolf B. Husar (St. Louis, USA)

Natalija Jolić (Zagreb, Croatia)

Josip Kasum (Split, Croatia)

Danko Kezić (Split, Croatia)

Tomislav Kos (Zagreb, Croatia)

Zlatan Kulenović (Split, Croatia)

Rosanda Mulić (Split, Croatia)

Sanja Steiner (Zagreb, Croatia)

Elen Twrđy (Portorož, Slovenia)

## EDITORIAL OFFICE

Transactions on Maritime Science

Faculty of Maritime Studies

Zrinsko-Frankopanska 38

21000 Split, Croatia

[www.toms.com.hr](http://www.toms.com.hr)

[office@toms.com.hr](mailto:office@toms.com.hr)

## PUBLISHER

Faculty of Maritime Studies

Zrinsko-Frankopanska 38,

21000 Split, Croatia

## DESIGN

Offstudio, Zagreb, Croatia

Ana Banić Göttlicher and Maša Vukmanović

## Abstracting/Indexing:

Hrčak

Index Copernicus

## Subscription

Subscription runs for full calendar year. The price per volume, supplements and surface postage included: institutional € 15, individual € 10, and student € 8, or equivalent in other currencies; for Croatia: institutional HRK 120, individual HRK 70, and student HRK 50. Orders can be placed at Faculty of Maritime Studies (for ToMS); IMEX Bank, account number 7000001039, IBAN HR7724920087000001030, BIC/SWIFT IMXXHR22.

Published twice a year.

Printed on acid-free paper

(print ISSN 1848-3305).

ToMS on line (ISSN 1848-3313)

offers free access to all articles.

[www.toms.com.hr](http://www.toms.com.hr)



[Transactions on Maritime Science \(ToMS\)](#) is a scientific journal with international peer review which publishes scientific papers in the following areas:

- ~ Marine Engineering,
- ~ Navigation,
- ~ Safety Systems
- ~ Marine Ecology,
- ~ Hydrography,
- ~ Marine Automation and Electronics,
- ~ Transportation and Modes of Transport,
- ~ Marine Information Systems,
- ~ Maritime Law,
- ~ Management of Marine Systems,
- ~ Marine Finance,
- ~ Bleeding-Edge Technologies,
- ~ Multimodal Transport,
- ~ Psycho-social and Legal Aspects of Long-term Working Aboard.

The journal is published in English as an open access journal, and as a classic paper journal (in limited editions).

ToMS aims to present best maritime research from South East Europe, particularly the Mediterranean area. Prior to being accepted for publication, each paper is reviewed by at least two reviewers. With the intention of providing an international perspective at least one of the reviewers will be from abroad. ToMS also promotes scientific collaboration with students and has a section titled Students' ToMS. These papers also undergo strict peer reviews. Furthermore, the journal publishes short reviews on significant papers, books and workshops in the fields of maritime science.

The views and opinions expressed in the papers are those of individual authors, and not necessarily those of the ToMS editors. Therefore, each author will take responsibility for his or her contribution as presented in the paper.

# Contents

4	<b>Editors's Word</b> Ivica Kuzmanić	35	<b>Cutting-edge Mathematical Tools in Processing and Analysis of Signals in Marine and Navy</b> Igor Vujović Joško Šoda Ivica Kuzmanić
	<b>INVITED PAPER</b>		
5	<b>May the Wind Be at Your Back</b> Matko Marušić	47	<b>The Importance of Correct Punctuation and Capitalisation</b> Siniša Ninčević Željka Zanchi
	<b>REGULAR PAPERS</b>		<b>ART</b>
12	<b>Valuation of Road Infrastructure in Urban and Traffic Study of the City of Split</b> Hrvoje Baričević Matija Glad	58	<b>Vela Luka</b> Gordana Burica
17	<b>Effectiveness and Ergonomic of Integrated Navigation System</b> Pero Vidan Tatjana Stanivuk Toni Bielić		<b>NEWS</b>
22	<b>Design of Deadlock Prevention Supervisor in Waterway with Multiple Locks and Canals</b> Danko Kezić Stjepan Bogdan Josip Kasum	59	<b>IMSC 2012: Upcoming Conference on Maritime Science</b>
		60	<b>Guidelines for Authors</b>

# Editor's Word

Ivica Kuzmanić



Dear Readers,

In front of you, after a long preparation and severe labour pains, there is the first issue of the internationally reviewed scientific journal "Transactions on Maritime Science." It is published by the Faculty of Maritime Studies in Split which is the successor to the institution based in 1959. This Journal has arisen from the Proceedings of the Maritime College in Split (ISSN 1332-585X) with 55 papers published in the 5 issues from the year 2000 to 2005. For the time being the Journal will be published twice a year: in April and October.

The Journal is published in an electronic, open access, and printed edition. Our desire is that readers can access it easily and cheaply. In addition to traditional technical, engineering issues visible in the publishing information, we publish papers from all scientific fields that gravitate toward seafaring. We believe that reviews of the basic activity by e.g. lawyers, economists and psychologists are also significant. They are not so common, but with us they will be gladly accepted. We will also nurture works that are created in collaboration with students, trying to involve them in scientific work.

From time to time artistic experiments related to sea will be accepted for publishing – the only thing that will be published in two languages, both in Croatian and, hoping for a successful translation, in the English language. It is our desire to preserve our language of the islanders. Despite the fact that Croatia is famous for its more than 1000 islands, their numerous dialects faced with the challenges of modern times are slowly disappearing.

For easier availability the Journal is published in English – the language essential in shipping. Therefore, this first issue brings forth a paper that aims at improving communication in English since we are all aware of how misunderstandings and poor communication may lead to accidents. This trend will continue.

This Journal would still not be available for quite a long time if it had not been for an unselfish assistance of professors Ana and Matko Marušić, editors-in-chief of the distinguished „Croatian Medical Journal“ for twenty years. I would like to thank them from my heart for making this possible!

We hope that the papers published will prompt you to cooperation. We heartily hope so!



# May the Wind Be at Your Back

Matko Marušić<sup>1</sup>

With this issue, the Faculty of Maritime Studies Split is starting a scientific journal, *Transactions on Maritime Science*. This I salute for two reasons: firstly because a scientific journal is culturally a very important achievement (Marušić, 2005; Marušić, 2006), and secondly because the editors have kindly asked my advice, considering me a seasoned editor (Marušić, 2010). They also asked me to write (a long) editorial for the first issue. This gives me the opportunity to offer my recommendations for the future of the journal, which I like to do (Marušić, 2010; Marušić, 2011). I wish the *Transactions* all that its editors certainly dream of – indexing in prestigious databases and then a decent impact factor. With good and dedicated work, this will take about a decade (Marušić and Marušić, 2002), and I will be safe even if that does not happen: advice was given (even published), and my work and responsibilities are over; anything else I do will constitute an added value, but the full responsibility is on the editors.

Starting a new scientific journal, especially in a small scientific community, is a daring, long-lasting and never-ending endeavour – one should think twice before embarking on such a task (Marušić, 2010; Marušić, 2011). Just as authors publish for many different reasons, so do editors start a new journal for different reasons, not only because they want to present the latest scientific discoveries, but also to teach, to inform, to console, to amuse, to stimulate discussion, to make money.

## KEY WORDS

- ~ Journals
- ~ Publishing
- ~ Open access
- ~ Indexing
- ~ Responsible publishing

## 1. WHY A NEW JOURNAL?

A scientific journal primarily promotes research culture in the community (Marušić and Marušić, 1995). The journal, in a very special way, is a centre of scientific activity; it sets scientific criteria and helps researchers make their work public (Marušić and Marušić, 1999). It also represents the local scientific community to the rest of the world. This is especially important for smaller and economically less privileged countries because via a scientific journal they can join the mainstream science, learn from it, and contribute to its achievements (Marušić et al., 2006; Marušić and Marušić, 2007; Marušić and Marušić, 2009). Good journals in small communities open the doors and windows to the world: doors because publishing in a local journal with international criteria will increase local criteria, knowledge and research integrity, and windows because the rest of the world can see and judge local science (Marušić and Marušić, 1999).

Although it is almost certain that scientists from a small and less developed country will not make any really significant discovery, supporting science in such countries is almost equally if not more important than in the large and developed ones. For small nations, the fastest route to advancement, progress, and closing or narrowing the gap to the developed countries is precisely through the development of science. Scientists are those who can most easily receive knowledge from the more developed countries and pass it on to the younger generations (Marušić, 2005). In other words, scientists are best students and best teachers. And there is no progress without learning.

Since the quality and quantity of scientific work is assessed on the international level – through scientific publications, which include at least two very strong control mechanisms – reviewing of the reports and their permanent visibility after publication – cheating is rendered practically impossible (Marušić, 2008); this means that science by itself is an activity that fosters and maintains integrity and honesty. Since there are no results without real and hard work, science develops working habits, orderliness, punctuality, and other virtues indispensable for personal and national progress (Marušić, 2005).

1. University of Split, School of Medicine, Šoltanska 2, 21000 Split, Croatia  
E-mail: matko.marusic@mefst.hr

### 1.1 Audience

As knowledge is the property of the whole humankind, scientists – wherever they are – should contribute to the generation of new scientific knowledge. The audience of a scientific journal can thus only be the global scientific community (Marušić, 2005). Some local scientific communities will contribute less and some other much more, but even the smallest contribution is addition to the global knowledge (Mohr, 1977). A scientific journal may publish articles of different quality and impact, but the key principle of internationality remains unchanged: a scientific journal must be open to all and aim at all scientists (Marušić, 1992).

### 1.2 Language

Publishing in a national language is necessary and important for the local community, and journals addressing national educational and professional issues should therefore exist and be supported (Nylenda et al., 2003; Sambunjak et al., 2009). However, English language has become the language of global science, so a new journal striving to make contributions to the global knowledge usually decides to publish in English. This is a pragmatic question – an effort to achieve recognition and acceptance in international research circles. It is harder to attract authors and readers if the international presentation of the journal is limited, and the same is true for citations, indexing in bibliographic databases, subscription and electronic publishing.

## 2. THE NICHE

The most important thing for a new (particularly small) journal is its profile, the niche it aims to fill in the crowded world of scientific journals (Marušić et al., 2005). Determination of the niche is directly related to the reasons why the journal was started. The journal may have educational, scientific, or professional purpose(s), and this purpose determines its readership. The characteristics of the readership determine the language of the journal, and the purpose of the journal determines the sources of financing (Marušić and Marušić, 2009).

There are many good scientific journals in the world, both in the mainstream science and the so-called “scientific periphery”. They cover all areas of research, even the smallest and most specific ones (Marušić and Marušić, 2009), and a new journal cannot often rely on the idea that it will be scientifically either better or more original than other journals. Therefore, if not endowed with some specificity, a new journal will immediately be lost in the endless pool of similar but already established journals. Thus, the first step of considering establishing a new journal is to find its place, its specific niche in the scientific world and then build its profile and all its other features accordingly (Marušić et al., 2005). The small cannot compete with the great in hot topics of the mainstream science, in the medical example (which I know)

– the heart physiology or molecular biology in medicine. Thus, they should seek their chance, even advantages, in the specific areas and ideas, needs, environmental characteristics, and social and political specificities of the country/ies they represent. In other words, local problems, even tragedies such as war (Marušić and Marušić, 2002; Sambunjak and Ivaniš, 2006), can be sources of precious knowledge for all mankind. It is impossible to give more specific advice on the question of journal's niche – except to reiterate that the founders of a new journal first have to define why they want to start it. A sincere answer to this question is the best beginning for a journal (Lacković, 1992). If the answer is “to have our own journal” on a specific topic, the life of the journal will be hard and, more often than not, brief.

## 3. LEGAL STATUS

Journals in small scientific communities usually start as an enthusiastic effort of an individual within an institution. Journal's legal position, rights and responsibilities are often not clear in a complicated and confusing organization of the system. This perhaps gives a certain freedom to the editor but burdens the position of the journal in the long run. I will take a liberty to strongly advise editors to think about the legal status of the journal and roles of all parties (stakeholders) involved in its making and functioning (Marušić et al., 2003; Huth, 2004). These issues should be considered early on, so that journal may grow into a stable institution embedded in the system, regardless of the system's weaknesses (Marušić and Marušić, 2007). The journal's organizational structure should involve all parties relevant for the journal's existence and clearly define their roles. Each party (the owners, publishers, sponsoring institutions, journal boards, editors) should have responsibilities and privileges and none, either by power or by weakness, should endanger the journal's existence and editorial freedom (Marušić et al., 2003).

## 4. FINANCING

There are three important points in running a journal in a small scientific community: first, the journal should have at least some financial independence; second, the publisher should be stimulated to make profit, however small it may be; and third, the financial burden should be distributed among all stakeholders involved. Each involved party must contribute (financially) to the journal because this stimulates responsible behaviour and active involvement (Marušić et al., 2003).

The question of editor's salary is a sensitive one, and should be solved decisively. Editors-in-chief of small learned journals are often active researchers and professionals, who take on the role of journal editor only part time and for a limited period. Editorship is for them more of an honorary position than a real workplace. I strongly recommend such editors not to take money

for their editorial work if they do not work full time. Volunteer position (they have not become editors or even started the journal because of money but because of genuine enthusiasm) gives the editor more freedom, strengthens his or her editorial independence and reduces possible conflict of interest. Salary for editorial work may be considered only if the growth of the journal requires it, or the editor decides on a full-time position.

## 5. PROMOTION

Small and newly-founded journals have fewer opportunities for promotion than the big and established ones: they have to make their name in the large family of already existing scientific journals. Regardless of the aims of journal promotion, its success is directly related to its quality. This does not mean only the quality of research published, but also the working ethics, quality of editorial work and dedication invested in the journal. It also means the wisdom to find the best niche for the journal, where it could show its quality and value and have greater chance to be recognized by the scientific community (Marušić and Marušić, 2005).

The promotion of a journal can target different populations and goals: it may wish to a) attract good authors, b) get more readers, c) make more money, or d) get included in bibliographic databases. Tactics of reaching these goals and their outcomes often overlap, because one success automatically brings about another one (Marušić and Marušić, 2005).

### 5.1 Attracting Authors

Authors are perhaps the best medium for journal promotion, because a happy author comes back again and also spreads the news of a good new journal. If an author has strong incentive to publish in a specific journal, he or she will not hesitate to pay colour pages, buy reprints, subscribe to the journal, and even recommend advertisements in the journal. Good authors will also be faithful readers and recommend it to other readers and librarians in their institution.

This is a goal whose outcome depends on the editor and the editorial staff. Honest and hard work, prompt responses to authors' manuscripts, and author-helpful policy are the key to success (Marušić and Marušić, 2001; Marušić and Marušić, 2005a, b; Mišak et al., 2005).

Author-helpful policy (Marušić and Marušić, 1999; Marušić and Marušić, 2001, Marušić and Marušić, 2005a, b; Mišak et al., 2005; Marušić et al., 2006) is very important for small journal from small or developing scientific communities, where researchers often have fewer opportunities to do expensive mainstream research and possess poorer writing skills. Journal editor should be a teacher in such a community (Marušić and Marušić, 2004; Marušić and Marušić, 2006; Marušić et al., 2004, Marušić et al., 2006; Mišak et al., 2005) and take active role in educating

fellow researchers how to do better research and write better manuscripts (Marušić and Marušić, 2003; Marušić and Marušić, 2004; Marušić et al., 2002, Marušić et al., 2006). Working with the authors for his or her own journal, the editors increase the ability of their authors to publish in other, even better and more influential mainstream journals. Later on, these authors will submit better papers to the journal of their editors-educators, and thus close a positive circle of improving journal quality (Marušić and Marušić, 2001). Such author-helpful policy really works (Marušić et al., 2006) and we recommend it to editors of small journals – it is a lot of work, but it pays off enormously, primarily in the quality and visibility of the journal.

### 5.2 Attracting Readers

Attracting readers is maybe even harder than attracting authors. An author-helpful policy and adequately defined niche of the journal may attract a sufficient number of contributors, but attracting the readers has less strategic ground, and basically cannot be measured. Most editors think, perhaps even subconsciously, that the readers will come along just by themselves – when they have a look at their beautiful new journal. This is wrong: with so many scientific journals around, scientists usually stick to what they know or like or respect, and read little outside their small selection of journals.

However, readers (who are often authors, too) search for information in bibliographic databases or on the Internet and will notice the new journal if the information on its articles is published in these media. Consequently, the two best approaches to increase the readership of the journal and its visibility are: 1) inclusion in bibliographic databases, such as general data bases of the Institute for Scientific Information (Science Citation Index, Current Contents, Web of Science) or specialized data bases, such as Medline for the biomedical field, PsychINFO for psychology, INSPEC for electrical engineering or Agricola for agriculture; and 2) publishing part or full text of the journal on the Internet.

Another approach to make journal more visible is complementary to the two listed above: make the journal available in the libraries of the institutions with potential readership and authorship.

Before deciding on these promotional measures, the editor of a small and new journal will have to make an important decision: whether he or she wants the journal to make money or become visible. Namely, albeit not clear-cut at the first glance, the strategy for making money actually contradicts the strategy aiming to make the journal visible to readers (Kljaković Gašpić et al., 2007). I maintain that the essence of the small journal's strategy is to bring back profit, but that profit not measured in monetary gain.

Most journals in small scientific communities have to rely on financial support from the government or supporting organization. They will probably never become journals based on

profit, and I recommend them to use the most part their financial subsidy to disseminate information about the journal as widely as possible (Kljaković Gašpić et al., 2007). At least three actions are possible: publishing journal on the web, exchanging journals with other journals, and donating journals to libraries (Marušić et al., 2002; Huić, 2008).

### 5.3 Electronic Access to the Journal

For small journals, just starting and trying to find their place in the large community of scientific journals, electronic visibility is imperative and the best promotional move, especially if the full text of the articles is available for free! Small and new journals do not have many subscribers and do not make profit in the beginning. If they will ever achieve that, it will be only after years of hard work and investment into visibility and quality of the journal.

The cost of making and maintaining journal's web-site is not high for most of the small journals because they can use web-sites and services of their academic or research institutions or associations.

Electronic visibility is especially important for journals still not indexed in bibliographic databases. Web search engines will bring information from the journal to an interested reader – the electronic edition of the journal will thus get more visibility and readers than the paper edition.

Even if the journal is indexed in bibliographic databases which provide abstract of the published articles, they can increase visibility by providing full-text articles on the web, either right after (or even before) the printed version or after some reasonable time (2-6 months). Most established journals practice some form of free access to their articles, without major losses to subscription rates (Kljaković Gašpić et al., 2007).

### 5.4 Journal Exchange

Journal exchange is another way of increasing readership of the printed journal. As most of the small journals are affiliated to research or academic institutions, and the editors are usually professionals in their field, their research activity and contacts can promote the journal. The editor(s) can give the journal to other researchers and ask them to offer exchange to their local journal. This is a noble action: it contains elements of information exchange, collegial cooperation and kindness, simple comradeship, and charity. The gain is twofold. The journal will officially arrive to the (library) of another institution and will be visible to more potential readers. Also, editor's institution will get other journals and thus increase literature pool for their own readers/researchers. The editor's institution could also save some money on institutional journal subscription, which can be an argument for directing some of that money to the new journal.

The editors of small and new journals are strongly advised to become members of editors' associations, such as European Association of Science Editors (EASE), and regularly attend their

meetings. In addition to the opportunity to learn a lot about their work as editors and the ways to improve the quality of their work and journal, they can meet other editors, arrange journal exchange and thus further increase the visibility of their journal.

### 5.5 Journal Donations

There are still many financially disadvantaged research communities in the world which are too small and undeveloped and lack both the access to scientific journals in general and existence of a local journal. There are different initiatives, such as HINARI (Aronson, 2004), to provide online access to mainstream journals even in these research environments. Donating your journal, i.e., sending it to libraries of research and academic institution in these countries can also increase the visibility of the journal. Maybe the journal will be even better noticed in an environment without many paper editions of journals. Also, researchers from these environments may be more interested in publishing in smaller journals than in prestigious mainstream journals with high rejection rate.

## 6. MAKING PROFIT

The dream of every editor and publisher is to have many, many subscribers, earn a lot of money so that the work in the journal would depend only on the quality of science. Unfortunately, money is the greatest problem for small journals, creating a vicious circle where lack of money adversely affects the quality and visibility of the journal, which in turn exerts the negative effect to the subscription to the journal; diminishing the subscription diminishes the earnings – which affects quality and visibility (Marušić and Marušić, 1999; Marušić et al., 2005).

As said before, the editor of a small journal should decide before the work on journal promotion whether he or she wants money or visibility. Visibility comes before money (Kljaković Gašpić et al., 2007). In reality, making profit for a small journal in a small country means earning money for sheer survival.

### 6.1 Subscribers

With time and visibility, the journal can focus on subscribers – now it has a good product and the promotion will certainly be more successful.

It is difficult to give advice on best ways to increase subscription. Perhaps the best is to find big publisher and become one in the big family of journals. In this case, all promotional activities are done by the publisher which makes them more successful because the journal is usually offered for subscription with a number of more influential journals, wanted by most libraries (Kljaković Gašpić et al., 2007).

To small journals that chose to stay with a small independent publisher or institution as publisher, I can recommend only to carefully choose the target group of potential subscribers. Little will be achieved by sending out (expensive) advertising leaflets

to many addresses. It is better to concentrate on specific groups or promote the journal at carefully chosen conferences. Journal authors can be utilized as the promotion medium, asking them to recommend journal subscription to the librarians in their institutions.

With the increase in quality and visibility, research topics published in the journal may attract interest of specific professional associations and some of them may ask the journal to be their official publication with membership subscription. This must be utilized in a precise manner, at least so that the association in question subscribes at least a portion of its members to the journal (Marušić et al., 2003).

## 6.2 Advertisements

Advertisements do bring income, but present a sensitive ethical issue for journal editors because they are thorn between the profit and responsibility towards their readers (Smith, 2003). The most recent version of the Uniform Requirements for Manuscripts Submitted to Biomedical Journals: Writing and Editing for Biomedical Publication ([www.icmje.org](http://www.icmje.org)) state: Journals should have formal, explicit, written policies for advertising in both print and electronic versions; website advertising policy should parallel policy for the print version as much as possible. Editors must have full and final authority for approving advertisements and enforcing advertising policy.

Editor of a small journal will have problems finding advertisements in the beginning, but will probably be approached by advertising companies as the journal becomes visible and respected. This is true especially for journals serving as official publications of a professional association – advertising agencies are interested in reaching as many as possible members of the population working in a given professional field. The journals targeting very small groups or general (non-national) scientific audience will always have problems with advertising.

## 6.3 Selling Reprints and Journal Copies

This is a considerable source of income, even for small journals. In principle, most of the authors gladly buy reprints and journal copies, even pay additional fee for colour pictures. The authors should be informed in time of the rules, prices, and deadlines. Moderate prices will attract more authors.

## 6.4 Electronic Access Fee

Most established journals request a fee for access to their electronic edition. Many also provide free access to their archives. For a small journal, the best promotional strategy, at least in the beginning, is to drop any access fees to their electronic edition. Promotion should come before profit. In that sense, the most profitable action is investing in the development of journal's web edition (Kljaković Gašpić et al., 2007).

## Indexing in Bibliographic Databases

Indexing the journal in bibliographic databases is both the aim and the outcome of its promotion. Indexing in most widely used science information databases means an automatic, objective, and permanent journal promotion, and should be the key strategic goal of journal promotion, existence, and growth. Visibility brings about readers, authors and citations, stability and strength, and finally at least some financial gain and independence (Marušić et al., 2006). This is especially true in the environments where publishing in indexed journals is a prerequisite for academic promotion. Journals indexed in major bibliographic indexes cannot fail (Marušić and Marušić, 2004). Indexing brings about a completely different attitude to journal promotion: after indexing it can concentrate on detail and specificities, because most of the work has been accomplished. Indexing will attract enough authors, which guarantees survival.

Regardless of its importance and desirability, the editor should not hurry with applications for indexing! The rules and conditions of each target database should be studied carefully and fulfilled completely, and more. Rejection is not only painful, but often also carries along a period during which the new application is not acceptable. In any case, hastily reapplication has less chance than the first one. Shortly, when applying for inclusion in a database, the editor must be sure that the journal will be accepted (Marušić and Marušić, 2002).

## 7. SUCCESS OR FAILURE

A journal (and its editor) is successful when it has a steady inflow of manuscripts, regular publishing, visibility in bibliographic databases, editorial independence and integrity, and relative financial independence. This is not easy to achieve in a small journal, especially if it is produced in a small scientific community. General quality standards are the same for all journals, but small journals, even when published in English, are adversely affected by many factors (Marušić and Marušić, 1999). These are the small pool of authors who can produce scientifically strong studies; small and unreliable pool of reviewers; poor, biased and unstable financial resources; and difficulty in achieving perfection in English language. These factors close a vicious circle of inadequacy (Marušić and Marušić, 1999), which can be overcome only by a bold breakthrough. The essence of this breakthrough is hard and highly ethical work (Marušić and Marušić, 2007; Marušić et al., 2007; Marušić, 2011). New, small journals can expect fair treatment and friendly assistance from big, established journals, editors' associations, bibliographic institutions, and international scientific community in general. However, the strength and key to success is in themselves and their work.

To make a long story short, the list of parameters of a successful journal's work is this (Tobin, 2004):



1. submitted manuscripts;
2. profitability & distribution;
3. publication lag;
4. serving needs of our members/readers;
5. involvement of readers (letters to the editor);
6. readability;
7. use of advances in technology (internet, pdf, email);
8. editorial processes to ensure integrity of contents;
9. editorial independence;
10. fairness to authors;
11. improved practice.

## 8. FINAL ADVICE

The multitude of advices listed in this text can be narrowed down to two essential ones (Marušić, 2011).

First, the editor should not stop thinking of what is the true niche (purpose) of his/her journal. Science is much wider, much more versatile than it looks at the first glance. So, a smart editor can handsomely perfect the niche of his or her journal by carefully watching for the journal's position in the „science versatility spectrum.“ In other words, do not compete with the bigger and better in the mainstream science, find where you are special, interesting, internationally important, where you are better.

Second, the editor should never, ever, get tempted to be influenced in his/her decisions by anything but science. Only perfect honesty and honest objectivity, makes a good journal. Once you start „trading“ and making deals, there is no return. There are no deals in editorial work.

I do not wish you the calm seas, Transactions on Maritime Science, because you cannot have it; instead I wish the wind be at your back, to take you to high seas and many exciting adventures in publishing..

## REFERENCES

Aronson, B., (2004), Improving online access to medical information for low-income countries, *The New England Journal of Medicine*, 350(10), pp. 966-968., <http://dx.doi.org/10.1056/NEJMp048009>

Huic, M., (2008), Fifteenth anniversary of the Croatian Medical Journal: still moving ahead, *Croatian Medical Journal*, 49(1), pp. 1-7., <http://dx.doi.org/10.3325/cmj.2008.1.1>

Huth, E.J., (2004), A model of journal governance, *Science Editor*, 27(3), pp. 102.

Kljaković-Gašpić, M., Petrak, J., Rudan, I. and Biloglav, Z., (2007), For free or for fee? Dilemma of small scientific journals, *Croatian Medical Journal*, 48(3), pp. 292-299.

Lackovic, Z., (1992), Who needs Croatian Medical Journal?, *Croatian Medical Journal*, 33(1), pp. 67-77.

Marušić, A., Katavić, V. and Marušić, M., (2007), Role of editors and journals in detecting and preventing scientific misconduct: strengths, weaknesses, opportunities, and threats, *Medicine and Law Journal*, 26(3), pp. 545-566.

Marušić, A. and Marušić, M., (1995), Struggle for visibility. A small journal in a small country. *INASP newsletter*, 5(1995), pp. 8-9.

Marušić, A. and Marušić, M., (1999), Small scientific journals from small countries: breaking from a vicious circle of inadequacy, *Croatian Medical Journal*, 40(4), pp. 508-514.

Marušić, A. and Marušić, M., (2002), *Croatian Medical Journal: kako smo ušli u Current Contents*, *Ruder*, 3(9), pp. 6.

Marušić, A. and Marušić, M., (2002), What can medical journal editors do in war?, *The Lancet*, 360, Suppl: s59-60., [http://dx.doi.org/10.1016/S0140-6736\(02\)11825-3](http://dx.doi.org/10.1016/S0140-6736(02)11825-3)

Marušić, A. and Marušić, M., (2003), Teaching students how to read and write science: a mandatory course on scientific research and communication in medicine, *Academic Medicine*, 78(12), pp. 1235-1239.

Marušić, A. and Marušić, M., (2004), Clinical teaching in a time of war, *The Clinical Teacher*, 1(1), pp. 19-22., <http://dx.doi.org/10.1111/j.1743-498X.2004.00012.X>

Marušić, A. and Marušić, M., (2005), Promotion of journals, especially small scholarly journals, In: *Science Editors' Handbook*, European Association of Science Editors, available at: <http://www.ease.org.uk/handbook/index.shtml/>, [accessed 20 September 2011.].

Marušić, A. and Marušić, M., (2005a), Should editors train authors in science communication?, *European Science Editing* 31(3), pp. 81-83.

Marušić, M., (1992), Editorial: the first issue of the Croatian Medical Journal, *Croatian Medical Journal*, 33(1), pp. 1-2.

Marušić, M., (2005), Science and patriotism, *Macedonian Academy of Sciences and Arts, Contributions, Section of Biological and Medical Sciences*, 26(1), pp. 5-11.

Marušić, M., (2006), Važnost znanosti za Hrvatsku i Hrvatske za znanost, In: *Ministarstvo znanosti, prosvjete i športa. Zbornik. Prvi kongres hrvatskih znanstvenika iz domovine i inozemstva, Vukovar 15.-19. studenoga 2004.*, Zagreb: *Ministarstvo znanosti, obrazovanja i športa*, pp. 366-378.

Marušić, M., (2010), *Life of an editor*, Zagreb: *Croatian Medical Journal and Medicinska naklada*.

Marušić, M., (2011), My life as an editor, *European Science Editing*, 37(1), pp. 19.

Marušić, M., Bošnjak, D., Rulic-Hren, S. and Marušić, A., (2003), Legal regulation of the Croatian Medical Journal: model for small academic journals, *Croatian Medical Journal*, 46(6), pp. 663-673.

Marušić, M., editor. (2008), *Principles of research in medicine*, 1st edition, Zagreb: *Medicinska naklada*.

Marušić, M. and Marušić, A., (2001), Good editorial practice: editors as educators, *Croatian Medical Journal*, 42(2), pp. 113-120.

Marušić, M. and Marušić, A., (2005b), Organizing the editorial office and educating contributors, In: *Science Editors' Handbook*. European Association of Science Editors, available at: <http://www.ease.org.uk/handbook/index.shtml/>, [accessed 20 September 2011.].

Marušić, M. and Marušić, A., (2007), Threats to the integrity of the Croatian Medical Journal, *Croatian Medical Journal*, 48(6), pp. 779-785.

Marušić, M. and Marušić, A., (2007), Načela državne politike u vođenju i poticanju izvrsnosti znanstvenih časopisa, In: *Vitale B i sur. Četiri stoljeća javnoga zdravstva i biomedicine u Hrvatskoj*. Zagreb: *Medicinska naklada i Akademija medicinskih znanosti Hrvatske*, pp. 354-65.

- Marušić, M. and Marušić, A. (2009), The purpose of scientific journals: small is important, *The Journal of Teheran University Heart Center*, 4(3), 143-147.
- Marušić, M., Markulin, H., Lukić, I.K. and Marušić, A., (2006), Academic advancement of authors receiving tutoring from a medical journal, *Teaching and Learning in Medicine*, 18(2), pp. 126-129., [http://dx.doi.org/10.1207/s15328015tlm1802\\_6](http://dx.doi.org/10.1207/s15328015tlm1802_6)
- Marušić, M., Marušić, A., King, R., and Tamber, S.P. (2005), Establishing a new journal, In: *Science Editors' Handbook*. European Association of Science Editors, available at: <http://www.ease.org.uk/handbook/index.shtml>, [accessed 20 September 2011.].
- Marušić, A., Mišak, A., Kljaković-Gašpić, M., and Marušić, M., (2002), Educatione ad excelentiam – ten years of the Croatian Medical Journal, *Croatian Medical Journal*, 43(1), pp. 1-7.
- Marušić, M., Mišak, A., Kljaković-Gašpić, M., Fišter, K., Hren, D. and Marušić, A., (2004), Producing a scientific journal in a small scientific community: an author-helpful policy, *International Microbiology*, 7(2), pp. 143-147.
- Marušić, A., Sambunjak, D. and Marušić, M., (2006), Journal quality and visibility: is there a way out of the scientific periphery?, *Macedonian Academy of Sciences and Arts, Contributions, Section of Biological and Medical Sciences*, 27(1), pp. 151-161.
- Marušić, M., Sambunjak, D. and Marušić, A., (2006), Life of small medical journal – how bibliographical indexing and international visibility affected editorial work in Croatian Medical Journal, *Croatian Medical Journal*, 47(3), pp. 372-375.
- Mišak, A., Marušić, M. and Marušić, A., (2005), Manuscript editing as a way of teaching academic writing: experience from a small scientific journal, *Journal of Second Language Writing*, 14(2), pp. 22-31., <http://dx.doi.org/10.1016/j.jslw.2005.05.001>
- Mohr, H., (1977), *Lectures on structure and significance of science*, New York-Heidelberg: Springer Verlag.
- Nylen, M., Hagve, T-A. and Marušić, A., (2003), Small journals and non-English journals, In: Godlee F, Jefferson T. *Peer review in health sciences*. London: BMJ Books, pp. 140-150.
- Sambunjak, D. and Ivaniš, A., (2006), Survive, help, learn: experience of a medical journal in war and post-war times, *Journal of Public Health Policy*, 27(2), pp. 124-135., <http://dx.doi.org/10.1057/palgrave.jphp.3200070>
- Sambunjak, D., Huić, M., Hren, D., Katić, M., Marušić, A. and Marušić, M., (2009), National vs. International Journals: Views of Medical Professionals in Croatia, *Learned Publishers*, 22(1), pp. 57-70., <http://dx.doi.org/10.1087/095315108X378785>
- Smith, R., (2003), Medical journals and pharmaceutical companies: uneasy bedfellows, *British Medical Journal*, 326(7400), 1202-1205., <http://dx.doi.org/10.1136/bmj.326.7400.1202>
- Tobin, MJ, (2004), Assessing the Performance of a Medical Journal, *American Journal of Respiratory and Critical Care Medicine*, 169(12), pp. 1268-1272., <http://dx.doi.org/10.1164/rccm.2404006>

# Valuation of Road Infrastructure in Urban and Traffic Study of the City of Split

Hrvoje Baričević<sup>1</sup>, Matija Glad<sup>2</sup>

Functional reciprocity of all transport sectors with their infrastructure support is most evident in ports. The port of Split, integrated in Split's traffic intersection, is a striking example of uniqueness of Split-Dalmatia County as a traffic and economic centre of Central Dalmatia. The development of City's harbour for passenger traffic and the North Port for cargo traffic has determined already set constellation of relations of maritime, road and rail traffic, and their mutual interference. The road transport and activities with regard to hinterland services generate economic development in which Split is no exception. This estimate is based on changes that can be expected in terms of redistribution of traffic flow in the central and southern Adriatic and the greater role of road transport, with Split having an increasingly important role.

## KEY WORDS

- ~ Port of Split
- ~ Cargo and passenger flows
- ~ Road infrastructure
- ~ Logistics

## 1. INTRODUCTION

Reciprocity operation of all transport sectors with their infrastructure support is most evident in ports. The port of Split integrated in Split's traffic intersection is a striking example of uniqueness of Split-Dalmatia County, as a traffic and economic centre of Central Dalmatia. At this relatively confined and high quality space overlap agglomeration of Split, Solin and Kaštela, and the related port systems. As a very important future longitudinal segment of The Adriatic-Ionian Corridor, Split has the role of transit, as well as the starting point of landing in the circulation of all types of transport substrate. For this reason, the urban functions of the largest agglomeration on the Croatian part of The Adriatic Sea are very demanding and complex. Split's connection with the hinterland is more difficult because of extended Kozjak Mountain, and organization of traffic flows in the central area is particularly problematic. Periods of saturation are most pronounced in summer during the high tourist season. The development of City's harbour for passenger traffic and the North Port for cargo traffic has determined already set constellation of relations of maritime, road and rail traffic, and their mutual interference.

## 2. BASIC TRANSPORT-TECHNOLOGICAL PARAMETERS

When accepting the European traffic flows from West, Central and East Europe, and distributing them in the city of Split and mentioned port-basins, Split's traffic junction is determined by its transverse disposition between the branches «b» and «c», Pan-European corridor V, and the longitudinal direction of the Adriatic-Ionian corridor. Relevant characteristics and determinants of future development are decided by the Regional

<sup>1</sup> Faculty of Maritime Studies, Studentska ulica 2, 51000 Rijeka, Croatia

E-mail: [hrvoje@pfri.hr](mailto:hrvoje@pfri.hr)

<sup>2</sup> Hrvatske ceste, Nikole Tesle 9, 51000 Rijeka, Croatia

E-mail: [matija.glad@hrvatske-ceste.hr](mailto:matija.glad@hrvatske-ceste.hr)



Plan of the city of Split, the General Urban Plan of the city of Split (no special traffic plan), a traffic study of the wider area of Split (IGH), a state-level Transport Development Strategy of Croatia since 1999, and other supporting documents which are focused on port facilities and supporting facilities for the road and rail infrastructure.

The layout of the City Port and the North Port is emphasized as it is of particular importance and having in mind all transport sectors and the capacity of their infrastructure. Practically, infrastructure facilities of the road and rail traffic face the inner city area, at the lowest elevations near the sea. Therefore, they are in a very specific and high quality coastal area in the centre of Split-Dalmatia County, and the city's urban structure in which the City and Port operate as two complex systems, with their complementary activities.

However, the inherited County's transportation network, particularly right in the city centre of Split cannot meet increasing traffic demands of the development of both, the Port and City, and has no other alternative but, only possible solution to build integrated, intermodal transport hubs that would operate on the principle of sustainable development with the aim of increasing long-term effectiveness of the transport system as a whole. In the field of infrastructure and superstructure, major buildings and complex structures should be planned and implemented, which will mitigate the effects of inconsistent long-term transport policies.

The area of the city of Split with the corresponding ring of settlements may experience the economic revival of activating uncontested logistical resources, both in passenger and in freight traffic.

### 3. BASIC INFRASTRUCTURE

On the narrow catchment area of the city of Split, road traffic is characterized by inadequate road network density with relatively fair traffic and technical characteristics, inadequate quality of roads, signs and safety features. As regards the road transport, the construction of motorways and expressways along the state lines has recently retained the dominance in the Republic of Croatia, what is justified by the spatial indented network and enabling «door to door» system. With construction of the high capacity road, A1 highway, Split-Dalmatia County permanently solved the problem of connection with the capital.

The relatively large distance (approximately 20 km) from the node Dugopolje to the city reduced its level of availability, and alternative Adriatic tourist road (JTC) partially retained the role of road links to Šibenik and Zadar.

Underlying Adriatic highway cannot adequately serve the primary flow connection with the littoral cities and villages of Central and South Dalmatia for traffic and exploitation, safety, environmental, economic exploitation and other reasons.

So the question of interregional connections and a need to

build a parallel four-lane highway remained opened.

With regard to the road transport, links with the hinterland of Split's harbour, there is a significant capital project Trans-European North – South (TEM) Motorway, which runs from Szczecina to Prague, Bratislava, Hungary, Zagreb and Rijeka to Dubrovnik and further on to Greece. Present status and development of road transport infrastructure in the logistics of the considered traffic direction, and the EU transport system determine the basic road corridors connecting The Republic of Croatia with Europe. These will form the basis for the conclusions on the state road network when it comes to linking the harbour of Split to its catchment area, as an important determinant for the evaluation of geotrafical position.

Apart from the standpoint of supply, competitiveness of existing road infrastructure should be considered, as already stated, in relation to traffic demand, the demands placed before it, set the current and potential market (users of transport services) transport route Zagreb-Split and given the continued motorway A1 towards Dubrovnik. Traffic demand in the road traffic is observed on the basis of data on traffic flows on road network obtained by counting the traffic on the roads, which is calculated using the average annual daily traffic (AADT) and the number of vehicles per day. Nota bene, with respect to the traffic from other countries, Split harbour has its greatest tourist transit traffic, it is expected that parts of the road in the Croatian territory which connect the port of Rijeka to Austria, the Check Republic, Slovakia and Hungary will be the most loaded in terms of traffic demand. This fact is confirmed by the data on the most burdened road corridors by the Adriatic Sea. The year 2010 highlights the following trends:

- Goričan – Zagreb – Rijeka – Pula ,  
8.717 vehicle / day
- Macelj – Zagreb – Knin – Split,  
7.334 vehicle / day
- Pasjak – Rijeka – Zadar – Split – Dubrovnik,  
5.122 vehicle / day

Most burdened roads to forecast the AADT in 2010, coincide with currently busiest roads and forecast amount of traffic as follows:

- Goričan – Zagreb – Rijeka – Pula  
6.536 vehicle / day
- Macelj – Zagreb – Knin – Split  
6.583 vehicle / day
- Pasjak – Rijeka – Zadar – Split – Dubrovnik – Karasovići  
11.581 vehicle / day
- Kneževo – Osijek – Slavonski Šamac; Metković – Opuzen  
11.921 vehicle / day

These data show that on the major European routes, so called E-roads, some improvements are needed when it comes to throughput and traffic safety. According to traffic forecasts, in order to reach a high level of service by 2015, the priorities should be to improve the range of existing transport networks and the quality of construction of new road sections.

The transport route from Zagreb to Split and the sea port of Split as a starting point (and as a transit point in relation to the island archipelago of Central and South Dalmatia) have marked a higher priority for connecting the road to the source points in the hinterland in relation to the distance of the train. It means that the size of the hinterland area of Split sea port, in relation to other sea ports is more competitive due to road distances, which certainly should be put in relation with all parameters that determine the transport service. These statements are based on actual data that impose different issues, of which some refer to it – is it really that the state (density and development) of roads between seaport Split – Zagreb – Central Europe, is much better compared to rail connections?

These results are affected by the fact that road transport logistics is preferred, particularly the use of high quality types of roads in the transport of high-tariff goods. Sometimes the freight is not always necessary to place this kind of roads for high level service. For this reason, it is often considered that the transport route used by inland road without charge consumes a lower level of service (the «old» road Zagreb-Split).

Road freight transport as compared with rail transport can be characterized as less economical mode of transport service. The reason for this is primarily limited by the static capacity and high service costs, and high cost of fuel. Limited availability of

road transport is especially true in container freight transport, given the limited dimensions and gross weight vehicles. The capacity of cargo of commercial vehicles is limited to 2 TEU, while also it is not possible to accept any container largely deviating from the standard. Regarding the relatively high costs of road traffic, determining exactly the same place of truck transport of containers in three major segments of the gravitational field of the maritime port of Split:

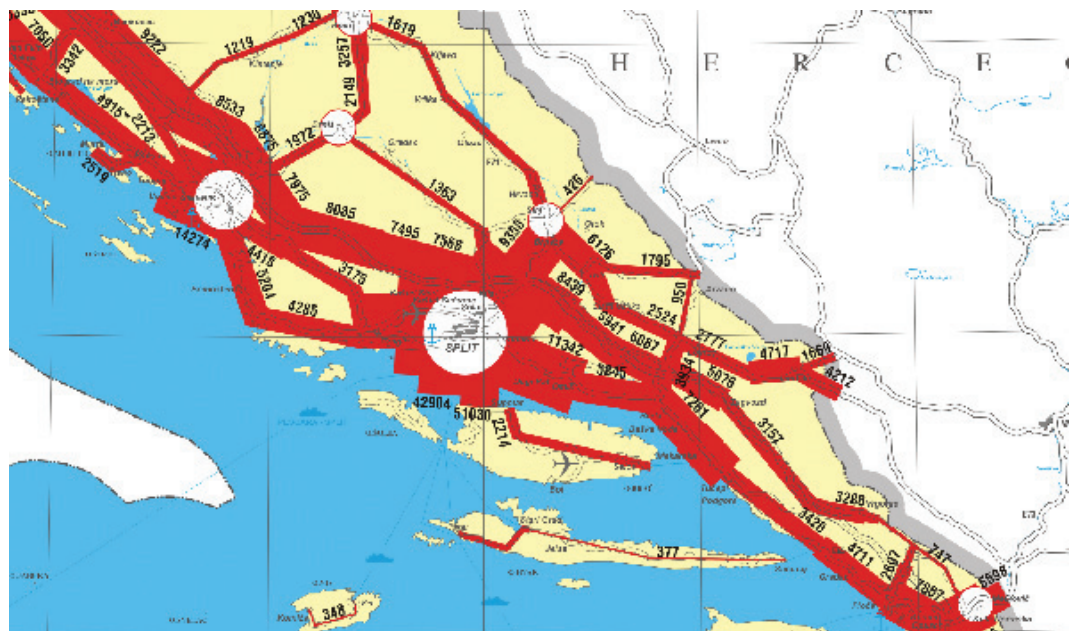
- urgent transport to the remote system (Split-Zagreb-Central Europe);
- land transportation of the narrow catchment area of the port of Split, or between production and consumer sites in the region (container terminal at the port of Ploče Pan-European Corridor Vc);
- internal transport from the sea port to the processing industrial centres in the port of Split (Industry Zone Dugopolje etc.).

The biggest advantage that can be attributed to road transports relates to the elasticity of transportation, which is reflected in the fact that the road vehicle can get to any place that could be reached by road infrastructure, and transport is not time limited. Elasticity contributes to the growing number of private road transport services (such as natural and legal persons), which often specialize in a particular coverage, the narrow part of the transport market, which then supports and improves transport services. Taking into consideration all the advantages of road transport, rail transport is the mode of transport which could be used for all these reasons and should be particularly encouraged.

**Figure 1.**

Traffic counting on the roads of Croatia.

Source: group of authors, 2011.



So the rail transportation should have a larger share in the carriage of cargo on the route of the future container terminal in the North Port to various destinations in the Central European hinterland. Regarding the economic relations and geo traffic predispositions in relation to the gravitating area of Bosnia and Herzegovina, there is no dispute in the marketing importance of these wining market potentials.

Nevertheless, it is important to point out that in Croatia, because of pronounced increase in the number of road carriers, and therefore the road transport capacity, the share of road transport is growing on the transport market. On the one hand, it is because of abolition of strict administrative ban on the import of vehicles, particularly the reduction of import and other duties, which are open to opportunities for uncontrollable massive import of used commercial transport vehicles. At the same time, this enables individuals performing road transport activities, even in international traffic, so there are many individuals inspired by the possibility for entering into this category of private enterprise.

As a rule, the economy of Split-Dalmatia County is not an exception, road transport capacity exceeds demand, and in most cases competes with rail transport. However, no matter what road carriers, on domestic and international markets, load in non-transparent ways, such as unfair competition by lowering prices below the threshold of economic feasibility, we should expect stronger regulatory function of competition. An example is the limited number of licenses for the transfer to other European countries with regard to the issue of road vehicles that do not meet the requirements for getting a carnet (TIR, CEMT, CMR, ATA etc.) that provide the cheapest and fastest crossing of state borders, the conditions of the insurance of carrier's liability, etc. Although road transport has played a leading role in the transport supply for certain types of cargo between the port of Split and the hinterland (e.g. the title of valuable general cargo) we should not ignore the view that for the advantages of rail logistics it could be difficult to replace the services with high levels of road courtesy, especially so called Dalmatina (highway A1). However, rail transport of mass and heavy loads, large amounts of cargo (e.g. cement) and long distances, with all major satisfactory environmental conditions and low transportation costs, have advantage over the road transport.

The remote road linking with the gravitational surrounding area of the Port of Split, the available capacity of motorway to the border with Hungary to AADT among 18000 – 20000 vehicles per day. The value of turnover in the previous operation was not reached even in peak loads during the tourist season, so the highway Zagreb-Split can be considered «a road perspective» that will be at its high level of service to generate and stimulate a new traffic demand. Sufficiency of capacity is not questionable for the projected volumes of traffic from Split's port, i.e. the predicted 7 million tons of cargo and approximately 6 million passengers by 2040. There may be certain periodic lowering, so

called, scale general eligibility (level of serviceability from B to E, according to the High Capacity Manual). The expected increase in transportation / waste containers and other general cargo terminal from the North Port sustainable in the case of bridging the Bay of Kaštela by a new bridge, three variants of connecting Split and Kaštela, according to a IGH study (Figure 2). The shortest



**Figure 2.**  
The Kaštela Bay Bridge.  
Source: IGH, 2011.

connection bridging The Kaštela Bay can be achieved in the variant No.1. The planned bridge touches the western side of RO-RO/container terminal and has a clearance for the passage of larger ships. Another, cheaper option No.2 has a shift towards the eastern part of the bay that touches the eastern side of this terminal. Variant No 3. is represented by the shortest and the lowest (cheapest) bridge at the extreme eastern part of Kaštela, but at least it is technologically justified.

Regarding the organization of traffic flows in the central part of the city network, it can be concluded that the capacitance limits of the road transport infrastructure in the Split node is in the absence of a consistent policy of planning and construction of capital infrastructure.

The expected trend of part loading will cause the saturated traffic and lowering of the courtesy level, it is necessary to build a



new road bridge across Kaštela Bay, and to construct a new road (Split-Kaštel Stari; Kaštel Stari-Trogir; Split-Dujmovača).

Since the capital facilities should initiate the construction of new bus station for remote and local traffic in Kopilice, which will, among other projects and upgrading of street network subsequently affect regime change operations in the central part of Split.

Future connection road between the City port – Kopilica constructed as a highway tunnel, is the «conditio sine qua non» of sustainability providing a new concept of the transport regimes of the City.

#### 4. CONCLUSION

The traffic of Split area is determined by the importance of all branches of transport within that county as the centre of Split and the central Dalmatian islands are structurally related. Road traffic and activities that are related to the servicing of mountainous hinterland at the same time generating economic development in which Split is no exception. The port of Split by its significance belongs to the group of the top passenger destinations on the Mediterranean. Its importance is reflected in facilitating the mobility of local population and connecting the islands with the mainland, and in the transfer of a large number of tourists, be it to their transit or final destination.

Because of such characteristics of the port where the passenger traffic is dominated by domestic sales with a 90% share, of which over 40% of the total turnover is achieved during the summer, we come to its essential feature, which is sensitive to seasonal changes as a result of tourism oscillations. This is tied to certain problems that are manifested through large crowds at peak loads, and the spatial constraints of road infrastructure. In

such circumstances it is necessary to find short term solutions, but also to determine the long-term development concept for the next 30-odd years, based on projections of traffic demand. Croatian accession to the European Union could make a real scenario possible, in which the passenger transport segment realize an average growth of 2% per year.

The function of Split harbour as a cargo port, also needs to be accepted even though the current traffic is almost entirely a function of the local industry. Projections of demand for freight traffic serving the particular industry should be taken with caution because the expectations are solely related to the operating policies of the entity that uses the port. However, there are realistic expectations that the future development of freight traffic in the port of Split will depend on the adjustments in the port for the reception of intermodal transport units (containers and ro-ro cargo) for various clients in a broad economic hinterland. It is estimated that this type of cargo transport will reach 40 000 TEUs (container sales) and 15 000 vehicles a year by 2040. This estimate is based on changes that can be expected in terms of redistribution of traffic flows in central and southern Adriatic and the greater role of road transport where Split could have an increasingly important role.

#### REFERENCES

- Baričević, H., (2001), Tehnologija kopnenog prometa, Rijeka: Pomorski fakultet.
- IGH-intranet, available at: <https://extranet.igh.hr>, [accessed 12 October 2011.].
- Group of authors, (2010), Prostorno-prometna studija prometnog sustava šireg područja grada (Studija pomorskog i lučkog sustava), Rijeka: Pomorski fakultet.
- Group of authors, (2011), Brojenje prometa na cestama RH u 2010.g, Zagreb: Hrvatske ceste, d.o.o.

# Effectiveness and Ergonomic of Integrated Navigation System

Pero Vidan<sup>1</sup>, Tatjana Stanivuk<sup>2</sup>, Toni Bielić<sup>3</sup>

Ergonomics increases the efficiency of people and device interaction. Nowadays, modern navigation bridges are designed in accordance with the requirements of navigators, designers and shipowners, production costs etc. The bridge design, various layouts, instrument arrangements and their capacities etc. have not been fully regulated by the SOLAS convention. The Convention regulates manufacturers' requirements which refer to accuracy, device sensitivity etc. However, factors that are important for ergonomics, and time required for familiarization and exploitation of the device are left to shipbuilders and charterers to decide. In this paper, authors are analyzing the ergonomics of the integrated navigation bridge - INS.

## KEY WORDS

- ~ Integrated navigation system
- ~ Effectiveness, ergonomics
- ~ Navigation safety
- ~ Navigation bridge

## 1. INTRODUCTION

Ergonomics is the engineering science whose aim is to study people and their behaviour. It determines the efficacy of interaction between machines and the people who use them. Ergonomics examines the ways of work quality improvement, increase in production, reduction of work related-injuries, professional diseases etc. Therefore, ergonomics increases the safety of object usage. It is related to the construction and technical projects as well as design (Bielić, 2004; Perić, 2004).

These days shipbuilding is focused on finding technical and technological solutions that would increase the cost-effectiveness of vessels, which is related to the profits they make.

Profits are possible by enlarging hold space, increasing the speed of cargo transport, reduction of crew, employment of cheap labour, reduction in maintenance costs, vessel registration under flags of convenience etc. The crew reduction has been a trend followed by current solutions for watch keeping, supervision, cargo handling, administration work etc.

Integrated Navigation System - INS implies the connection of navigation equipment and programme packages intended for adjustment of all required navigation parameters. It consists of various navigation components connected to the main computer network whose aim is adjustment and supervision of the system and provision of information relevant for navigation (Bowditch, 2002).

## 2. INS CONSTRUCTION

The bridge construction mostly depends on the shipowners' requirements i.e. the purpose of the vessel, as well as on modern trends in naval architecture. The construction and design should provide a good layout for the navigator. The navigating bridge must fulfil the requirements of the "International Convention for the Safety of Life at Sea"-SOLAS.

1, 2 University of Split, Faculty of Maritime Studies, Zrinsko-Frankopanska 38, 21000 Split, Croatia

E-mails: pvidan@pfst.hr, tstanivu@pfst.hr

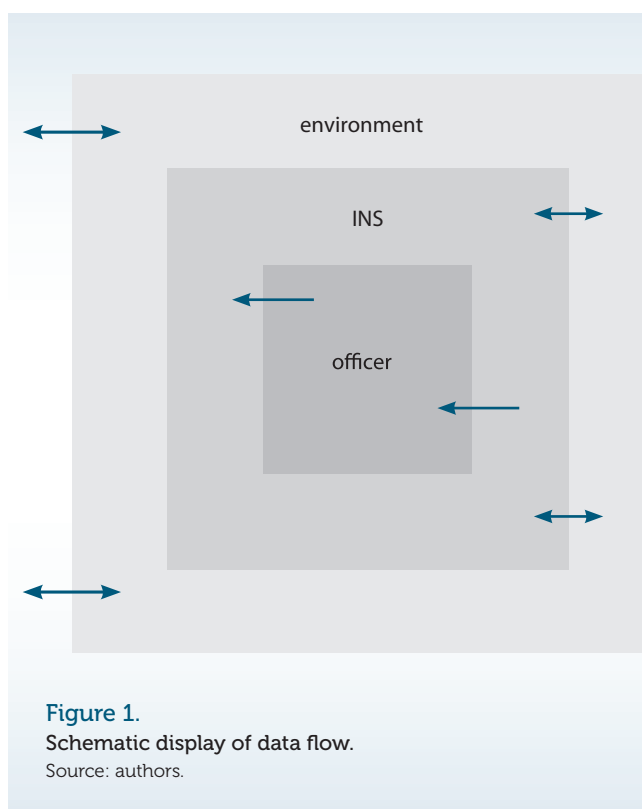
3 University of Zadar, Department of Transport and Maritime Studies, Mihovila Pavlinovića bb, 23000 Zadar, Croatia

E-mail: tbielic@unizd.hr

The SOLAS regulation for vessels over 45 m in length was defined by the 1998 rule III/3.12. The regulation governs the bridge construction and design requirements. The vessels constructed for special purpose with different design and construction of the navigating bridge must have a special approval for such exceptions by the Register (Rules, 2001).

The navigating bridge equipment on modern merchant vessels has to be approved in compliance with the standards and rules of SOLAS.

The watch officer on duty is often too busy with navigating his vessel. One of the reasons is that he receives relatively numerous data from the systems of vessel and her environment (Figure 1).



The amount of data depends on the current state of the vessel (whether she is loaded or unloaded, preparing for survey etc.), and her environment such as administration, intensity of traffic, presence of dangers to navigation and the like. On modern bridge there are numerous electronic aids which provide a great amount of data in relatively short period of time. Therefore, it is to be expected that such large amount of data would require time to be processed into information which would assist the officer of the watch in making the right decision. Unnecessary data supply results in officer's distraction and fatigue. For that reason, the data need to be processed before reaching the operator.

Very sophisticated computer models with high capacity and speed are used for data processing. Their task is processing, display and printing of the data that need to be saved. In this way the time needed for data processing is reduced and information is supplied in less time. The time saved in data processing and their selections allow the officer to be more focused on decision making.

### 3. INS ROLE

The basic aim of the integrated navigation system (Figure 2) is to secure the added value to the functions and information required by the officer on navigation duty for planning, supervision and control of the vessel underway.

INS assists the safety of navigation. Its role is to evaluate the inlet data from various independent sensors, to fully supervise and to supply the information for safe navigation.

### 4. INS ERGONOMICS

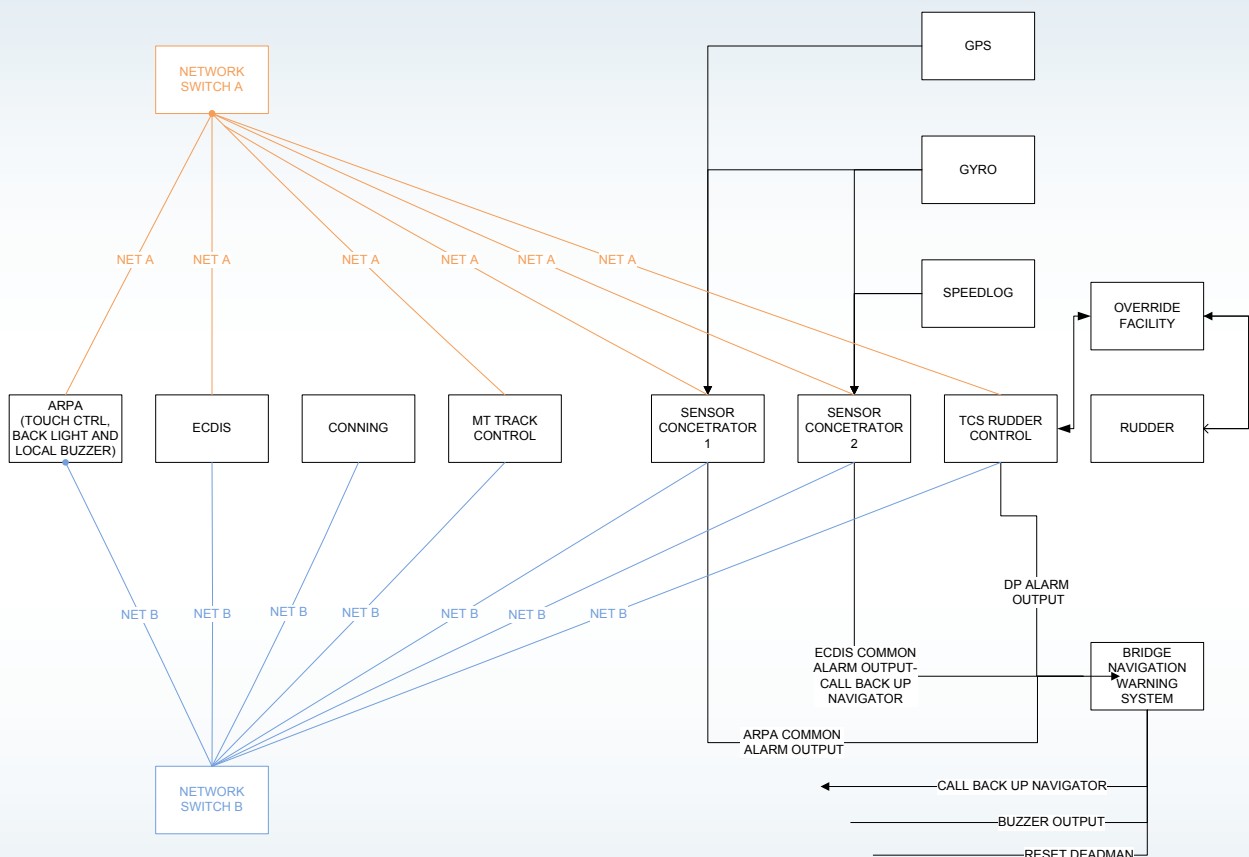
The bridge E ergonomics can be expressed functionally as a dependant variable on navigation safety (S). The ergonomics will prove successful if all instruments are adjusted to the officer's needs in all possible situations. The use of ergonomically solved INS should significantly reduce the risk of human errors in ship handling (H):

$$f(S) = \frac{f(E)}{f(H)} \quad (1)$$

The INS equipment design should not disturb the vessel layout. Therefore, it is preferred that the counters with electronic aids are arranged so as to allow the access to all glass surfaces of the bridge. The size of the consoles should be adequate to improve significantly the access to all other bridge consoles, windows, wings etc.

Electronic navigation aids should be designed in compliance with the norms. It is suggested that the special norms be adopted by SOLAS. These norms would propose the construction of several types of bridges which would be ergonomically acceptable for various types of vessels. The equipment used on the bridge would be prescribed and unified (Figure 3). Special STCW training should be offered to enable navigators to attend specialized courses for a particular bridge type. Such specialization would be recognized by the issuance of certificates and it would certainly have effect on reduction of time needed for getting familiar with the bridge (Cockpit5You).

Also, there is a proposal for unification of the main navigation instrument menus. Their use should not be too demanding. Simplification of functional keys is especially useful for instrument tuning. These often contain settings which are not used in navigation. Many functional keys may cause distress



**Figure 2**  
Schematic INS display.  
Source: authors.

situations and navigator's error if improperly used. Therefore, the access to such options should be limited.

A proposal for instrument layout to be regulated by SOLAS is also considered. The quality as regards the period of exploitation could be subject to different prices, but the outlook and usage methods should be unified by all manufacturers. This would enable competition amongst producers with regard to the price, reliability and quality but the outlook would be unified as well as the instrument options that are not used in navigation.

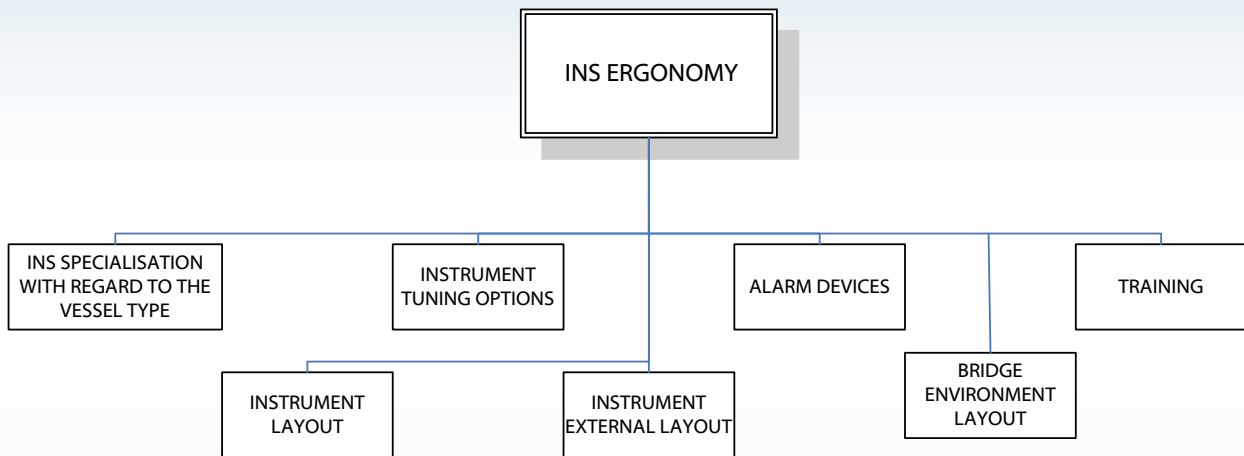
Warning alarms on the bridge should use various types of sound warnings. Having the alarm with voice message explaining the cause of alarm ought to be considered. Such demand becomes important if alarm is activated at the critical moment such as the manoeuvre, anchoring, sailing in bad weather, collision avoidance etc. In this way the time for alarm cancellation is reduced and the time saved is used for decision making which adds to the quality of the decision.

## 5. INS EFFECTIVENESS

The error in choosing the right information can lead to the wrong decision that can finally cause distress. Integrated navigation system has to be able to:

- Choose the relevant data;
- Process data and collect information;
- Give warning regarding the importance of information and system failure;
- Supply the navigator with quality information and more time for decision making.

The configuration of integrated navigation system depends on the needs and finances of the user. It can vary in simplicity and in quality. The reliability of the system can be expressed numerically by the probability of its operation without errors or failures. Therefore, the probability of the expected functioning of the system is the measure of its reliability. Such systems demand



**Figure 3.**  
Schematic display of INS ergonomics usage.  
Source: authors.

high reliability which can be accomplished in two ways by:

- Choosing components (Ik)
- System execution (Is) (Balic, 2010).

Choosing components affects the reliability of the component itself, as well as the entire system. Reliability is the feature which depends on various factors such as: sensitivity, accuracy of data processing, number of possible errors, number of disturbances and other, as prescribed by the SOLAS Convention. The reliability of the system is guaranteed by the manufacturer. If approved by the SOLAS Convention, they can be used onboard.

Integrated INS component prices are sometimes three times higher than the conventional ones. Their reliability has been assessed to 100 times better than the one of conventional devices (Balic, 2010). It could be said that the choice of components depends on the price (PR), quality (C) and adaptability of the system (AS):

$$Ik = f(PR, C, AS) \quad (2)$$

The price of components is conditioned by the market, i.e. the manufacturer. The same could be said about the quality. These two values are usually proportional to each other.

The system execution (Is) demands doubling and tripling of the number of devices in order to ensure satisfactory INS reliability. Thus it is important for Is to be larger so as to have better performances of INS. Actually, in order to increase the reliability of Is, individual components of Is system have parallel connections so that the failure of the first subsystem automatically activates the other subsystem.

As the navigation instruments are highly reliable, the regulations rarely require more than to duplicate components. The most important factor in the development of new solutions is the extended use of the latest IT solutions. The execution of the system should be such that it has as few failures as possible i.e. that the system is as reliable as it possibly could be. When the failure rate is closer to zero, then the reliability is closer to one. By the increase of the number of failures, reliability is closer to zero. Then the failure density function  $f(t)$  would be as in Figure 4.

Effectiveness of the system is limited by its usage. The main limitation regards the relation of effectiveness and efficiency of the system i.e. cost-effectiveness of the system.

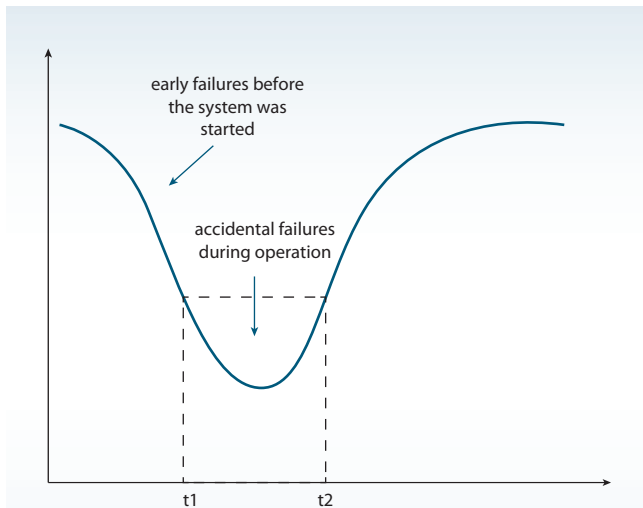
In Table 1, there is a hypothetical display of the reliability coefficient value of individual devices in the integrated navigation system (A-F), as well as the reliability of the operator (O).

The error of the operator is an unknown and it is designated by „x“. x varies depending on the factors which affect the operator such as: knowledge, training, fatigue, omission etc. The probability of error occurrence in the device from A to F is designated by  $P(x_A)$  do  $P(x_F)$ .

- $a_1$  = knowledge  $x_A$  error occurrence in device A,
- $a_2$  = training  $x_B$  error occurrence in device B,
- $a_3$  = fatigue  $x_C$  error occurrence in device C,
- $a_4$  = omission  $x_D$  error occurrence in device D,
- $a_n$  = some other factor,
- $x_F$  = error occurrence in device F.

As it is matter of conditioned probability in several devices which interact with the operator, probability of error in device A,





**Figure 4.**  
Hypothetical  $f(t)$  INS display.  
Source: authors.

or at least one error due to the factors which affect the operator, can be calculated by the following formulae:

$$P(x_A) = 1 - (1 - P(a_1))(1 - P(a_2)) \dots (1 - P(a_n)) \quad (2)$$

Probability of error in device B or at least one error due to the factors that affect the operator:

$$P(x_B) = 1 - (1 - P(a_1))(1 - P(a_2)) \dots (1 - P(a_n)) \quad (3)$$

Probability of error in device C or at least one error due to the factors that affect the operator:

$$P(x_C) = 1 - (1 - P(a_1))(1 - P(a_2)) \dots (1 - P(a_n)) \quad (4)$$

Probability of error in device D or at least one error due to the factors that affect the operator:

$$P(x_D) = 1 - (1 - P(a_1))(1 - P(a_2)) \dots (1 - P(a_n)) \quad (5)$$

**Table 1.**  
Reliability of individual system devices and INS operator.

A = 2%	B = 1%	C = 1%
D = 2.5%	E = 1%	F = 1.7%
O = x		

Probability of error in the device E or at least one error due to the factors that affect the operator:

$$P(x_E) = 1 - (1 - P(a_1))(1 - P(a_2)) \dots (1 - P(a_n)) \quad (6)$$

Probability of error in device F or at least one error due to the factors that affect the operator:

$$P(x_F) = 1 - (1 - P(a_1))(1 - P(a_2)) \dots (1 - P(a_n)) \quad (7)$$

Probability of at least one error has been shown by the following formulae (8):

$$P(x) = 1 - (1 - P(x_A))(1 - P(x_B)) \dots (1 - P(x_n)) \quad (8)$$

## 6. CONCLUSIONS

Modern navigating bridge is the central place for the vessel control. Apart from the navigation aids, on the bridge, there are also devices for cargo space control, firefighting system, ballast control system, communication system etc. The concept of the navigating bridge is important and it is subservient to the officer. The navigating bridge should be user friendly in a way that it does not lose any of its quality and functionality. Therefore, it is important to apply the ergonomic principles by choosing the most appropriate components. The component design should be regulated by SOLAS. INS should fulfil the SOLAS requirements regarding its quality, longevity, functionality, reliability, sensitivity, precision etc. Finally, according to everything aforementioned, a special training should be prescribed for each type of INS.

## REFERENCES

- Balic, I., (2010), Utjecaj tehnologije na sigurnost i organizaciju rada na brodu, Master Thesis, Split: Faculty of Maritime Studies.
- Bielić, T., (2004), Utjecaj ergonomskih čimbenika na upravljanje brodom, Naše more, 51(5-6), pp. 172-177.
- Bowditch, N., (2002), The American Practical Navigator: Book, Maryland: National Imagery and Mapping Agency.
- Cockpit 4 You- Aviation Service, (2010), available at: <http://www.cockpit4u.de/en/pilots/boeing.html>, [accessed 7 November 2010.].
- Medicina.hr, (2011), available at: <http://www.medicina.hr/clanci/ergonomija.htm>, [accessed 21 September 2010.].
- Perić, T., Struberger, N. and Perić, D., (2004), Influence of Ergonomics on Traffic safety and Economy Development, Promet-Traffic, 16 (5), pp. 247-256.
- Rules for Classification of Ships 2001, (2001), available at: <http://exchange.dnv.com/Publishing/RulesShip/2001-01/ts411.pdf>, [accessed 1 November 2010.].
- Steiner, S., Radacic, Z. and Pavlin, S., (1999), Croatian air traffic in the integration process of the countries of the 21st century Europe, Promet-Traffic, 11(2-3), pp. 179-183.

# Design of Deadlock Prevention Supervisor in Waterway with Multiple Locks and Canals

Danko Kezić<sup>1</sup>, Stjepan Bogdan<sup>2</sup>, Josip Kasum<sup>3</sup>

To avoid conflict and deadlock states in waterway with multiple locks and canals, a computer based traffic management system with proper control policy must be applied. The paper proposes a formal method for design of deadlock prevention supervisor by using discrete event theory, multiple reentrant flowlines class of Petri net and P-invariants control places calculation. By using and/or matrix algebra, authors analyze the structural characteristics of Petri net in order to find first and second level deadlocks. First level deadlocks are prevented by maintaining the number of vessels in the critical subsystems below the number of vessels in the critical circuits. A method for second level deadlock prevention, which is based on P-invariants, ensures that the key resources would not be the last available resources in the system. Functionality of the supervisor is verified by a computer simulation using Matlab software with Petri net toolbox and P-timed Petri net model of waterway.

## KEY WORDS

- ~ Waterway traffic management system
- ~ Supervisory control
- ~ Deadlock prevention

## 1. INTRODUCTION

A waterway is any navigable body of water, such as river, lake, sea, ocean, and canal. Some waterways are combination of rivers, lakes and narrow canals with different levels of water. In such waterways, herein named complex waterway system (CWS), vessels must use multiple locks (devices for raising and lowering boats between stretches of water of different levels) to move through the system of locks and canals.

Safe navigation in CWS is very demanding process and needs coordination between crew members aboard vessel and traffic management staff on the ground. Some of the problems that need to be solved by the traffic management staff are: a) How to control traffic in a way that vessels moving in opposite directions make as few stops as possible during the passage through the waterway (maximally permissive control policy)? b) How to resolve possible conflicts in case that more vessels try to acquire particular lock (canal, basin) at the same time? c) How to avoid possible deadlocks in the dense traffic?

To resolve above mentioned problems in situations of dense *traffic in waterway system*, a computer based traffic management system (TMS), which observes and controls vessels in CWS, must be applied. Intelligent traffic management system is also used for real-time traffic management of the urban motorway network (Hernandez, et. al., 2002).

The exact positions of the vessels in CWS can be monitored by using DGPS and AIS on board ship with wireless communication between vessels and TMS. In our approach locks, canals and basins are treated as resources of the CWS. Resource can be *non-shared* (resource that can be occupied by the vessels moving in only one direction), and also *shared* (resource that can be occupied by the vessels moving in the opposite directions). The availability of resources is monitored by various electronic

1, 3 Faculty of Maritime Studies, Zrinsko Frankopanska 38, Split, Croatia

E-mail: [danko.kezic@pfst.hr](mailto:danko.kezic@pfst.hr), [josip.kasum@pfst.hr](mailto:josip.kasum@pfst.hr)

2 Faculty of Electrical Engineering and Computing, Unska 3, Zagreb, Croatia

E-mail: [stjepan.bogdan@fer.hr](mailto:stjepan.bogdan@fer.hr)

sensors like camera or proximity sensors. Main task of TMS is not only to analyze data from sensors, but also to evaluate traffic situation, and advise the traffic management staff how to resolve ongoing situation. Properly designed TMS should have the properties of an expert that is capable to cope with complex traffic situations in CWS.

The vessels moving through the resources of CWS, can generally be described as a discrete event system (DES), which consists of discrete states and events. Some of these states, such as conflicts and deadlocks, are undesirable (even dangerous). In this view, TMS should implement supervisory policy that prevents execution of some events (entering or leaving lock, canal, basin) in order to restrict the set of reachable discrete states in the system to the set of permissible (safe) states. This can be done by direct control of CWS traffic lights system or throughout a set of recommendations to CWS human operator.

The method of deadlock prevention by control places was developed in (Barkaoui & Abdallah, 1995). An algorithm for deadlock prevention for the ordinary and conservative  $S^3PR$  class of Petri nets was developed in (Ezpelta, et al., 1995). The paper from Ezpelta et al. (1995) is usually considered to be the first that uses structural analysis to design monitor-based liveness-enforcing Petri net supervisor for the flexible manufacturing systems (FMS). The algorithm for finding the minimal siphons inside the net as well as the algorithm for deadlock prevention by control places for ordinary Petri nets which do not contain source places was investigated in (Lautenbach & Ridder, 1996). Further, an efficient algorithm for deadlock prevention in the specific class of Petri nets that describes FMS was developed in (Lewis, et al., 1998). A deadlock prevention which uses iterative siphon control method is described in (Iordache & Moody, 2000) and (Kezić, et al., 2006). Similar approaches can be found in (Barkaoui, et al. 1997), (Barkaoui & Petrucci, 1988), (Tricías, et al. 2000), (Tricas, et al., 2005). Deadlock prevention policy based on elementary siphons for FMS is proposed in (Mingming, et. al., 2009). The divide-and-conquer strategy is used in (ZhiWu Li, et. al., 2009) to investigate the deadlock prevention in FMS. Efficient deadlock prevention in Petri nets through the generation of selected siphons is proposed in (Piroddi, et. al., 2009).

This paper presents enhancement of the algorithm presented in (Kezić, et al. 2009) where deadlock avoidance algorithm for river traffic system uses multiple re-entrant flowlines class of Petri net ( $MRF_1PN$ ) with only one key resource (Bogdan, et al., 1997). Herein we propose a solution in case of CWS with multiple key resources. The solution represents deadlock prevention supervisor in a sense that vessels are stopped only in a case of immediate dangerous situation in dense traffic.

The first task in TMS design is modeling of the traffic system by using  $MRF_1PN$ , which consists of disjoint sets of job and resource places. The second task is structural analysis of  $MRF_1PN$ , i.e. determination of simple and cyclic circular waits,

critical siphons, and finally critical subsystems. To avoid first level deadlocks, it is necessary to control number of vessels in every critical subsystem. In Petri net formalism this can be achieved by adding additional control places which block firing of particular transition and restrict the number of tokens in critical subsystems. For prevention of second level deadlocks one has to take care of so called *key resources*, i.e. the supervisor must ensure that the key resources are not the only available resources in the net.

The paper is organized as follows: section 2 reviews basics of supervisory control and Petri net theory. Section 3 describes  $P$ -invariant method of control places design. In section 4, a matrix description of  $MRF_1PN$  is presented and modeling of CWS with  $MRF_1PN$  is described. A matrix approach to deadlock prevention supervisor design, using  $MRF_1PN$ , is shown in section 5. Finally, a case study example of supervisor design for CWS, similar to Panama canal, is given in section 6.

## 2. BASICS OF SUPERVISORY CONTROL AND PETRI NET

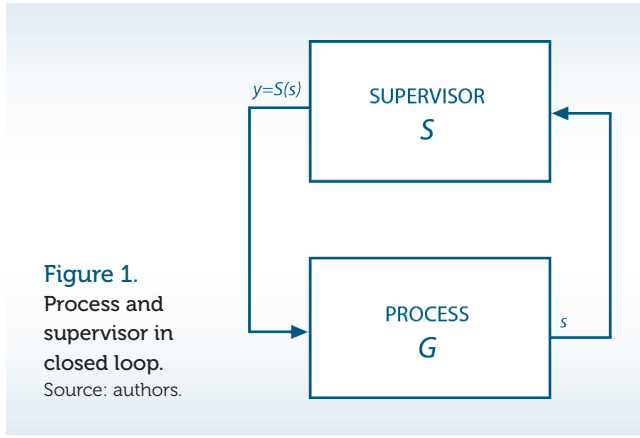
A process can be defined as a set of interdependent tasks or jobs which are necessary to achieve a goal. In this paper, the main goal is to achieve uninterrupted passage of vessels through CWS. The supervisor has to ensure that the process does not get into any of forbidden states and that it performs in accordance with the given requirements (Charbonnier, et al., 2001).

The theory of DES supervisory control deals with the problem of synthesis of the supervisor, which is connected to the given process in closed loop, and which ensures the desired behavior of the whole system. The theory of supervisory control is described in (Boffey, 1982), (Overkamp & Van Schuppen, 1995), (Vaz & Wonham, 1986), (Yamalidou, et al., 1996). The theory originates from the language theory generated by the automata and Petri nets, a useful tool for analyzing DES (Hopcroft & Ullman, 1979). Petri nets formalism is a graphical and mathematical tool adapted to the modeling of the main features of discrete event systems (Gallego et. al, 1996).

The basics of supervisory control can be described using Fig 1. Suppose that the process  $G$  can be modeled as a DES with the finite set of discrete states and events. Every task or job in the process can be modeled as particular state. The sequence of the jobs in the process  $G$  causes changing of the states and generates set of events  $s$ . The behavior of process  $G$ , as a rule, does not correspond to the specified process requirements (process  $G$ , for example, may get into a so called deadlock state – the state in which no more events are possible) and therefore it is necessary to “modify” its behavior by introducing the supervisor  $S$ . The supervisor  $S$ , which is also DES, is connected into a closed loop with the process  $G$ . The task of the supervisor  $S$  is to monitor generated events  $s$  from the process  $G$  and, if necessary, block events in the process  $G$  which can cause forbidden state. In other words, the task of the supervisor  $S$  is to restrict the set of

events generated by the process  $G$  to the set of allowable events  $\gamma = S(s)$ . This ensures absence of unallowable forbidden states in process  $G$ .

In this paper, we are using Petri net theory for modeling process  $G$ , and designing appropriate supervisor  $S$ . The advantage of Petri nets as compared to other DES modeling methods is in their rich structure, which enables the analysis of numerous characteristics of the system from the structure of the net itself, and without having to analyze the whole discrete state space. Place - transition P/T Petri net is a 6-tuple (Murata, 1989):



**Figure 1.**  
Process and supervisor in closed loop.  
Source: authors.

$$Q = (P, T, I, O, M, m_0) \quad (1)$$

where:

$P = \{p_1, p_2, \dots, p_n\}$  - set of places,  
 $T = \{t_1, t_2, \dots, t_n\}$  - set of transitions,  
 $P \cap T = \emptyset$ ,  
 $I_{(n \times m)} : P \times T \rightarrow \{0, 1\}$  - an input incidence matrix,  
 $O_{(n \times m)} : T \times P \rightarrow \{0, 1\}$  - an output incidence matrix,  
 $M : I, O \rightarrow \{1, 2, 3, \dots\}$  - is a weight function,  
 $m_0$  - initial marking.

Places and transitions  $v \in P \cup T$  are calling nodes and denote states and events in the DES. Given any node  $v$ , let  $\bullet v$  and  $v \bullet$  denote pre-set and post-set of  $v$ , i.e. the set of nodes that have arcs to and from  $v$ , respectively. An available resource or an ongoing job in DES is indicated by token in respective place. Transition  $t \in T$  is enabled at marking  $m(p)$  iff  $\forall p \in \bullet t, m(p) \geq w(p, t)$  ( $\bullet t$  is a set of input places to transition  $t$ , and  $w(p, t)$  is weight of the arc between  $p$  and  $t$ ). Transition  $t$  that meets enabled condition is free to fire. When transition  $t$  fires, all of its input places lose  $w(p, t)$  tokens, and all of its output places gain  $w(t, p_j)$  tokens. In Petri net  $Q$  with  $n$  transitions and  $m$  places, the incidence matrix  $A$  is an  $n \times m$  matrix defined as:

$$A = O - I \quad (2)$$

where elements  $a_{ij}^+$  and  $a_{ij}^-$  of  $O$  and  $I$  are:  
 $a_{ij}^+ = w(p_i, t_j)$  if  $(p_i, t_j) \in I$  and  $a_{ij}^+ = 0$  otherwise,  
 $a_{ij}^- = w(t_j, p_i)$  if  $(t_j, p_i) \in O$  and  $a_{ij}^- = 0$  otherwise.

The matrices  $I$  (input matrix) and  $O$  (output matrix) provide a complete description of the structure of a Petri net. If there are no self loops  $\bullet p \cap p \bullet = \emptyset$ , the structure can be described by incidence matrix  $A$ . The incidence matrix allows an algebraic description of the evolution of Petri net:

$$m_{k+1} = m_k + A^T \cdot \sigma \quad (3)$$

where:

$A$  - incidence matrix,  
 $\sigma$  - firing vector.

The firing vector  $\sigma$  is composed of non-negative integers that correspond with the number of times a particular transition has been fired between markings  $m_k$  and  $m_{k+1}$ .

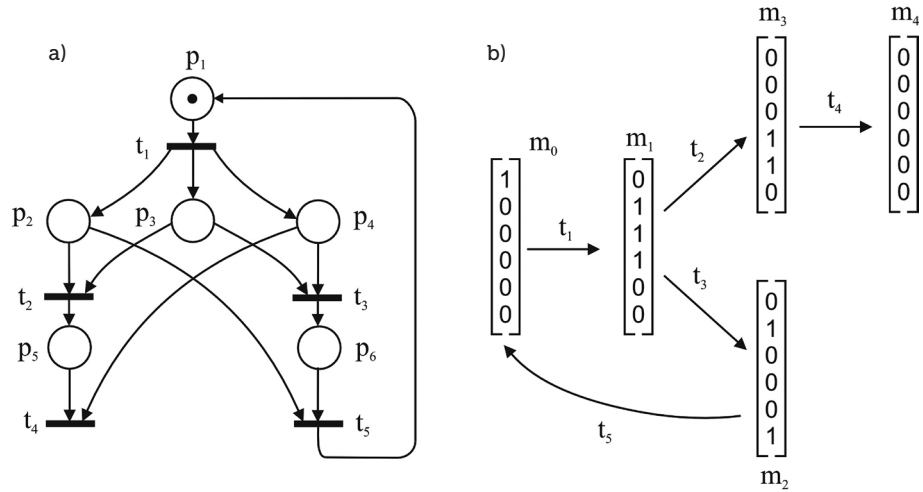
A PN is said to be live if, no matter what marking has been reached from the initial marking  $m_0$ , it is possible to ultimately fire any transition of the net by progressing through some further firing sequences. A transition  $t \in T$  is said to be dead at  $m$  if there exists no  $m' \in \mathfrak{R}(m)$  that enables it, with  $\mathfrak{R}(m)$  defined as the set of markings reachable from  $m$ . A marking  $m$  is said to be dead if no  $t \in T$  is enabled at  $m$ . A place  $p \in P$  is said to be dead or deadlocked at  $m$  if  $m = m' = 0$  for all  $m' \in \mathfrak{R}(m)$ .  $P$  invariant corresponds to the set of places whose weighted token count remains constant for all possible markings.  $P$  invariant  $P$  can be found by solving equation:

$$A \cdot P = 0 \quad (4)$$

Siphon  $S$  is the set of Petri net places for which holds that each transition having an output arc from  $S$  also has an input arc into the  $S$  ( $\bullet S \subseteq S \bullet$ ). Trap  $T$  is the set of places for which it holds that each transition having an input arc into  $T$  also has an output arc from  $T$  ( $T \bullet \subseteq \bullet T$ ). Once the trap becomes marked, it will always be marked for all future reachable markings. Once the siphon becomes empty, it will always remain empty (Murata, 1989).

A reachability set or reachability tree shows the set of all possible markings reachable from  $m_0$  and displays every possible state that can occur in the Petri net after firing all transitions. It is possible to see some important PN properties like boundness (no capacity overflow), liveness (absence of deadlock), conservativeness (conservation of no consumable resources), and reversibility (cyclic behavior) from the reachability

**Figure 2.**  
P/T Petri net  
a) and its reachability  
tree b).  
Source: authors.



tree. An algorithm for calculating reachability tree is shown in (Kezić, 2004).

Example:

A simple P/T Petri net with 6 places (circles) and 5 transitions (bars) is shown in Fig.2 a. Reachability tree is shown in Fig. 2b.

Petri net in Fig 2a) is safe because the maximum number of tokens in the places is 1, and is partially reversible because it is possible to reach initial state  $m_0$  after firing transitions  $\{t_1, t_3, t_5\}$ . Firing the  $t_i$  from the state  $m_3$  cause deadlock state  $m_4$ . From the state  $m_4$  it is not possible to reach any other state.

The net in Fig 2 is not live. There are no place invariants in the net. The incidence matrix  $A$  of Petri net in Fig. 2 is:

$$A = \begin{bmatrix} 1 & -1 & -1 & -1 & 0 & 0 \\ 0 & 1 & 1 & 0 & -1 & 0 \\ 0 & 0 & 1 & 1 & 0 & -1 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ -1 & 1 & 0 & 0 & 1 & 1 \end{bmatrix}$$

### 3. P-INVARIANT BASED CONTROL PLACE CALCULATION

Petri net model of a process, so called Process Petri net (PPN), may contain forbidden states. These states can be avoided by using control places, which must be added and connected to the PPN. These control places form Supervisor Petri net (SPN). P-invariant method for control place calculation is one of techniques for SPN design. Short overview of this technique is shown in this paper. More can be found in (Iordache & Moody, 2000).

Suppose that process  $G$  is DES and is modeled by a PPN described by process incidence matrix  $A_p = [a_{ij}]_{n \times m_p}$ .

The supervisor  $S$ , in the form of SPN, prevents occurrence of forbidden states  $M_f$ , by applying constraints to the set of all reachable states of PPN. SPN can be described by supervisor incidence matrix  $A_s = [a_{ij}]_{n_s \times m_s}$ .

To connect process  $G$  and supervisor  $S$  in closed loop (Fig 1), SPN and PPN connect together and form a new Composite Petri net (CPN) without forbidden states.

The CPN incidence matrix  $A_{pc} = [a_{ij}]_{n \times (m_p + m_s)}$  describes a topology of composite Petri net. Each supervisor control place defines a constraint over the set of reachable states of the PPN. The constraint can be expressed in the form of linear inequality:

$$\sum_{i=1}^m l_i m(p_i) \leq \beta \quad (5)$$

in which:

$m(p_i)$  - number of tokens in place  $p_i$ ,

$l_i \beta$  - integer constants.

The set of inequalities (5) can be transformed into matrix equation:

$$L \cdot m_p + m_c = b \quad (6)$$

in which:

$L$  - constraints matrix  $g_c \times m_p$ ,

$b$  - vector  $m_c \times 1$ ,

$m_p$  - marking vector of PPN  $m_p \times 1$ ,

$m_c$  - marking vector of SPN  $m_c \times 1$ .

$g_c$  - number of constraints.

Note that the number of control places  $m_c$  must be equal to the number of constraints  $g_c$ , so  $g_c = m_c$ .

$P$  invariant  $P$ , defined by relation (4), must satisfy the requirements of equation (6) so we can calculate supervisor

incidence matrix  $A_c$  and supervisor initial marking  $m_{c0}$  as:

$$A_c = -A_p \cdot L^T \quad (7)$$

$$m_{c0} = b - L \cdot m_{p0} \quad (8)$$

in which:

$m_{c0}$  - SPN initial marking,

$m_{p0}$  - PPN initial marking.

Matrix  $A_c$  and vector  $m_{c0}$  completely determine initial marking of control places, as well as the connection between each control place and other places of PPN.

The complete CPN design is partitioned in the following steps:

1. Determine a PPN. From the PPN it is possible to define process incidence matrix  $A_p = [a_{ij}]_{n \times m_p}$  and  $m_{p0}$ ,
2. Define the set of constraints of type (6) in order to reduce the set of reachable markings to allowed states,
3. Calculate  $A_c$  and  $m_{c0}$  from equations (7) and (8),
4. Design a CPN from the composite incidence matrix  $A_{pc}$ . Check the set of reachable markings.
5. If there are forbidden states in CPN, go to step 2.

#### 4. MODELING CWS WITH MRF<sub>1</sub>PN

Deadlock prevention supervisor design begins with the traffic system modeling by using MRF<sub>1</sub>PN, which is a subclass of P/T Petri net specially designed for analysis of multiple re-entrant flowlines flexible manufacturing systems (MRF system).

##### 4.1 MRF<sub>1</sub> Petri net

In the MRF<sub>1</sub>PN, each part type  $k \in \Pi$  is characterized by predetermined sequence of jobs  $J^k = \{J_1^k, J_2^k, \dots, J_{L_k}^k\}$ , with at least one resource for each job ( $L_k$  is the number of jobs for particular part type  $k$ ). Let  $R$  denote the set of system resources, with each  $r \in R$  a pool of multiple copies of a given resource. Places  $P$  are divided in the MRF<sub>1</sub>PN as  $P = R \cup J \cup J_{in} \cup J_{out}$  with  $R$ ,  $J_{in}$ ,  $J_{out}$  and  $J$  as the set of places respectively representing the availability of resources, units arrivals and finished units, and  $J$  as the set of places representing the ongoing jobs. The set of transitions  $T$  can be partitioned as  $T = \bigcup_{k \in \Pi} T^k$ , where  $T^k = \{t_1^k, t_2^k, \dots, t_{L_k+1}^k\}$ , with  $t_i^k = \bullet J_i^k = J_{i-1}^k \bullet$ , for  $i \notin \{1, L_k\}$ ; while  $t_1^k = \bullet J_1^k = J_{in}^k \bullet$  and  $t_{L_k+1}^k = \bullet J_{L_k+1}^k = J_{out}^k \bullet$ . Transition  $t$  is said to be job (resource) enabled if  $m(\bullet t \cap J) > 0$  and  $m(\bullet t \cap R) > 0$ . For any  $r \in R$ , define the job set  $J(r)$  as the set of jobs using  $r$ , and resource loop  $L(r) = r \cup J(r)$ . Given a set of resources  $Q \subset R$ , define the job set of  $Q$  as  $J(Q) = \bigcup_{r \in Q} J(r)$ . We denote  $R(J_i^k)$  as the set of resources used by job  $J_i^k$ .

MRF<sub>1</sub>PN satisfies following conditions: (i)  $\forall p \in P$ ,  $\bullet p \cap p \bullet = \emptyset$ ; (ii)  $\forall k \in \Pi$ ,  $t_1^k \bullet \cap P \setminus J = \emptyset$  and  $\bullet t_{L_k+1}^k \cap P \setminus J = \emptyset$ ;

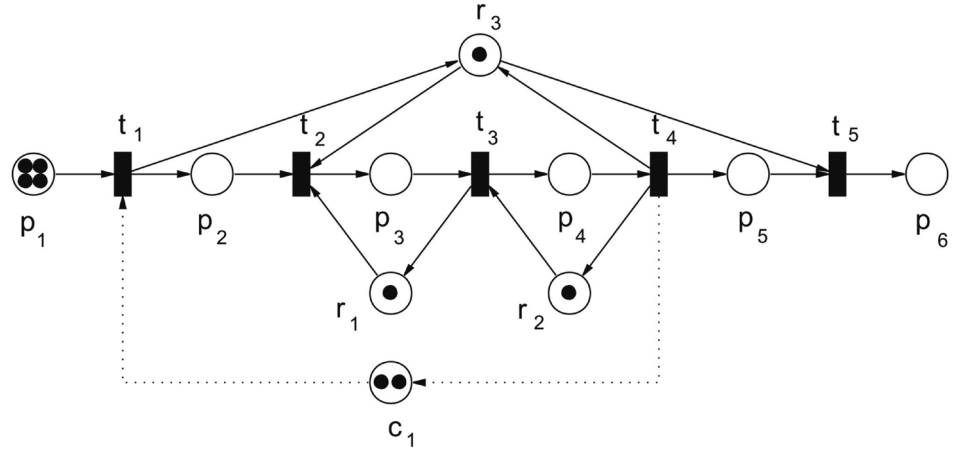
(iii)  $\forall J_i^k \in J$ ,  $|R(J_i^k)| = 1$  and  $R(J_i^k) \neq R(J_{i+1}^k)$ ; (iv)  $\forall J_i^k \in J$ ,  $|J_i^k \bullet| = 1$ ; (v)  $\forall t_i^k \in J$ ,  $|\bullet t_i^k \cap J| \leq 1$ ; (vi)  $\forall r \in R$ ,  $|J(r)| \geq 1$ . This means that (i) there are no self loops, (ii) each unit-path has a well defined beginning and an end, (iii) every job requires one and only one resource with no two consequent jobs using the same resource, (iv) and (v), there are no choice jobs and no assembly jobs, (vi) there are shared resources. In MRF<sub>1</sub>PN, for any  $r \in R$ ,  $J(r) = r \bullet \bullet \cap J = \bullet \bullet r \cap J$  and  $R(J_i^k) = \bullet \bullet J_i^k \cap R = J_i^k \bullet \bullet \cap R$ . For any two  $r_i, r_j \in R$ ,  $r_i$  is said to wait  $r_j$ , denoted  $r_i \rightarrow r_j$ , if the availability of  $r_j$  is an immediate requirement for the release of  $r_i$ , i.e.,  $\bullet r_i \cap r_j \bullet \neq \emptyset$ , or equivalently, if there exists at least one transitions  $t \in \bullet r_i \cap r_j \bullet$ .

Any set of resources is called *circular wait* CW, if among the set of resources  $r_a, r_b, \dots, r_w$  exist wait relations among them such that  $r_a \rightarrow r_b \rightarrow \dots \rightarrow r_w$  and  $r_w \rightarrow r_a$ . CW relations are characteristic among shared and nonshared resources in MRF<sub>1</sub>PN and contain at least one shared resource. *Simple circular wait* (SCW) is composed of different resources while *cyclic circular wait* (CCW) is composed of unions of nondisjoint simple CWs. *Deadlock* in the MRF<sub>1</sub>PN is connected with the system condition called *circular blocking* CB, which is a consequence of the existence of circular wait relations CW among resources in the system. A CW  $C$  is said to be in CB if (i)  $m(C) = 0$ ; and (ii) for each  $r \in C$ ,  $\forall p \in J(r)$  with  $m(p) \neq 0$ ,  $p \bullet \in C \bullet$ . Avoiding CB is necessary but generally not sufficient for deadlock-free dispatching policy.

To prevent deadlock in MRF<sub>1</sub>PN we must first avoid CB conditions, which are closely related to the critical siphon. A *critical siphon*  $S$  is a minimal siphon that does not contain any resource loop. The next step is to find sets of job places, so called *critical subsystems*  $J_0(C)$ , A CW  $C$  is in CB at any  $m_0 \in \mathfrak{R}(m)$  if and only if particular critical siphon becomes empty ( $m(S_C) = 0$ ). The critical siphon is empty if and only if  $m(J_0(C)) = m_0(C)$ ; or equivalently, to avoid deadlock we must ensure that the  $m(S_C) \neq 0$  by applying constraint  $m(J_0(C)) < m_0(C)$  to the set  $\mathfrak{R}(m_0)$ . The token sum in the critical subsystem  $J_0(C)$  must be limited above value  $m_0(C) - 1$ . To achieve this, we must connect control places to PPN which form  $P$ -invariant with critical subsystems  $J_0(C)$ .

The deadlock which occurs due to improper "loading" of critical systems  $J_0(C)$  is called *first level deadlock*. The system for which avoiding CB is a necessary and sufficient condition for avoiding deadlock is so called *regular system*. Regular systems contain only first level deadlocks. The above is not true for irregular systems. The *irregular system* contains a key resource. It must be noted that when system contains a key resource, the system may have so called cyclic circular wait relation CCW, that, in particular circumstances, could lead in so called second level deadlock. A *second level deadlock* is a state that is not currently a deadlock, but leads to a deadlock after the next transitions. To avoid second level deadlocks, one must find key resources and apply such control policy that key resource does not remain the last available resource in CCW.





**Figure 3.**  
MRF1PN class of Petri net.  
Source: authors.

This paper focuses on the design of a deadlock prevention supervisor for CWS system which contains only first and second level deadlocks. However, there are other systems with higher level deadlocks, and the deadlock free supervisor design for such systems is presented in (Lee & Tilbury, 2007)

Example:

Fig 3. which shows MRF<sub>1</sub>PN with one input and one output place  $J_{in} = p_1$  and  $J_{out} = p_6$ . There is a set of job places  $J = \{p_2, p_3, p_4, p_5\}$ , a set of resource places  $R = \{r_1, r_2, r_3\}$ , one SCW  $C = \{r_1, r_2, r_3\}$  and one critical subsystem  $J_0(C) = \{p_2, p_3, p_4\}$ . Initial marking of SCW is  $m_0(C) = 3$ .

Matrix  $A_p$  and  $m_{p0}$  of PPN (MRF<sub>1</sub>PN in Fig 3 without  $c_1$ ) are:

$$A_p = \begin{bmatrix} 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\ 0 & 1 & -1 & 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & -1 & 0 & 0 & -1 & 1 & 0 \\ 0 & 0 & 0 & 1 & -1 & 0 & 0 & -1 & -1 \\ 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 1 \end{bmatrix}$$

$$m_{p0} = [4 \ 0 \ 0 \ 0 \ 0 \ 0 \ 1 \ 1 \ 1]^T$$

To avoid deadlock, one must apply constraint  $m(p_2) + m(p_3) + m(p_4) \leq 2$ , hence:

$$L = [0 \ 1 \ 1 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0], \ b = [2].$$

By using (7) and (8) it is possible to calculate control matrix  $A_c$  and  $m_{s0}$ :

$$A_c = [1 \ 0 \ 0 \ -1 \ 0]^T$$

$$m_{c0} = [2]$$

From  $A_c = [1 \ 0 \ 0 \ -1 \ 0]^T$  it is clear that SPN has control place  $c_1$ , with one input arc from  $t_4$  and one output arc to  $t_1$ . Control place  $c_1$  maintains the number of tokens in the critical subsystem to maximum 2. It should be noted that the system in Fig 3. is regular as there are no key resources and second level deadlocks.

One way to calculate supervisors for complex systems is to describe MRF<sub>1</sub>PN by system matrices. There are two sets of system matrices:  $F_u, F_y, F_v, F_r$  and  $S_u, S_v, S_r, S_y$ . Matrices  $F$  capture conditions that must be fulfilled before firing of transitions, while matrices  $S$  are responsible for actions after firing of transitions. A number of rows of  $F_u, F_y, F_v, F_r$  define the number of transitions, while the number of columns defines the number of input places, jobs, resources and output places respectively. A number of columns of  $S_u, S_v, S_r, S_y$  define the number of transitions, while the number of rows defines the number of input places, jobs, resources and output places respectively. Each entry  $(f_r)_{ij}$  in the resource-requirements matrix  $F_r$  is associated with an arc connecting a place, representing resource availability, with the corresponding transition; each entry  $(s_r)_{ij}$  in the resource-release matrix  $S_r$  expresses the connections between transitions and places that hold tokens when resources are idle. Correspondingly, each entry  $(f_v)_{i,j}$  and  $(s_v)_{i,j}$  in job-sequencing matrix  $F_v$  and job-start matrix  $S_v$  represent arcs connecting transitions and places associated operations executed by resources. The input matrix  $F_u$  portrays output arcs from input places, while output matrix  $S_y$  depicts input arcs to output places. Since we assume that input places are source places (places with no input transitions) and output places are sink places (places with no output transitions), matrices  $F_y$  and  $S_u$  are null matrices,  $F_y = S_u = [0]$ . As a result, PN input and output incidence matrices  $I$  and  $O$  can be obtained from the system matrices:

$$I = [F_u \ F_v \ F_r \ F_y] = F \quad (9)$$

$$O = [S_u^T \ S_v^T \ S_r^T \ S_y^T] = S^T \quad (10)$$

System matrices  $F_u, F_y, F_v, F_r$  and  $S_u, S_v, S_r, S_y$  can be derived directly from the MRF<sub>1</sub>PN.

## 5. MATRIX APPROACH OF DEADLOCK PREVENTION SUPERVISOR DESIGN USING MRF<sub>1</sub>PN

The procedure for finding deadlock prevention supervisor for PPN can be divided in eight steps:

*Step 1:* Find all resource loops  $L(r)$  via computing their covering binary P-invariants. The binary basis for P-invariants is given by the columns of the matrix  $\mathbf{P}$ :

$$\mathbf{P} = \begin{bmatrix} -(\hat{\mathbf{S}}_v^T - \hat{\mathbf{F}}_v)^{-1} \cdot (\hat{\mathbf{S}}_r^T - \hat{\mathbf{F}}_r)^{-1} \\ \mathbf{I}_{rst} \end{bmatrix} \quad (11)$$

where:

$\mathbf{I}_{rst}$  - identity matrix with  $r$  resources in the system

Matrices  $\hat{\mathbf{F}}_v$  and  $\hat{\mathbf{F}}_r$  are formed by deleting rows that correspond to the terminal transitions. Matrices  $\hat{\mathbf{S}}_v$  and  $\hat{\mathbf{S}}_r$  are formed by deleting columns that correspond to the terminal transitions. Terminal transition have output arc to  $J_{out}$ .

*Step 2:* Find wait relation matrix  $\mathbf{G}_w$ , all SCW and CCW. Wait relations are captured by the wait relation matrix:

$$\mathbf{G}_w = \mathbf{S}_r \otimes \mathbf{F}_r \quad (12)$$

Where matrix operation  $\otimes$  is defined in and/or algebra, i.e. standard addition and multiplication of matrices elements are replaced by the logical "and" and "or", respectively.

Having obtained matrix  $\mathbf{G}_w$ , there are standard efficient techniques of polynomial complexity, such as string algebra, for identifying matrices  $\mathbf{C}$  and  $\mathbf{O}$ . From  $\mathbf{C}_{r \times (SCW+CCW)}$  it is possible to determine all  $C_i$ , and from  $\mathbf{O}_{SCW \times (SCW+CCW)}$  it is possible to detect which SCW-s are involved in particular CCW. Columns of matrix  $\mathbf{C}$  which contain non shared resources are denoted by vector  $\mathbf{C}_i$ , and those containing shared resources are denoted by vector  $\mathbf{C}_{si}$  (Bogdan, et al., 2006).

*Step 3:* Find critical siphons matrix  $\mathbf{S}_{c_i}$  and critical subsystem matrix  $\mathbf{J}_0(\mathbf{C})$  by using equations:

$$\mathbf{S}_{c_i} = \begin{bmatrix} \mathbf{C}_{si}^T \otimes \mathbf{S}_r \otimes \mathbf{F}_v \wedge \mathbf{C}_i^T \otimes \mathbf{F}_r \otimes \mathbf{F}_v \\ \mathbf{C}_i \end{bmatrix} \quad (13)$$

$$\mathbf{J}_0(\mathbf{C}) = \mathbf{P} \otimes \mathbf{C} \wedge \overline{\mathbf{S}_{c_i}} \quad (14)$$

Where matrix operation  $\wedge$  denotes element-by element logical "and" operation.

Columns of matrix  $\mathbf{S}_{c_i}$  are critical siphons, and column of matrix  $\mathbf{J}_0(\mathbf{C})$  are critical subsystem.

The DES modeled by MRF<sub>1</sub>PN can be regular or irregular. For regular system, only condition for deadlock free policy is that the token count in the critical subsystem must be controlled to ensure the system stability in sense of deadlock. If the system is

irregular, than the second level deadlock can arise, and one must find key resources, which can be done by using next step.

*Step 4:* Key resources can be identified by analyzing interconnections of SCWs and their siphons. To confirm the existence of key resources, one must determine presence of CCW loops. These structures specify a particular sharing among circular waits, and are a requisite for the existence of key resources. To find CCWs among all CWs in the system, one must calculate  $\mathbf{C}_{cw}$ :

$$\mathbf{C}_{cw} = (\mathbf{T}_{sc}^{-T} \otimes \mathbf{T}_{sc}^+)^T \wedge (\mathbf{T}_{sc}^T \otimes \mathbf{T}_{sc}^+) \quad (15)$$

where:

$\mathbf{T}_{sc}^{-T} = (\mathbf{v}_{oc}^T \otimes \mathbf{S}_v - \mathbf{v}_{oc}^T \otimes \mathbf{S}_v \wedge \mathbf{v}_{oc}^T \otimes \mathbf{F}_v^T)$  - is matrix containing transitions which decrease token counts in every critical siphon and

$\mathbf{T}_{sc}^+ = (\mathbf{v}_{oc}^T \otimes \mathbf{S}_v - \mathbf{v}_{oc}^T \otimes \mathbf{S}_v \wedge \mathbf{v}_{oc}^T \otimes \mathbf{F}_v^T)$  - is matrix containing transitions which increase token counts in every critical siphon,  $\mathbf{v}_{oc}$  - critical subsystems matrix.

When  $\mathbf{C}_{cw} = [0]$  the system is *regular*, otherwise an element  $C_{cw}(i, j) = 1$  indicates that  $C_i$  and  $C_j$  form a CCW. Obviously  $\mathbf{C}_{cw}$  is symmetric matrix.

To identify the key resources we must apply the following straightforward matrix formula:

$$\mathbf{R}_{ccw} = (\mathbf{F}_r^T \otimes \mathbf{T}_{ccw}^+) \wedge (\mathbf{F}_r^T \otimes \mathbf{T}_{ccw}^-) \quad (16)$$

where:

$\mathbf{T}_{ccw}^- = (\mathbf{T}_{sc}^+ \otimes \mathbf{C}_{cw}) \wedge \mathbf{T}_{sc}^+$  - matrix containing transitions which decrease token counts in CCWs

$\mathbf{T}_{ccw}^+ = (\mathbf{T}_{sc}^- \otimes \mathbf{C}_{cw}) \wedge \mathbf{T}_{sc}^-$  - matrix containing transitions which increase token counts in CCWs

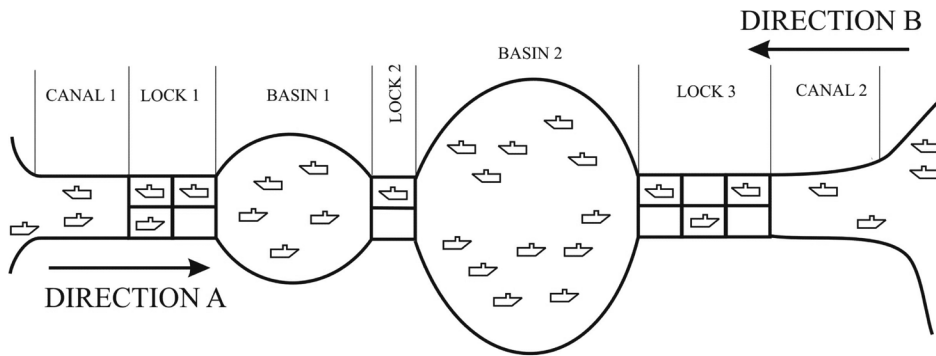
Matrix  $\mathbf{R}_{ccw}$  provides key resources which are shared with other CWs in one or more CCW. If this matrix is zero, there are no key resources in the system.

*Step 5:* To avoid first level deadlock, one must define a set of constraints of type (5) to ensure that the token count in each critical subsystem  $J_0(\mathbf{C})$  remains below  $m_0(\mathbf{C}) - 1$ . Using P invariant method (section 3), calculate a control place for each  $J_0(\mathbf{C})$  and add to PPN to derive CPN.

*Step 6:* After identifying all key resources in step 4, one must find all second level deadlocks in the CPN derived in step 5. These second level deadlocks arise when one or more key resources become last available resources in the net. To find second level deadlocks, one must calculate reachability tree (Kezić, 2004).

*Step 7:* To avoid second level deadlocks in step 6, the constraints of type (5) must be applied to the CPN. The new control places can be calculated using P-invariant method





**Figure 4.**  
Complex waterway  
system.  
Source: authors.

described in section 3 and added to Petri net to derive final CPN for irregular system.

*Step 8:* Find reachability tree of the CPN derived in step 7. If there are new deadlocks go to step 5, otherwise the algorithm ends and final deadlock free CPN is found.

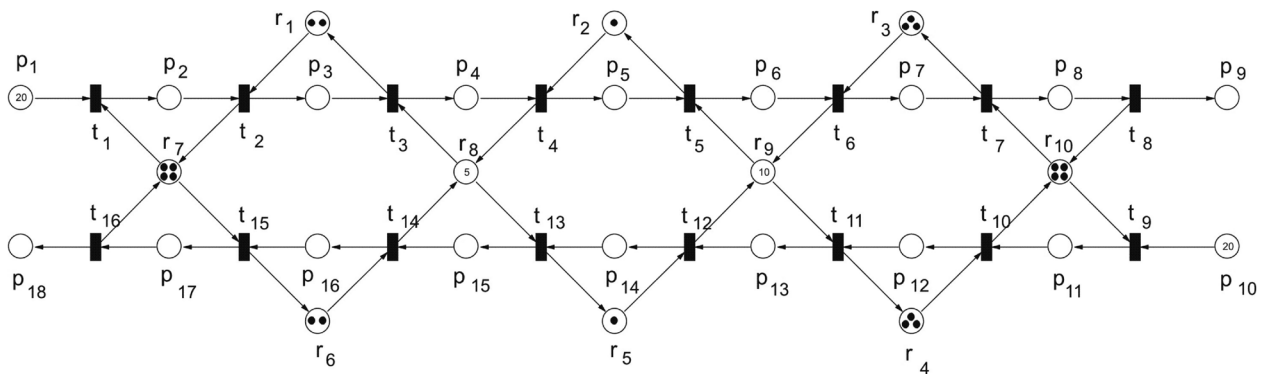
## 6. DEADLOCK AVOIDANCE IN WATERWAY WITH MULTIPLE LOCKS AND CANALS – CASE STUDY

This chapter deals with a supervisor design of the CWS (Fig. 4). This example will clarify the theory presented in previous sections. The presented case study example is very similar to the Panama canal. However, the above theory is applicable for more complex systems.

The CWS in Fig.4 connects two oceans, and consists of 2 canals ( $Cl_1, Cl_2$ ), 3 double locks ( $L_1, L_2, L_3$ ) for lifting or lowering the vessels, 2 lakes or basins ( $B_1, B_2$ ). Lake  $B_1$  is above sea level, and lake  $B_2$  is above water level of  $B_1$ . The vessels in direction A are moving through the  $Cl_1$ , lift in lock  $L_1$ , move and wait for the

availability of the lock  $L_2$  in the lake  $B_1$ . Then lift in the lock  $L_2$  to the level  $B_2$ , move toward the lock  $L_3$  and lower to the sea level. The procedure for direction B is inversed. The vessels can move through the CWS using their own propulsion, tugboats or towing vehicles. All canals, locks and basins represent resources of a CWS. The vessels in both directions share canals  $Cl$  and basins  $B$ . All locks  $L$  are one, two or three stages double locks with one side for direction A, and the other for direction B.

Number of vessels in resources (capacity of resources) is, as a rule, limited due to the various reasons (numbers of available tugboats, weather conditions, water and sea conditions etc). If a particular resource is occupied in a moment of time, and if there are vessels waiting to use them, then these vessels wait for the availability of the occupied resource at the exit of the resource where they are in the moment of time. When the resource becomes available, it is occupied by awaiting vessels. The capacities  $Cap(r)$  of canals and basins are  $Cap(Cl_1, Cl_2) = 4$ ,  $Cap(B_1) = 5$ ,  $Cap(B_2) = 10$ . The capacities of locks in direction A are:  $Cap(L_1) = 2$ ,  $Cap(L_2) = 1$ ,  $Cap(L_3) = 3$  (same capacity in direction B).



**Figure 5.**  
Process Petri net of CWS.  
Source: authors.

The first step which must be taken is to make MRF<sub>1</sub>PN model of CWS. Figure 5 shows PPN of CWS, and Table 1 describes places belonging to PPN. Tokens in input places  $\{p_1, p_{10}\}$  represent the vessels waiting for entering the system, and the tokens in the set of output places  $\{p_9, p_{18}\}$  represent the vessels leaving the system. The set of all places that represent jobs in the system (the number of tokens in a job place represent the number of vessels in particular resource) are  $\{p_2, \dots, p_{17}\}$ , and the set of places that represent availability of resources is  $\{r_1, \dots, r_{10}\}$  (the number of tokens in a resource place represents the capacity of particular resource).

Table 1 shows description of the places  $p_i$  in the PPN (Fig. 5), their initial marking  $m_0(p_i)$ , and time  $T_i$  in hours associated to the places (simulation in Fig 7, 8). Places  $\{p_1, \dots, p_9, r_1, r_2, r_3\}$  describe moving in direction A, places  $\{p_{11}, \dots, p_{18}, r_4, r_5, r_6\}$  describe moving in direction B. Places  $\{r_7, \dots, r_{10}\}$  are shared resources.

There are two problems that must be solved. The first problem is a conflict, and the second problem is deadlock. The conflict arises when vessels from both directions try to occupy the same shared resources  $\{r_7, \dots, r_{10}\}$  with limited capacity. In this situation the 4 pairs of transitions ( $t_1, t_{15}$  and/or  $t_3, t_{13}$  and/or  $t_5, t_{11}$  and/or  $t_7, t_9$ ) can be in conflict (both transitions are enabled at the same time). A conflict free supervisor disables one of the transitions in conflict. Firing both of the transitions in conflict cannot occur simultaneously.

The second problem is how to design the deadlock free supervisor. The supervisor is required to be the maximally permissible i.e. not hindering the passage of the vessels. To achieve this we must apply matrix approach described in section 6. Here are the results:

*Step 1:* The  $P$  invariants can be calculated applying (6). There are 10  $P$ -invariants in the net:  $P_1 = \{p_3, r_1\}$ ,  $P_2 = \{p_5, r_2\}$ ,  $P_3 = \{p_7, r_3\}$ ,  $P_4 = \{p_{12}, r_4\}$ ,  $P_5 = \{p_{14}, r_5\}$ ,  $P_6 = \{p_{16}, r_6\}$ ,  $P_7 = \{p_2, p_{17}, r_7\}$ ,  $P_8 = \{p_4, p_{15}, r_8\}$ ,  $P_9 = \{p_6, p_{13}, r_9\}$ ,  $P_{10} = \{p_8, p_{11}, r_{10}\}$

*Step 2:* Applying (12) and string algebra we can find 3 SSW,  $C_1 = \{r_1, r_6, r_7, r_8\}$ ,  $C_2 = \{r_2, r_5, r_8, r_9\}$ ,  $C_3 = \{r_3, r_4, r_9, r_{10}\}$ , and 3 CCW:  $C_4 = C_1 + C_2 = \{r_1, r_2, r_5, r_6, r_7, r_8, r_9\}$ ,  $C_5 = C_2 + C_3 = \{r_2, r_3, r_4, r_5, r_8, r_9, r_{10}\}$ ,  $C_6 = C_1 + C_2 + C_3 = \{r_1, r_2, r_3, r_4, r_5, r_6, r_7, r_8, r_9, r_{10}\}$

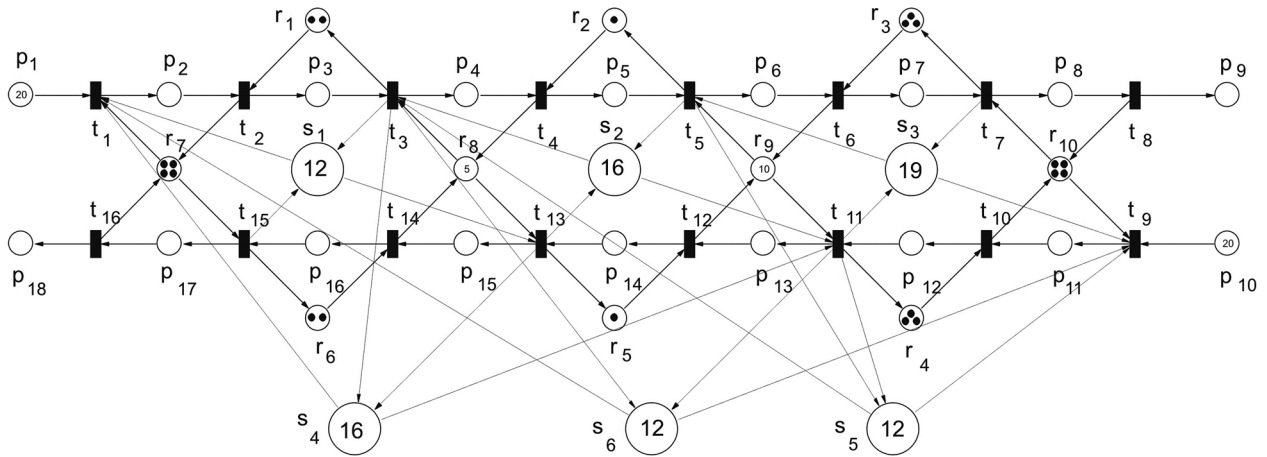
*Step 3:* By applying (13) and (14) it is possible to find all critical siphons and critical subsystems.

There are 6 critical siphons:

$S_{C_1} = \{r_1, r_6, r_7, r_8, p_4, p_{17}\}$ ,  
 $S_{C_2} = \{r_2, r_5, r_8, r_9, p_6, p_{15}\}$ ,  
 $S_{C_3} = \{r_3, r_4, r_9, r_{10}, p_8, p_{13}\}$ ,  
 $S_{C_4} = \{r_1, r_2, r_5, r_6, r_7, r_8, r_9, p_6, p_{17}\}$ ,  
 $S_{C_5} = \{r_2, r_3, r_4, r_5, r_8, r_9, r_{10}, p_8, p_{15}\}$ ,  
 $S_{C_6} = \{r_1, r_2, r_3, r_4, r_5, r_6, r_7, r_8, r_9, r_{10}, p_8, p_{17}\}$   
and 6 critical subsystems

**Table 1.**  
Description of the PPN in Figure 5.  
Source: authors.

$p_i$	Description	$m_0(p_i)$	$T_i$ [h]
$\{p_1\}$	Waiting for $Cl_1$	20	0
$\{p_2\}$	Vessel is in $Cl_1$	0	0,9
$\{p_3\}$	Vessel is $L_1$	0	0,784
$\{p_4\}$	Vessel is in $B_1$	0	0,78
$\{p_5\}$	Vessel is in $L_2$	0	0,39
$\{p_6\}$	Vessel is in $B_2$	0	3,77
$\{p_7\}$	Vessel is in $L_3$	0	1,69
$\{p_8\}$	Vessel is in $Cl_2$	0	0,9
$\{p_9\}$	Passed CWS	0	0
$\{p_{10}\}$	Waiting for $Cl_2$	20	0
$\{p_{11}\}$	Vessel is in $Cl_2$	0	0,9
$\{p_{12}\}$	Vessel is in $L_3$	0	1,69
$\{p_{13}\}$	Vessel is in $B_2$	0	3,77
$\{p_{14}\}$	Vessel is in $L_2$	0	0,39
$\{p_{15}\}$	Vessel is in $B_1$	0	0,78
$\{p_{16}\}$	Vessel is in $L_1$	0	0,784
$\{p_{17}\}$	Vessel is in $Cl_1$	0	0,9
$\{p_{18}\}$	Passed CWS	0	0
$\{r_1\}$	$L_1$ is available	2	0
$\{r_2\}$	$L_2$ is available	1	0
$\{r_3\}$	$L_3$ is available	3	0
$\{r_4\}$	$L_3$ is available	3	0
$\{r_5\}$	$L_2$ is available	1	0
$\{r_6\}$	$L_1$ is available	2	0
$\{r_7\}$	$Cl_1$ is available	4	0
$\{r_8\}$	$B_1$ is available	5	0
$\{r_9\}$	$B_2$ is available	10	0
$\{r_{10}\}$	$Cl_2$ is available	4	0



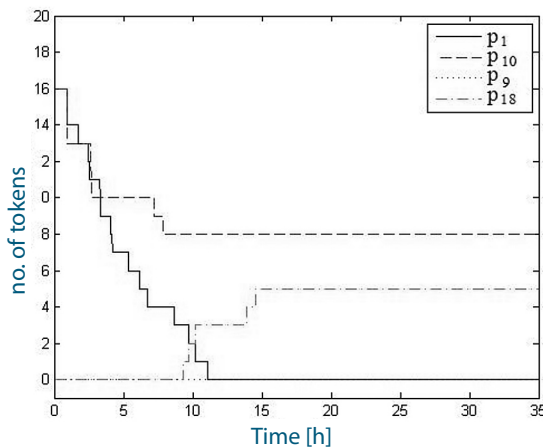
**Figure 6.**  
Final Composite Petri net of CWS  
Source: authors.

$$\begin{aligned}
 J_{0_1} &= \{p_2, p_3, p_{15}, p_{16}\}, \\
 J_{0_2} &= \{p_4, p_5, p_{13}, p_{14}\}, \\
 J_{0_3} &= \{p_6, p_7, p_{11}, p_{12}\}, \\
 J_{0_4} &= \{p_2, \dots, p_5, p_{13}, \dots, p_{16}\}, \\
 J_{0_5} &= \{p_4, \dots, p_7, p_{11}, \dots, p_{14}\}, \\
 J_{0_6} &= \{p_2, \dots, p_7, p_{11}, \dots, p_{16}\}.
 \end{aligned}$$

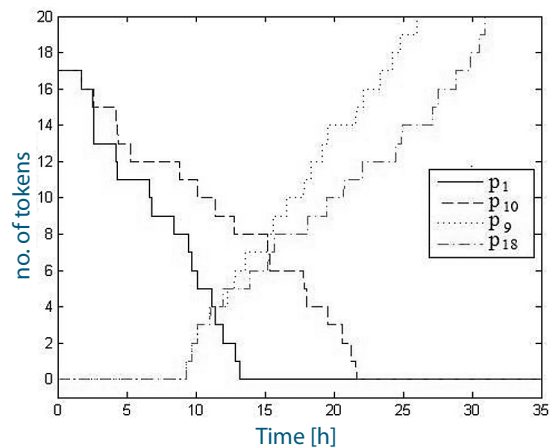
*Step 4:* To check if the system is regular, matrix  $C_{CW}$  must be calculated by applying (15). The system is irregular  $C_{CW} \neq [0]$ . From  $R_{CCW}$ , by applying (16), it is possible to see that the key resources in the system are  $r_7$  and  $r_8$  ( $B_1$  and  $B_2$ ).

*Step 5:* The initial markings of CWs are  $m_0(C_1)=13$ ,  $m_0(C_2)=17$ ,  $m_0(C_3)=20$ ,  $m_0(C_4)=25$ ,  $m_0(C_5)=27$  and  $m_0(C_6)=35$ . To avoid first level deadlock we can calculate 3 control places ( $S_1$ ,  $S_2$  and  $S_3$ ) for controlling  $J_{0_1}$ ,  $J_{0_2}$ ,  $J_{0_3}$ . By applying constraints  $m(J_0) \leq m_0(C) - 1$  it is possible to calculate  $m_0(s_1)=12$ ,  $m_0(s_2)=16$ ,  $m_0(s_3)=19$ . We are adding control places  $S_1$ ,  $S_2$  and  $S_3$  to the PPN (large circuits in Fig 5). There is no need for controlling  $J_{0_4}$ ,  $J_{0_5}$ ,  $J_{0_6}$ .

*Step 6:* To ensure the absence of second level deadlock, the supervisor has to take care of the availability of key resources  $r_7$



**Figure 7.**  
CWS without supervisor.  
Source: authors.



**Figure 8.**  
CWS with supervisor.  
Source: authors.

and  $r_8$  in the way that each of the resources and both of them must not remain last available resources in the system. From the reachability tree one can find three deadlocks which occur in case of:

$$m(p_2 + p_3 + p_{13} + p_{14}) = m(r_1 + r_5 + r_7 + r_9),$$

$$m(p_4 + p_5 + p_{11} + p_{12}) = m(r_2 + r_4 + r_8 + r_{10})$$

$$m(p_2 + p_3 + p_{11} + p_{12}) = m(r_1 + r_4 + r_7 + r_{10})$$

*Step 7:* To avoid second level deadlocks in step 6 one must calculate additional control places  $s_4, s_5, s_6$  using the constraints:

Control place  $s_4$ :

$$m(p_2 + p_3 + p_{13} + p_{14}) \leq m(r_1 + r_5 + r_7 + r_9) - 1$$

Control place  $s_5$ :

$$m(p_4 + p_5 + p_{11} + p_{12}) \leq m(r_2 + r_4 + r_8 + r_{10}) - 1$$

Control place  $s_6$ :

$$m(p_2 + p_3 + p_{11} + p_{12}) \leq m(r_1 + r_4 + r_7 + r_{10}) - 1$$

The initial markings are  $m_0(s_4) = 16$ ,  $m_0(s_5) = 12$ ,  $m_0(s_6) = 12$  can be derived from (8). New control places  $s_4$ ,  $s_5$  and  $s_6$  are added to the PPN.

*Step 8:* There are no new deadlocks in reachability tree of the CPN derived in step 7 and the algorithm ends. In total, six control places are added to the PPN to derive deadlock free CPN in Fig 6.

The deadlock prevention supervisor for CWS is verified using computer simulation and P-timed Petri net, in which time is associated to the particular places (see Table 1). Fig 7 and Fig 8 show number of vessels in input and output places  $\{p_1, p_9, p_{10}, p_{11}\}$ . First buffer first served control policy is applied, and maximum number of vessels in both directions passing through the CWS. Graph in Fig. 7 shows number of vessels in CWS without supervisor (deadlock occurs in critical system  $J_{03}$ , 15 h after beginning of simulation). Fig 8 shows a deadlock free CWS with supervisor. All vessels passed CWS in 31 h.

## 7. CONCLUSION

This paper shows a straightforward matrix based method for calculating conflict and deadlock prevention supervisor using MRF<sub>1</sub>PN class of Petri net and P-invariant method for control places design. To achieve this, the first step is to make a suitable Petri net model of complex waterway system. Then, the structural properties of the Petri net, like P-invariants, circular waits, critical siphons and critical subsystems are investigated. The authors propose the addition of control places to the Petri net, which forms a supervisor. Conflicts and the first level deadlock can be avoided by adding control places, which disable firing of particular transitions and limit the number of vessels in critical subsystems. The second level deadlock can still exist if the system is irregular and if it contains so called key resource, and the existence of key resources must be checked. To avoid the second level deadlock, the supervisor must take care that one or more key resources would not be the last available resource in the net. The authors propose the novel method for second level deadlock prevention in case of more key resources. The calculated controller is verified using a P-timed Petri net model and computer simulation by using Matlab environment. The proposed matrix based method of supervisor design is not time consuming, and is suitable for design of complex traffic management system and can be easily implemented by men or by traffic lights. Future research will be focused on deadlock analysis and avoidance of systems with nondeterministic job routing.

## APPENDIX: LIST OF MATRICES

Step 1: **P** matrix

	$P_1$	$P_2$	$P_3$	$P_4$	$P_5$	$P_6$	$P_7$	$P_8$	$P_9$	$P_{10}$
$p_2$	0	0	0	0	0	0	1	0	0	0
$p_3$	1	0	0	0	0	0	0	0	0	0
$p_4$	0	0	0	0	0	0	0	1	0	0
$p_5$	0	1	0	0	0	0	0	0	0	0
$p_6$	0	0	0	0	0	0	0	0	1	0
$p_7$	0	0	1	0	0	0	0	0	0	0
$p_8$	0	0	0	0	0	0	0	0	0	1
$p_{10}$	0	0	0	0	0	0	0	0	0	1
$p_{12}$	0	0	0	1	0	0	0	0	0	0
$p_{13}$	0	0	0	0	0	0	0	0	1	0
$p_{14}$	0	0	0	0	1	0	0	0	0	0
$p_{15}$	0	0	0	0	0	0	0	1	0	0
$p_{16}$	0	0	0	0	0	1	0	0	0	0
$p_{17}$	0	0	0	0	0	0	1	0	0	0
$r_1$	1	0	0	0	0	0	0	0	0	0
$r_2$	0	1	0	0	0	0	0	0	0	0
$r_3$	0	0	1	0	0	0	0	0	0	0
$r_4$	0	0	0	1	0	0	0	0	0	0
$r_5$	0	0	0	0	1	0	0	0	0	0
$r_6$	0	0	0	0	0	1	0	0	0	0
$r_7$	0	0	0	0	0	0	1	0	0	0
$r_8$	0	0	0	0	0	0	0	1	0	0
$r_9$	0	0	0	0	0	0	0	0	1	0
$r_{10}$	0	0	0	0	0	0	0	0	0	1

Step 2: **C** matrix

	$C_1$	$C_2$	$C_3$	$C_{12}$	$C_{23}$	$C_{123}$
$r_1$	1	0	0	1	0	1
$r_2$	0	1	0	1	1	1
$r_3$	0	0	1	0	1	1
$r_4$	0	0	1	0	1	1
$r_5$	0	1	0	1	1	1
$r_6$	1	0	0	1	0	1
$r_7$	1	0	0	1	0	1
$r_8$	1	1	0	1	1	1
$r_9$	0	1	1	1	1	1
$r_{10}$	0	0	1	0	1	1

Step 3: **S<sub>C</sub>** and **J<sub>o</sub>(C)** matrices

<b>S<sub>C</sub></b>	<b>J<sub>o</sub>(C)</b>
$S_{C_1}$ $S_{C_2}$ $S_{C_3}$ $S_{C_4}$ $S_{C_5}$ $S_{C_6}$	$J_{0_1}$ $J_{0_2}$ $J_{0_3}$ $J_{0_4}$ $J_{0_5}$ $J_{0_6}$
$p_2$	$p_2$
$p_2$	$p_3$
$p_3$	$p_4$
$p_4$	$p_5$
$p_5$	$p_6$
$p_6$	$p_7$
$p_7$	$p_8$
$p_8$	$p_{11}$
$p_{11}$	$p_{12}$
$p_{12}$	$p_{13}$
$p_{13}$	$p_{14}$
$p_{14}$	$p_{15}$
$p_{15}$	$p_{16}$
$p_{16}$	$p_{17}$
$p_{17}$	$r_1$
$r_1$	$r_2$
$r_2$	$r_3$
$r_3$	$r_4$
$r_4$	$r_5$
$r_5$	$r_6$
$r_6$	$r_7$
$r_7$	$r_8$
$r_8$	$r_9$
$r_9$	$r_{10}$
$r_{10}$	

Step 4,5: **C<sub>cw</sub>** and **R<sub>ccw</sub>** matrices

**C<sub>cw</sub> ≠ [0]**

	$r_1$	$r_2$	$r_3$	$r_4$	$r_5$	$r_6$	$r_7$	$r_8$	$r_9$	$r_{10}$
$C_1$	0	0	0	0	0	0	0	1	0	0
$C_2$	0	0	0	0	0	0	0	1	1	0
$C_3$	0	0	0	0	0	0	0	0	1	0
$C_{12}$	0	0	0	0	0	0	0	1	0	0
$C_{23}$	0	0	0	0	0	0	0	0	1	0
$C_{123}$	0	0	0	0	0	0	0	1	1	0

## REFERENCES

- Barkaoui, K. and Abdallah, J., (1995), Deadlock avoidance in FMS based on structural theory of Petri Nets, IEEE Symposium on Emerging Technologies and Factory Automation, Paris, France, 10 – 13 October 1995, pp. 499-510., <http://dx.doi.org/10.1109/ISIE.2005.1528915>
- Barkaoui, K., Chaoui, A. and Zuoari, B., (1997), Supervisory control of discrete event systems based on structure theory of Petri nets, In IEEE Proceeding of International Conference on System, Man, Cybernetic, Orlando, FL, pp. 3750-3755., <http://dx.doi.org/10.1109/ICSMC.1997.633253>
- Barkaoui, K. and Petrucci, L., (1988), Structural analysis of workflow nets with shared resources, In Proceedings Workshop Workflow Management: Net – Based Concepts, Models, Tech, Tools, Lisbon, Portugal, 22 June 1988, pp. 82-85.
- Boffey, T.B., (1982), Graph theory in Operations research, London: Macmillan.
- Bogdan, S. and Lewis, F.L., (1997), Matrix approach to deadlock avoidance of dispatching in multi-class finite buffer reentrant flow lines, IEEE Proceedings of the International Symposium of Intelligent control, Istanbul, Turkey, 16-18 July 1997, pp. 397 – 402. <http://dx.doi.org/10.1109/ISIC.1997.626525>
- Bogdan, S., Lewis, F.L., Kovačić, Z. and Mireles, J., (2006), Manufacturing systems control design – A matrix-based approach, London: Springer.
- Charbonnier, F., Alla, H. and David, R., (2001), The Supervised Control of Discrete-Event Dynamic Systems, IEEE Transactions on Control Systems Technology, 7(2), pp. 175–187.
- Ezpelta, J., Colom, J. and Martinez, J., (1995), A Petri net based deadlock prevention policy for flexible manufacturing systems, IEEE Transactions on Robotics and Automation, 11(2), pp. 173-184. <http://dx.doi.org/10.1109/ISIC.1997.626525>
- Gallego, J.L., Farges, J.L. and Henry, J.J., (1996), Design by Petri nets of an intersection signal controller, Transportation Research Part C: Emerging Technologies, 4(4), pp. 231-248.
- Hernández, J., Ossowski, S. and Garcia-Serrano, A., (2002), Multiagent architectures for intelligent traffic management systems, Transportation Research Part C: Emerging Technologies, 10(5-6), pp. 473-506.
- Hopcroft, J.E. and Ullman, J.D., (1979), Introduction to Automata Theory, Languages, and Computation, Reading: Addison-Wesley.
- Iordache, M.V., Moody, J.O. and Antsaklis, P.J., (2000), Automated synthesis of deadlock prevention supervisor using Petri nets, Technical report of the ISIS Group at the University of Notre Dame, ISIS-2000-003.
- Kezić, D., (2004), Sprječavanje potpunog zastoja u sustavima s diskretnim događajima primjenom Petrijevih mreža, PhD Thesis, Faculty of Electrical Engineering and Computing, University of Zagreb.
- Kezić, D., Perić, N. and Petrović, I., (2006), An algorithm for deadlock prevention based on iterative siphon control of Petri net, Automatica, 47(1-2), pp. 19–30.
- Kezić, D., Gudelj, A. and Vujović, I., (2009), Matrix Based Supervisor Design of Marine Traffic System. In Proceedings of the International conference ports and waterways, Zagreb, Croatia, 10-11 September 2009.
- Lautenbach, K. and Ridder, H., (1996), The linear algebra of deadlock avoidance – a Petri net approach, Research Report of Institute for Computer Science, University of Koblenz.
- Lee, S. and Tilbury, D. M., (2007), Deadlock-Free Resource Allocation Control for a Reconfigurable Manufacturing System With Serial and Parallel Configuration, IEEE Transactions on System, Man and Cybernetics – Part C, 37(6), pp. 1373-1381., <http://dx.doi.org/10.1109/TSMCC.2007.905843>
- Lewis, F., Huang, H., Tacconi, D., Gurel, A. and Pastravanu, O., (1998), Analysis of deadlocks and circular waits using a matrix model for discrete event systems, Automatica, 34(9), pp. 1083-1100.
- Mingming, Y., Hesuan, H. and Zhiwu, L., (2008), Deadlock Prevention Policy based on Elementary Siphons for Flexible Manufacturing Systems, Proceedings of the International conference on advanced intelligent mechatronics, Xi'an, China, 2-5 July 2008, pp. 229-234. <http://dx.doi.org/10.1109/AIM.2008.4601664>
- Murata, T., (1989), Petri Nets: „Properties, Analysis and Applications“, In IEEE Proceedings, 77(4), pp. 541-580.
- Overkamp, A.A.F. and van Schuppen, J.H., (1995), Control of discrete event systems – Research at the interface of control theory and computer science, CWI Quarterly, 8 (1995), pp. 31-45.
- Piroddi, L., Cordone, R. and Fumagalli, I., (2009), Efficient Deadlock Prevention in Petri Nets through the Generation of Selected Siphons, American Control Conference, St. Louis, MO, USA, 10-12 June 2009, pp. 5006-5011. <http://dx.doi.org/10.1109/ACC.2009.5159861>
- Tricas, F., Garcia-Valles, F., Colom, J. M. and Ezpelta J., (2000), An iterative method for deadlock prevention in FMS, In Proceedings of the 5th Workshop Discrete Event System Ghent, Belgium, 21-23 August 2000, pp. 139 –148.
- Tricas, F., Garcia-Valles, F., Colom, J. M. and Ezpelta J., (2005), A Petri net structure based deadlock prevention solution for sequential resource allocation systems, In Proceedings of the IEEE International Conference on Robotic and Automation, Barcelona, Spain, 18-22 April 2005, pp. 271-277. <http://dx.doi.org/10.1109/ROBOT.2005.1570131>
- Vaz, A.F. and Wonham, W.M., (1986), On supervisor reduction in discrete-event systems, International Journal of Control, 44(2), pp. 475-491. <http://dx.doi.org/10.1080/00207178608933613>
- Yamalidou, K., Moody, J., Lemmon, M. and Antsaklis, P., (1996), Feedback Control of Petri Nets Based on Place Invariants., Automatica, 32(1), pp. 15-28.
- ZhiWu, L., Sen, Z. and MengChu, Z., (2009), A Divide-and-Conquer Strategy to Deadlock Prevention in flexible Manufacturing Systems, IEEE Transactions on System, Man and Cybernetics, 39(2), pp. 156-169. <http://dx.doi.org/10.1109/TSMCC.2008.2007246>

# Cutting-edge Mathematical Tools in Processing and Analysis of Signals in Marine and Navy

Igor Vujović<sup>1</sup>, Joško Šoda<sup>2</sup>, Ivica Kuzmanić<sup>3</sup>

Signal processing plays a pivotal role in information gathering and decision making. This paper presents and compares different signal processing techniques used in marine and navy applications, primarily based on using wavelets as kernel. The article covers Fourier transform, time frequency wavelet based techniques such as bandelets, contourlets, curvelets, edgelets, wedgelets, shapelets, and ridgelets. In the example section of the paper, several transform techniques are presented and commented on the harbour surveillance video stream example.

## KEY WORDS

- ~ Harbour surveillance
- ~ Wavelet
- ~ Fourier transform
- ~ Signal processing
- ~ Edgelets
- ~ Curvelets

## 1. INTRODUCTION

Modern electronic equipment such as GPS, radar, electronic charts, autopilot, alarm systems, automatic control systems regularly uses some sort of signal processing and analysis techniques. Signals can be divided in different sets such as stationary or non-stationary, periodic or aperiodic, deterministic or stochastic. They contain information in time, frequency and/or any other spatial domain. Classical approach of extracting information from a signal is to transform the signal from the original domain, usually time domain, to the transformed domain, usually frequency domain. Frequency information of a given signal is usually compressed or embedded into the signal and could be extracted by applying one of the feature extraction techniques. Due to the fact that most of nowadays signals are of nonstationary and stochastic nature, and depending on the application, applying Fourier based techniques for signal analysis is not efficient. Therefore, novel mathematical tools were needed and have been proposed.

Area of image processing and analysis had rapid development in many applications in last decade – so as in the marine. Image processing and analysis play important role in the cutting-edge applications, such as in security, contra-terrorism, cargo flow, smuggling of narcotics, people (trafficking) or other goods, etc.

Among novel transforms, which are covered in the article, are wavelet-inspired transforms.

The paper is organized as follows. The Second section presents foundation of wavelet transforms chronologically, and various implementations. Also a Short Time Fourier Transform is presented as an introduction to time-frequency wavelet based techniques. The third section introduces and compares novel time frequency techniques based on wavelet kernel, such as

1, 3 University of Split, Faculty of Maritime Studies, Zrinsko-Frankopanska 38, 21000 Split, Croatia

E-mail: [ivujovic@pfst.hr](mailto:ivujovic@pfst.hr), [ikuzman@pfst.hr](mailto:ikuzman@pfst.hr)

2 University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Ruđera Boškovića 32, 21000 Split, Croatia

E-mail: [jsoda@fesb.hr](mailto:jsoda@fesb.hr)



edgelets, curvelets, contourlets, bandelets, wedgelets, chirplets and grouplets. Wavelet based time frequency techniques introduced in the second and third sections are applied, on real time port surveillance video stream, in the fourth section. Appropriate comments are given and there is a conclusion in the last section of the paper.

## 2. WAVELET BASED TIME FREQUENCY ALGORITHMS, A BRIEF INTRODUCTION

Fourier transform (FT) is a standard tool in many signal processing applications such as radio communications. FT is defined by (Proakis and Manolakis, 2007):

$$F(\omega) = \int_{-\infty}^{\infty} f(t) e^{-i\omega t} dt = |F(\omega)| \cdot e^{i \arctg(F(\omega))} \quad (1)$$

where a  $f(t)$  is an observed signal in the time-domain,  $F(\omega)$  a spectrum of the observed signal. For a given frequency,  $\omega$ , equation (1) measures how much sine wave at frequency  $\omega$  is comprised in the observed signal  $f(t)$ . The greater the value of a  $|F(\omega)|$ , frequency  $\omega$  considerably contributes in the spectrum of observed signal  $f(t)$ .

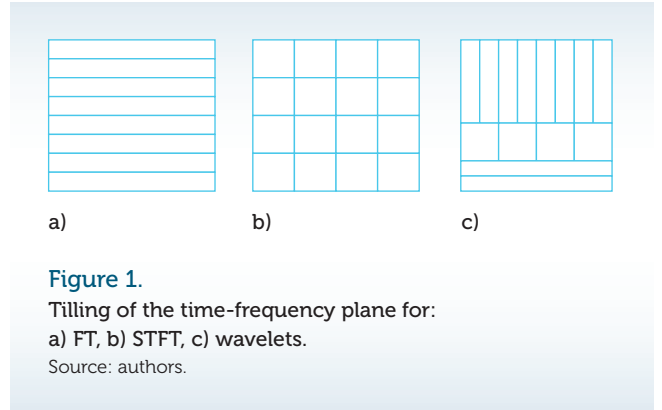
However, in real applications non-stationary signals, whether periodical or non-periodical, are the most common signals obtained from measurements and systems. It is well known fact (Strang and Nguen, 1997; Antoniou, 2006) that FT is not appropriate tool for analyzing non-stationary signals since it loses information about time domain. Therefore, new transforms, which compute time and frequency domain at the same time, are proposed.

Historically, Short Time Fourier Transform (STFT) or Windowed Fourier Transform (WFT) has been the first linear time-frequency transform proposed (Wickerhauser, 1994; Strang and Nguen, 1997). It is defined by:

$$STFT_f^\omega(\tau, \omega) = \int_t [f(t) \cdot W(t - \tau)] \cdot e^{-j\omega t} dt \quad (2)$$

where a STFT of a signal  $f(t)$  is computed for each window centred at a  $t = \tau$ , at  $\omega = \omega_0$  frequency, which is called localized spectrum.  $A \cdot W(t - \tau)$  is referred to as windowing function or analysis window. An expression  $e^{-j\omega t}$  is referred as FT kernel. STFT segments analyzed signal into narrow time intervals, which are narrow enough to be considered stationary on the interval. After that Fourier Transform is applied on each segment, (Gabor, 1946; Polikar, 2002).

In order to depict basis functions of time-frequency transform a time-frequency plane is proposed (Herley et al., 1993) which is also called tiling or time-frequency tiling. The time-frequency plane of a particular basis function designates the region in the plane which contains most of that function's energy, which is shown in Figure 1.



In a time-frequency plane, segments of the signal  $f(t)$  have a time spread, denoted as  $\Delta t$ ,

$$\Delta t = \int_{-\infty}^{+\infty} t^2 \cdot |f(t)|^2 dt \quad (3)$$

and frequency spread, denoted  $\Delta \omega$ ,

$$\Delta \omega = \int_{-\infty}^{+\infty} \omega^2 \cdot |F(\omega)|^2 d\omega \quad (4)$$

Then, the well-known uncertainty principle, i.e. Heisenberg principle (Wichmann, 1988), imposes the following lower bound on the product of time and frequency spreads:

$$\Delta t^2 \cdot \Delta \omega^2 \geq \pi/2 \quad (5)$$

Figure 1a shows time-frequency tiling for Fourier Transform. Since sine waves which are basis function for FT, have infinite compact support in time axis and ideal frequency resolution in frequency axis. Therefore horizontal strips represent time-frequency tiling. Figure 1b shows time-frequency tiling for Short Time Fourier Transform. Due to the existence of window function,  $W(t - \tau)$ , there is a compact support in time axis and in frequency axis, therefore time-frequency tiling is presented with squares. In order to extract some features from the analyzed signal, some applications require an adaptable window function,  $W(t - \tau)$ , for which STFT is not suitable. In order to overcome aforementioned problem, a Wavelet Transform is proposed (Daubechies, 1992). It can be defined as follows.

**Definition 2.1.** Let  $\psi(t) \in L_2(R)$  be the wavelet in the time domain and  $\Psi(\omega)$  the same wavelet in the frequency domain. If and only if exists the integral:

$$CWT_r(a, b) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{\infty} f(t) \psi^* \left( \frac{t-b}{a} \right) dt = \langle \psi_{a,b}(t), f(t) \rangle \quad (6)$$



the following rules apply:

$$1^{\circ} \int \psi(t) dt = \Psi(\omega=0) = 0$$

2<sup>o</sup> Translated (which is presented with parameter b) and scaled (which is presented with parameter a) function of  $\psi(t)$

is described as  $\psi_{a,b}(t) = \frac{1}{\sqrt{|a|}} \cdot \psi\left(\frac{t-b}{a}\right)$  where  $a, b \in \mathbb{R}$  and  $a \neq 0$ . Function  $\psi(t)$  is called mother wavelet, and  $\psi\left(\frac{t-b}{a}\right)$  is

dilated version of mother wavelet at given scale  $a$ . In practical applications, scale parameter is always  $a \leq 1$ .

3<sup>o</sup> Normalization rules apply:  $\|\psi_{a,b}(t)\| = \|\psi(t)\|$  and

4<sup>o</sup> Then the CWT satisfies the sufficient and necessary conditions and it is called Continuous Wavelet Transform (CWT) (Kingsbury and Magarey, 1997).

Wavelets  $\psi(t)$  can be considered as band pass filters (Vetterli and Kovačević, 1995; Rioul and Vetterli, 1991).

Figure 1c shows time-frequency tiling for Continuous Wavelet Transform. Since wavelets are compactly supported in both axes, an adaptable window exists in time-frequency plane. At high frequencies there is good localization in time, and at low frequencies there is good localization in frequency (Mallat, 1999). It has to be pointed out that the area of time-frequency window is always constant so Heisenberg's uncertainty principle is preserved.

In order to use Continuous Wavelet Transform with computer and in order to ensure convergence of CWT algorithm, sampling of coefficients is needed (Kingsbury and Magarey, 1997). An algorithm obtained by sampling coefficients of CWT transform is known as Discretized Continuous Wavelet Transform (Christopher and Walnut, 2006).

If the wavelet equation  $\psi_{a,b}(t) = \frac{1}{\sqrt{|a|}} \cdot \psi\left(\frac{t-b}{a}\right)$  is

discretized by choosing coefficients of the scale,  $a$ , and the translation,  $b$ , to form a dyadic pair, (Vetterli and Kovačević, 1995), a discretized version of wavelet equation is obtained:

$$\psi_{m,n}(t) = 2^{-m/2} \cdot \psi(2^{-m/2} \cdot t - n) \quad (7)$$

Then eq. (6) becomes:

$$\begin{aligned} c_{m,n} &= 2^{-m/2} \int_{-\infty}^{\infty} f(t) \cdot \psi(2^{-m/2} \cdot t - n) dt = \\ &= \langle f(t), \psi_{m,n}(t) \rangle \end{aligned} \quad (8)$$

which is known as Discretized Continuous Wavelet Transform. It is well known that in practical applications, function  $f(t)$ , from Eq. (6), cannot be described analytically, therefore solving an

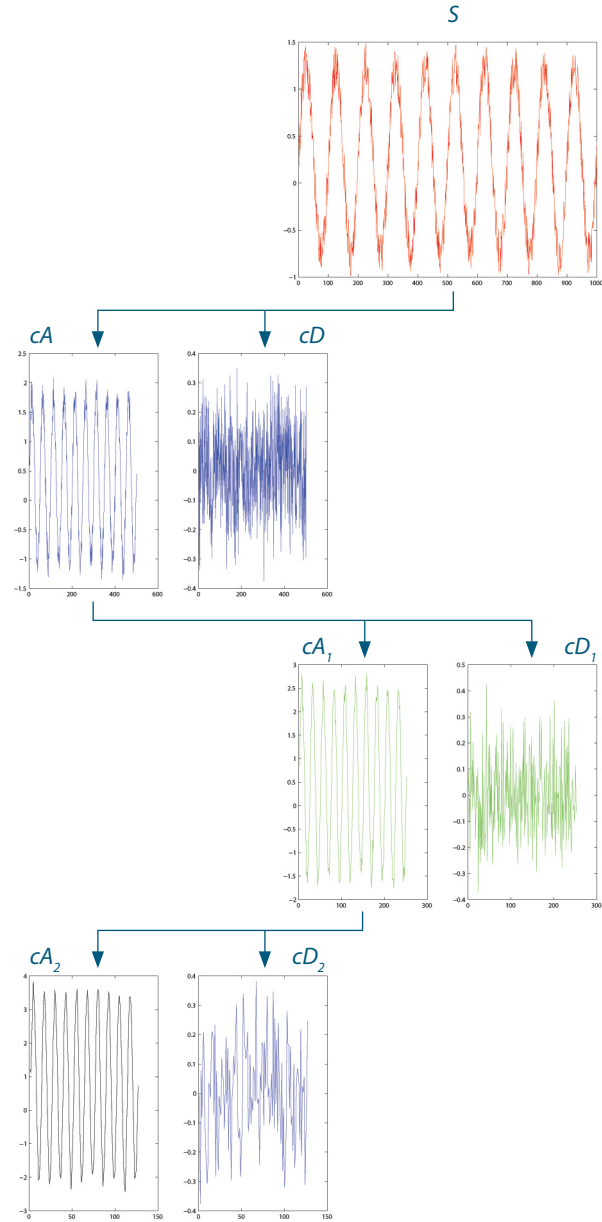


Figure 2.

Wavelet decomposition of the signal (Misiti et al, 1997).

Source: authors.

integral (6) is time consuming at best, or even impossible. In order to overcome aforementioned problem a new transform is proposed, Discrete Wavelet Transform (DWT).

DWT overcomes problem of computing CWT coefficients, and it is suitable in fast computer algorithms. Moreover, since DWT algorithm converges rapidly, it is suitable for real time applications.

Historically, two groups of authors, in late 20<sup>th</sup> Century, proposed techniques for computing DWT coefficients. First group of authors (Vetterli and Gall, 1989) proposed Multiresolution Signal Analysis (MRA) technique or pyramidal algorithm. Second group (Crochiere et al., 1975; Crochiere and Sambur, 1977) proposed subband coding algorithm. Pyramidal algorithm is especially suitable and widely used in image processing applications (Mallat, 2009). Relationship between MRA and wavelet analysis are investigated and presented by Mallat (Mallat, 2009) and Daubechies (Daubechies, 1992).

Foundations of Discrete Wavelet Transform are based on Multiresolution Analysis and Filter Bank Theory (Strang and Nguen, 1997).

A subband coding algorithm is the fast algorithm that computes discrete wavelet coefficients, and it is based on filter banks.

In order to implement filter bank theory with MRA introduction of a scaling function,  $\phi(t)$ , is proposed (Strang and Nguen, 1997). Scaling function,  $\phi(t)$ , is defined as follows:

$$\phi(t) = \sum_{k=0}^N 2 \cdot h(n) \cdot \phi(2t - n) \quad (9)$$

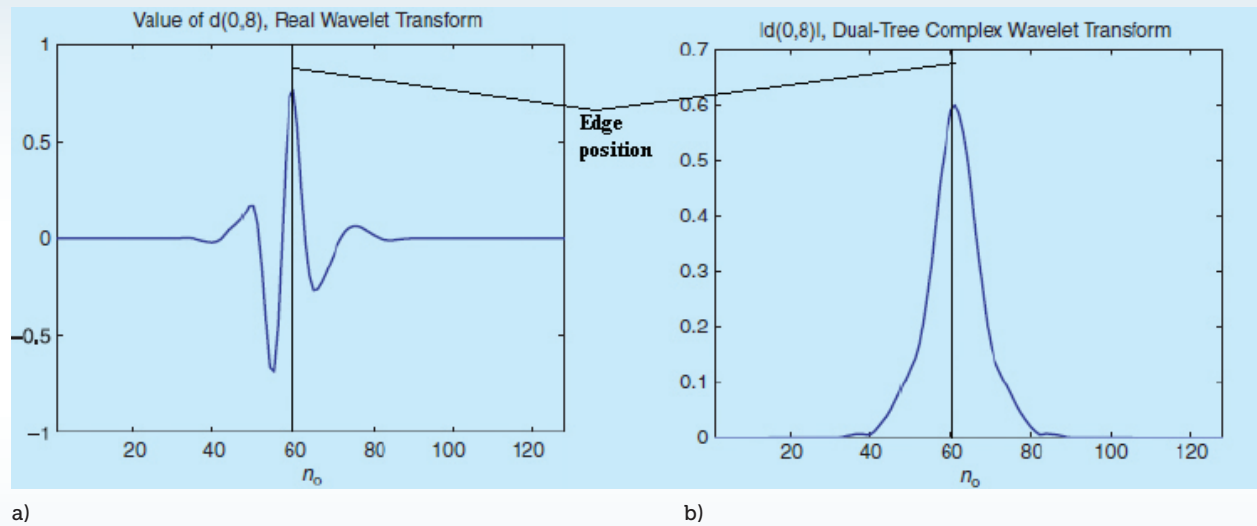
where a  $h(n)$  are coefficients of a low pass half band filter. Equation (9) is known as dilation equation (Vetterli and Kovačić, 1995). Relationship between wavelet equation and FB theory is given with the following equation:

$$\psi(t) = \sum_{k=0}^N 2 \cdot d(n) \cdot \phi(2t - n) \quad (10)$$

where a  $d(n)$  is coefficients of a high pass half band filter. Equation (10) is known as wavelet equation (Vetterli and Kovačić, 1995).

Figure 1 shows decomposition of a signal,  $S$ , at three levels, applying subband coding algorithm (Misiti et al., 1997). After a signal  $S$  is passed through the filter bank, which consists of two filters, half band low pass filter and half band high pass filter, and then applying downsampling procedure, a coefficients of approximation,  $cA1$ , and a coefficients of details,  $cD1$ , are obtained, at the first level of decomposition. It has to be pointed out that with applying aforementioned procedure, coefficients  $cA1$  and  $cD2$  are halved with respect of total number of coefficients of analyzed signal  $S$ . At the second level of decomposition, approximation coefficients  $cA1$ , are passed through filter bank and then downsampled, which produces approximation and details coefficients,  $cA2$  and  $cD2$ .  $cA2$  and  $cD2$  coefficients contain exactly half of the total number of  $cA1$ . At the last level of decomposition,  $cA1$  coefficients are passed through filter bank and then downsampled, which produces  $cA3$  and  $cD3$  coefficients at the third level. As previously, coefficients  $cA3$  and  $cD3$  contain half of the total number of  $cA2$  coefficients. Wavelet decomposition algorithm is also known as logarithmic signal decomposition algorithm (Christopher and Walnut, 2006).

Described procedure has one potential drawback, in order to be able to assemble algorithm, you need to have an extensive knowledge about Fourier analysis and filter bank theory, since all programming is required to be done in frequency domain. In order to avoid frequency domain, Wim Sweldens proposed Second Generation Wavelet, SGW (Sweldens, 1998). His algorithm



**Figure 3.**  
Edge detection by: a) DWT, b) dual-tree CWT.  
Source: authors.

is programmed entirely in time domain and is known as lifting scheme (Jansen and Oonincx, 2005).

DWT exhibits four main flaws: oscillations, shift variance, aliasing and lack of directionality which are especially emphasized in image processing. It is well known that wavelet functions have zeroed mean. Therefore, the shape of the wavelet function is oscillating and wavelet coefficients can gain either positive or negative value. By applying the DWT results in weak edge definitions of the observed signal, and smear edge effect could be produced, in discontinuity localization. Figure 3 illustrates the edge detection by applying DWT and CWT transform in the same image. Figure 3a shows position of DWT wavelet on the edge of an image. Since wavelet has zeroed mean it oscillates on the edge, and results in smear edge effect which is presented in the analysis image. Figure 3b shows position of CWT wavelet on the edge of an image. Since the coefficients of CWT are only positive, edges of the image are more emphasized.

Shift variance presents the problem in interpretation of the signal since it greatly perturbs the wavelet coefficient oscillation pattern around singularities. Shift variance also complicates wavelet-domain processing since algorithms must be made capable of coping with wide range of possible wavelet coefficient patterns caused by shifted singularities (Selesnick et al., 2005).

When DWT transform is applied, at each level of signal decomposition, coefficients are computed by applying non-ideal low-pass and high-pass filters and then they are downsampled, which results in substantial aliasing. Since in real application some of the thresholding, filtering or quantization follows, it is impossible to obtain perfect reconstruction, which leads to artefacts in the reconstructed signal. Lack of directionality is also presented in higher dimensions. While Fourier bases functions are highly directional plane waves, a wavelet function lacks directionality. Non-directionality presents a problem in advance image processing and analysis applications, such as finding edges and ridges. It has to be pointed out that Fourier basis does not suffer from the same problems as wavelets.

To overcome mentioned DWT problems, and with Fourier transform as guidance, a complex wavelet are proposed (Selesnick et al., 2005), denoted  $\psi_c(t)$  :

$$\psi_c(t) = \psi_r(t) + j + \psi_i(t) \quad (11)$$

where a  $\psi_r(t)$  is an even function, a  $\psi_i(t)$  an odd function. A  $\psi_r(t)$  and a  $\psi_i(t)$  are phase shifted by  $90^\circ$  and make so called Hilbert transformation pair. The necessary condition is that a  $\psi_c(t)$  is an analytical function. It can be shown that the large signal magnitudes correspond with the existence of the discontinuity in the analyzed signal and sudden phase changes correspond with the position of the discontinuity.

Complex wavelets are proposed in order to comply with more and more demanding applications. Complex Wavelet

Transform (CWT) is built on the DWT basis (Selesnick et al., 2005). First papers which deal with CWT were published in 1995. (Gagnon, Lina and Goulard, 1995; Lina and Gagnon, 1995). Algorithm for CWT calculation is introduced in 1997 (Kingsbury and Magarey, 1997; Kingsbury, 1998), and it is known as Dual-Tree Complex Wavelet Transform algorithm.

CWT is primarily used in image processing applications, radar, speech, music, and multidimensional signals applications.

Wavelets are also widely used in navy coding of the secret data. They are also used in coding the video information in Internet transmission standards, video coding, digital imaging, etc. Due to increasing use of communication and multimedia in modern ships, all the areas of application can be found in various ships.

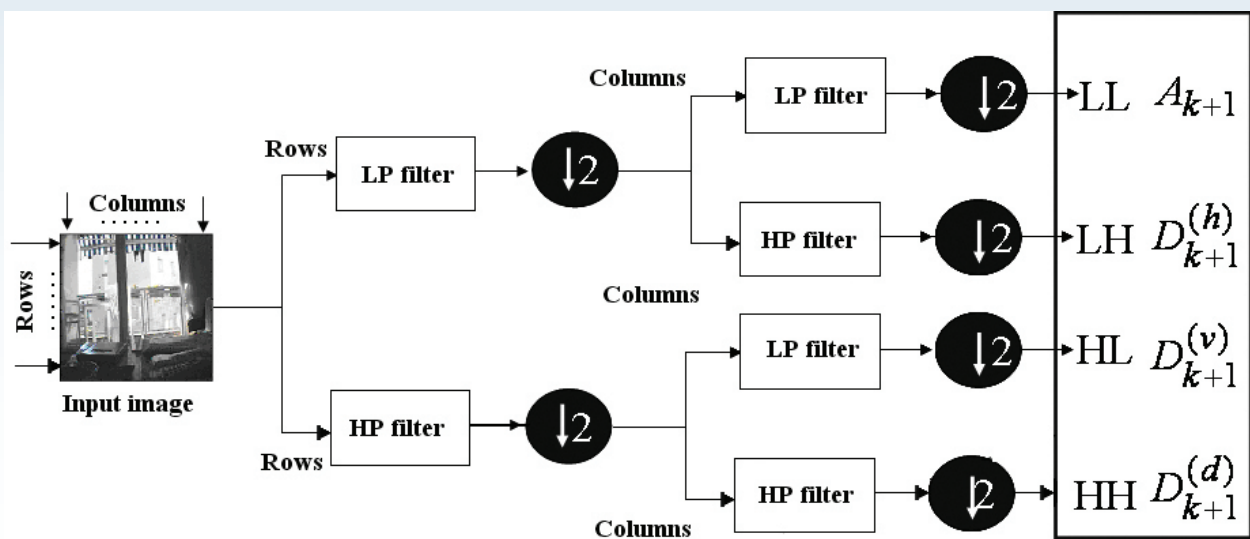
## 2.1. Multidimensional wavelet transform

All transforms mentioned in previous section are one-dimensional. In order to implement transforms for multidimensional signals, such as images, one must extend one-dimensional theory to multidimensional case. This generalization is not always as simple as it may seem. Implementation of the DWT to multidimensional case requires separable wavelet bases in all dimensions.

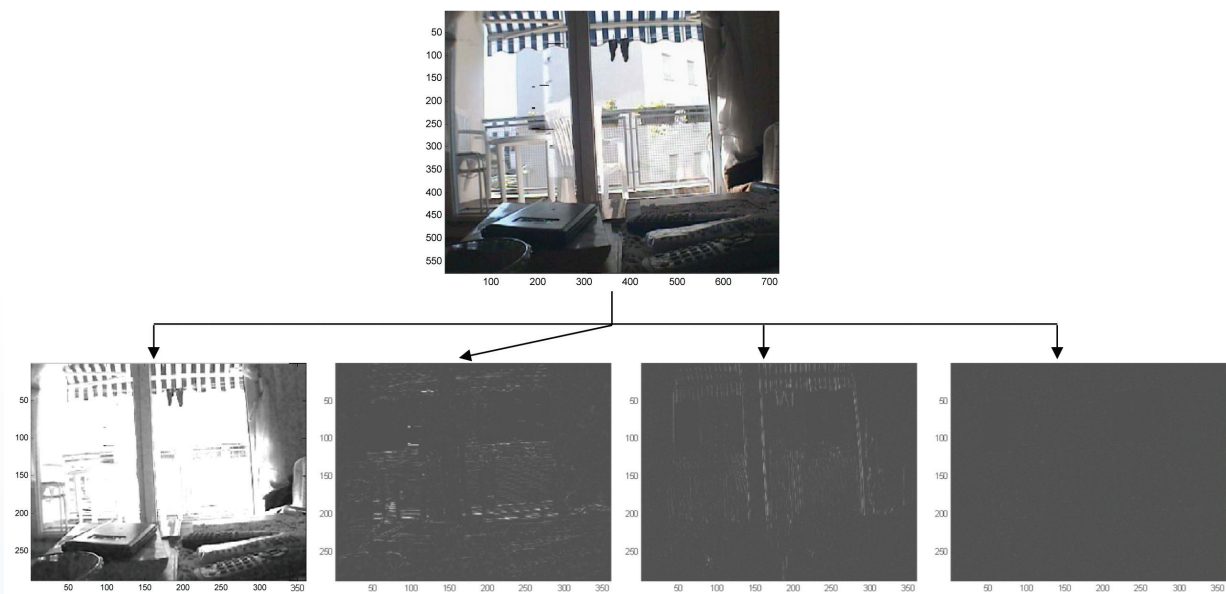
In wavelet theory, it is usual to operate with time and frequency. However, physical interpretation can be different. The axis which denotes time can be replaced with some other axis. The frequency axis can also be replaced with the other axis. The mathematical properties of the transform remain the same. In image analysis, meanings of the axis are colour, number of pixels and coordinates of the pixel with denoted colour. Multidimensional transform involves causality problems. Therefore, a trick is used: one-dimensional algorithm is extended to more general case by separable approach and use of tensors.

Application of DWT to the image implies processing of rows and columns separately. Firstly, rows are filtered by LP and HP filters, then downsampling is performed. After that, the same is performed with columns. This process is shown in Figure 4. Final results are coefficients of two-dimensional wavelet transform. An  $A_{k+1}$  is an approximation obtained by applying low pass filtering of both the rows and columns, i.e. LL output. Combinations of low and high and high and low filtering result in coefficients of details, i.e. LH and HL coefficients, which are known as horizontal and vertical coefficients. Finally, if both rows and columns are filtered with HP filter, then diagonal details are obtained.

One level of the reconstruction can be described with equation:



a)



b)

**Figure 4.**  
Wavelet analysis of the image: a) scheme (Polikar, 2002), b) an example.  
Source: authors.

$$f_k(x, y) = \sum_{n=-\infty}^{\infty} \sum_{p=-\infty}^{\infty} (A_{k+1}(n, p) \cdot \phi(x-n) \cdot \phi(x-n) + D_{k+1}^h(n, p) \cdot \phi(x-n) \cdot \psi(x-n) + D_{k+1}^v(n, p) \cdot \psi(x-n) \cdot \phi(x-n) + D_{k+1}^d(n, p) \cdot \psi(x-n) \cdot \psi(x-n)) \quad (12)$$

where a  $\phi$  is the scaling function and a  $\psi$  the wavelet function.

Nowadays applications operate mostly with video streams or images. Due to increased need for image processing algorithms, novel transforms are mostly used in multidimensional case.

### 3. NOVEL WAVELET-INSPIRED TRANSFORMS

Wavelets have exhibited a huge success in one-dimensional problems of signal processing and analysis. Furthermore, wavelets have a great success in image compression tasks, for example as in FBI application for fingertip database storage. In images consisting domains of smoothly varying grey values, separated by smooth boundaries, DWT exhibits problems that are visible in the form of compression artefacts. The problem is visible in the form of compression artefacts. Tensor-product construction (used in 2D-WT) is not flexible enough, causing the inability to repeat results obtained in 1D case (Führ et al., 2006). In order to further improve and enhance analysis, different transforms are proposed.

The phenomena of interest occur often along curves and sheets. The examples are the edges in the image. However, wavelets are suited for dealing with e.g. singularities, but there are ill-suited for detecting and dealing with intermediate dimensional structures.

#### 3.1. Bandelets

Bandelets are constructed from an orthonormal basis that is adapted to geometric boundaries (Pennec and Mallat, 2005). Bandelets can be constructed and regarded as a warped wavelet basis. They are used to transform smooth functions on smoothly bounded domains. Since many other transforms utilize wavelets as well, they are called wavelet-inspired novel transforms. Contourlets and curvelets take account of geometric structure, but they utilize wavelets as well (Peyre et al., 2007). All novel transforms start with wavelet basis. The point is in changing the coordinate system and/or rotating the basis.

**Proposition 3.1.** Bandeletization of wavelet coefficients using an Alpert transform defines a set of bandelet coefficients if and only if a vector corresponding to a sampling of a function with an anisotropic regularity is well approximated with a few vectors from the Alpert basis. These coefficients can be written as inner products  $\langle f, b_{j,\ell,n}^k \rangle$  of the original image  $f$  with bandlet functions that are linear combinations of wavelet functions:

$$b_{j,\ell,n}^k(x) = \sum_p a_{\ell,n}[p] \psi_{j,p}^k(x) \quad (13)$$

where an  $a_{\ell,n}[p]$  is the coefficient of the Alpert transform.

#### 3.2. Curvelet transform

The curvelet transform is a multiscale pyramid with many directions and positions at each length scale, and needle-shaped elements at fine scales (Candés et al., 2006). Scaling part of the curvelets obey a parabolic law. Namely, at scale  $2^{-j}$ , each element has an envelope which is aligned along a ridge of length  $2^{-j/2}$  and width  $2^{-j}$ . Curvelets provide optimally sparse representation of objects with edges or wave propagators. There also have micro local features that help in reconstruction of severely ill-posed problems.

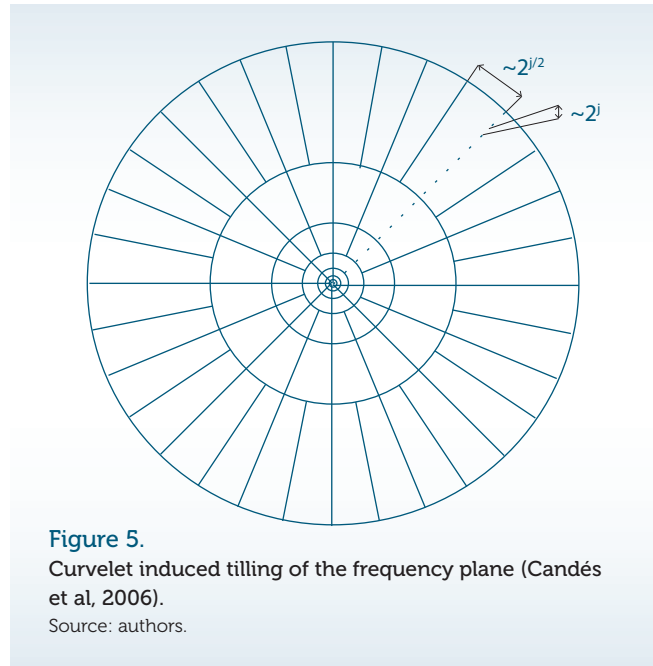


Figure 5.

Curvelet induced tiling of the frequency plane (Candés et al, 2006).

Source: authors.

**Definition 3.1.** (Candés et al., 2006) Let  $x = (x_1, x_2)$  be random variable. Curvelet is defined at scale  $2^{-j}$  orientation  $\theta_j$  and position  $x_k^{(j,\ell)} = R_{\theta_j}^{-1}(k_1 \cdot 2^{-j}, k_2 \cdot 2^{-j/2})$  by:

$$\varphi_{j,k,\ell}(x) = \varphi_j(R_{\theta_j}(x - x_k^{(j,\ell)})) \quad (14)$$

where a  $R_\theta$  is the rotation by  $\theta$  radians and it is mathematically Givens rotation (Golub et al., 1996):

$$R_\theta = \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix} \quad (15)$$

The most important properties of the curvelet transform are (Candés et al., 2006): tight frames, parabolic scaling, oscillatory



behaviour and vanishing moments.

The polar dyadic parabolic partition of the frequency plane is the bases of the curvelets construction. If different tilling is used, other transforms are obtained. For example (Candés et al., 2006):

a) A directional wavelet transform is obtained if we divide the corona into a constant number regardless of scale.

b) A ridgelet transform is obtained by subdividing each dyadic corona into  $C \cdot 2^j$  angles.

c) A Gabor analysis is obtained if we substitute coronae with fixed width for dyadic coronae.

Furthermore, an adaptive partitioning of the frequency plane can be created, which best matches the features of the analyzed signal. This is the construction of so called „ridgelet packets“.

### 3.3. Contourlets

The contourlet transform is a geometrical image based transform. In this transform, the Laplacian Pyramid is firstly used to capture the point discontinuities, then it is followed by a Directional Filter Bank to link point discontinuities into linear structures. The Laplacian Pyramid is used to decompose an image into a number of radial subbands. The Directional Filter Bank is used to decompose each radial subband into a number of directional subbands (Anaraki et al., 2007).

### 3.4. Shapelets, Ridgelets, Edgelets and other transforms

**Proposition 3.2.** The shapelet decomposition enables an approximation calculation of the 2D object by a finite series (Melchior et al., 2007):

$$I(\bar{x}) = \sum_{n_1, n_2}^{n_1 + n_2 = n_{\max}} I_{\bar{n}} B_{\bar{n}}(\bar{x} - \bar{x}_c; \beta) \quad (16)$$

where a  $\bar{x} = (x_1, x_2)$ , a  $\bar{n} = (n_1, n_2)$ , and the shapelets basis function is expressed by (Refregier, 2003):

$$B_{\bar{n}}(x; \beta) = \beta^{-1} \phi_{n_1}(\beta^{-1} x_1) \phi_{n_2}(\beta^{-1} x_2) \quad (17)$$

The basis is related to the 1D Gauss-Hermite polynomials with:

$$\phi_n(x) = [2^n \pi^{0.5} n!]^{-0.5} H_n(x) e^{-0.5x^2} \quad (18)$$

where a  $H_n(x)$  is a Hermite polynomial of an order  $n$ .

The wavelet-inspired transforms use the wavelet basis that is a dimensional generalization of the wavelet transform designed to represent images at different scales and different angles. The ridgelet transform uses the Finite Radon Transform (FRAT) as a basic building block.

Wedgelets were proposed in 1999 (Donoho, 1999; Donoho et al., 1999). The purpose of proposed transform was

approximation of the piecewise constant images with smooth boundaries.

**Proposition 3.3.** Let  $Q_j$  be the set of dyadic squares of size  $2^{-j}$  expressed by:

$$Q_j = \left\{ \left[ 2^{-j} k : 2^{-j} (k+1) \right] \times \left[ 2^{-j} \ell : 2^{-j} (\ell+1) \right] \right\} \quad (19)$$

with  $0 \leq k, \ell \leq 2^j$ . The set is the union:

$$Q = \bigcup_{j=0}^{\infty} Q_j \quad (20)$$

Dyadic portion of the image is given by the tilling  $Q$  defined in the domain  $[0, 1]^2$  of dyadic squares of arbitrary size. If  $Q$  is defined as above, a wedgelet tilling is obtained by splitting each element  $q \in Q$  into at most two wedges along a suitable straight line.

An edgelet is a short segment of line or curve (Wu and Nevatia, 2005).

**Proposition 3.4.** The affinity between the edgelet and the image  $I$  at location  $w$  can be calculated by the expression:

$$S(w) = \frac{1}{k} \sum_{i=1}^k M'(u_i + w) \left\langle n'(u_i + w), n_i^E \right\rangle$$

where  $\{u_i\}_{i=1}^k$  denote the location of points in the edgelet,  $\{n_i^E\}_{i=1}^k$  normal vectors at those points, a  $k$  the length of the edgelet, a  $I$  the input image, which have  $M(p)$  as edge intensity and  $n(p)$  normal vector at location  $p$  of the image  $I$ .

Note: Since edge intensity and normal vector are unknown, it is impossible to solve proposition 3.4. Therefore, the mentioned unknowns must be calculated by one of the edge detectors. In (Wu and Nevatia, 2005) the problem is solved by Sobel kernel of size  $3 \times 3$ . However, we submit that Canny or some wavelet detector can produce better results. If same wavelets are used to generate an edgelet and an edge detector, time of execution can be reduced.

## 4. APPLYING WAVELET BASED TIME FREQUENCY TECHNIQUES ON PORT SURVEILLANCE VIDEO STREAM EXAMPLE

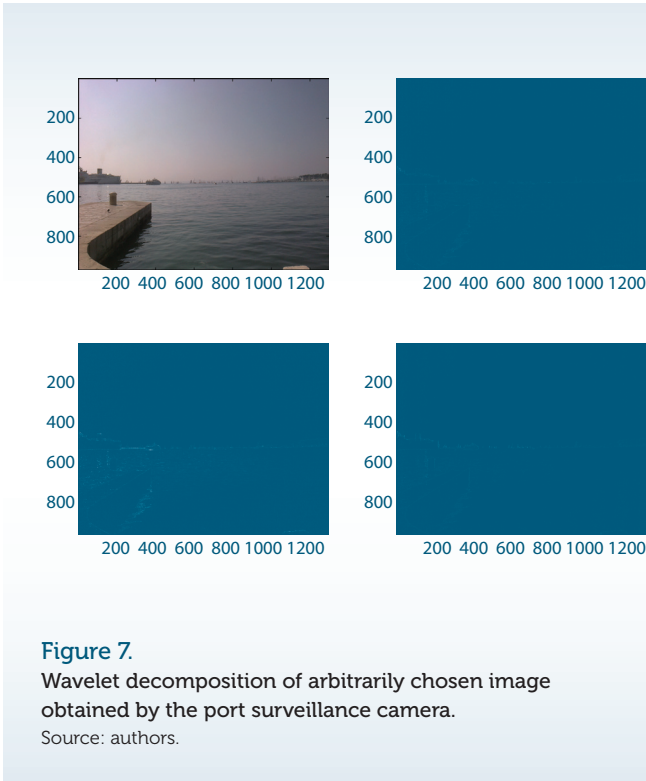
Image processing and analysis play an increasing role in the security of ports due to increasing threats in the marine transport. Therefore, example of the image as the signal is taken deliberately. The chosen image shows the high traffic of small vessels, which can be the potential problem. Camera can detect suspicious movement, i.e. terrorist attack or fire aboard.

Figure 6 shows an arbitrarily chosen image from the port surveillance camera. It is the JPG file of the size  $2592 \times 1944$ . The colour space is RGB. It is analyzed by:





**Figure 6.**  
The original arbitrarily chosen image from the port surveillance camera.  
Source: authors.



**Figure 7.**  
Wavelet decomposition of arbitrarily chosen image obtained by the port surveillance camera.  
Source: authors.



**Figure 8.**  
Conturelet coefficients at two levels of decomposition.  
Source: authors.



**Figure 9.**  
Contourlet coefficients at three levels of decomposition.  
Source: authors.

- DWT
- contourlet and
- curvelet transform.

Figure 7 shows an example of the wavelet decomposition at the first level. The upper left part of the image shows approximation coefficients. Horizontal details are shown in upper right part of the image. Due to small values of the coefficients, it would appear black. To be visible, we multiplied it by factor 8 in comparison to the approximation coefficients. The lower left part of the image shows vertical details and lower right diagonal details. All details are multiplied by 8 to be visible. It can be observed that the wavelet approximation takes all the energy contained in the image signal (the brightest image). The details exhibit chaotic behaviour at the sea level, and regular smoothness at the dock.

The wavelet produced coefficients are too scattered and do not show the direction of possible movement. Moreover, the wavelet coefficients do not emphasize the motion of any kind.

It can be calculated that the size of the sum of DWT coefficients and original image are the same. Therefore, any gains can be obtained only by reducing the coefficients by thresholding

or the exclusion of the coefficients which are redundant.

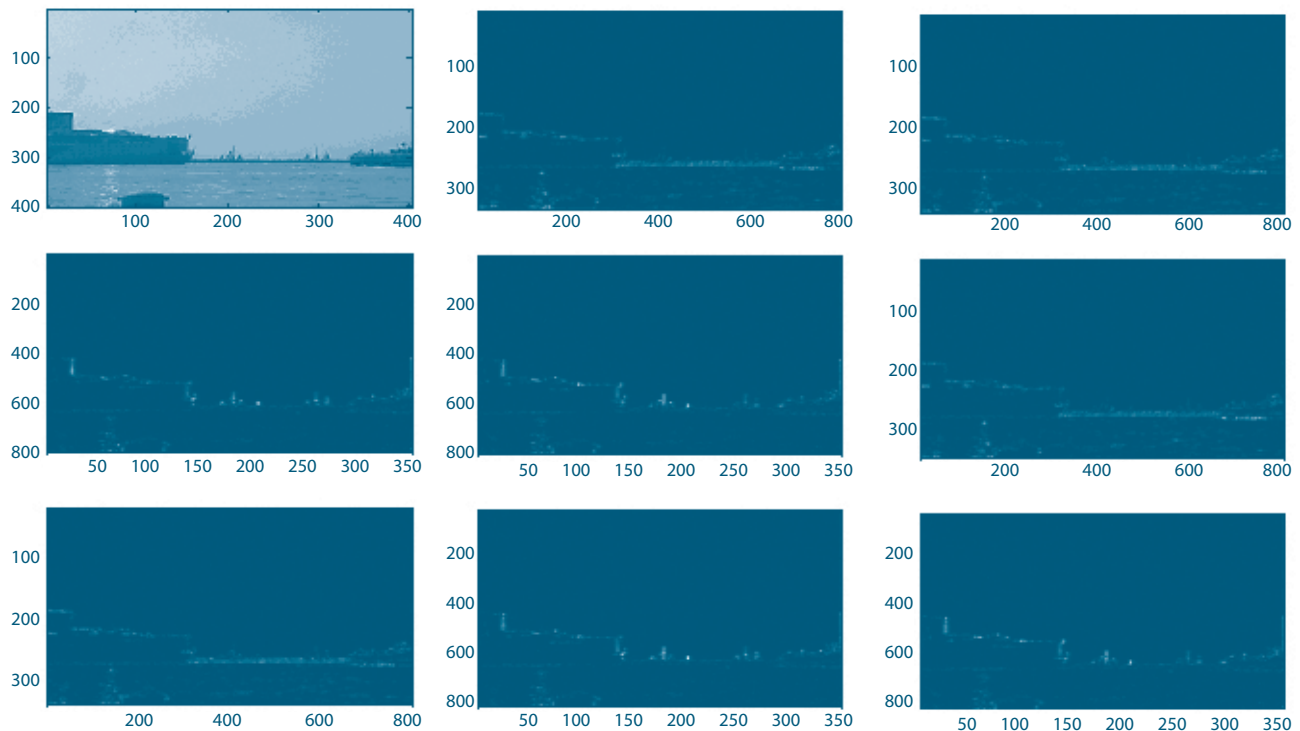
Figures 8 and 9 show the results of the contourlet decomposition at two and three levels. The input image is shown in Figure 6. It can be seen that contourlet transform emphasizes the sharp edges.

However, the grain structure of the image prevents higher vision applications to segment the image correctly. In favour of the contourlets, it should be noted that the example is arbitrary in choosing contourlet as well. It is possible that other contourlet would produce better results.

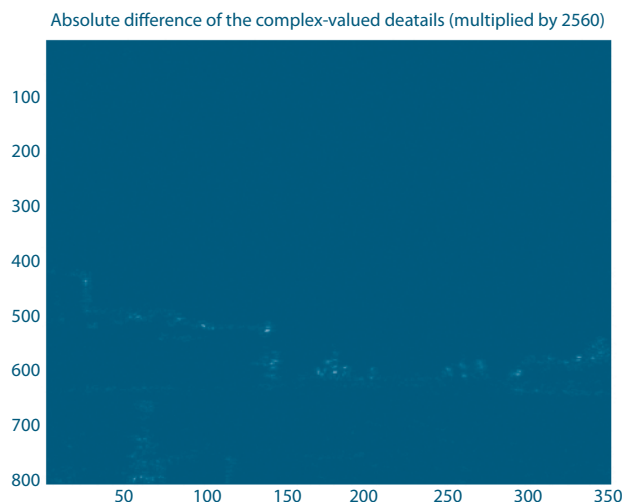
Figure 10 shows the analysis of the Figure 6 by applying Fast Discrete Curvelet Transform via wedge wrapping. Curvelets can be real or complex-valued. In the presented example, the complex-valued curvelets are chosen. Regarding the software application, possibilities for the coefficients at the finest level are curvelets and wavelets. Curvelets are selected as the example shown in the image.

Upper right image is the curvelet approximation of the Figure 6. Note that the 8 details (by different angle of curvelet basis) should look black. They are multiplied by 2048 times in order to be visible by the human eyes in offprint.

It can be observed that the size of the details is rotating



**Figure 10.**  
Curvelet transform example.  
Source: authors.



**Figure 11.**  
Absolute difference of the details.  
Source: authors.

and that approximation has different size. It is the opposite to the wavelet transforms, which all have the same sizes (both approximation and details).

Figure 11 shows the absolute difference of the details multiplied in order to be visible.

## 5. CONCLUSIONS

The cutting-edge mathematical tools for signal processing and analysis can be divided into two groups:

- adaptive geometry-based tools such as wedgelets and related constructions and
- directional frames, such as curvelets or ridgelets, to name but a few.

Depending on application, a researcher has to be able to choose appropriate wavelet based transform algorithm.

All presented techniques, however advanced, are not applicable in every instance. Lot of care has to be taken in order to choose the right algorithm. Some techniques are better suited for the signal processing (such as DWT) and some for the signal analysis (such as CWT). DWT and other fast transforms are more suited for the signal processing, because of the reductions in data necessary for the execution, which is especially important in real-time signal processing applications. On the other hand, CWT is redundant, which leaves a lot of data for analysis at i.e. higher vision applications.

The presented example shows that all mentioned transforms could have problems in segmenting the motion in a presence of larger waves.

## REFERENCES

- Anaraki, M.S., Dong, F., Hirota, K. and Nobuhara, H., (2007), A Multidirectional Multiresolution Transform for Image Representation, 8th International Symposium on Advanced Intelligent Systems ISIS 2007, Sokcho-City, Korea, September 5-8, 2007., available at: <http://isis2007.fuzzy.or.kr/submission/upload/A1331.pdf>, [accessed 22 August 2011.].
- Antoniou, A., (2006), Digital Signal Processing – Signals, Systems and Filters, New York: McGraw-Hill Inc.
- Candés, E., Demanet, L., Donoho, D. and Ying, L., (2006), Fast Discrete Curvelet Transforms, Multiscale Modeling and Simulation, 5(3), pp. 861-899., <http://dx.doi.org/%2010.1137/05064182X>
- Christopher, H. and Walnut, D. F., (2006), Fundamental Papers in Wavelet Theory, London: Princeton University Press.
- Crochiere, R. E. and Sambur, M. R., (1977), A Variable-Band Coding Scheme for Speech Encoding at 4.8 kb/s, The Bell System Technical Journal, 56(5), pp. 771-779.
- Crochiere, R. E., Webber, S. A. and Flanagan, J. L., (1975), Digital Coding of Speech in Subbands, The Bell System Technical Journal, 55(8), pp. 1069-1085.
- Daubechies, I., (1992), Ten Lectures on Wavelets, Philadelphia: Society for Industrial and Applied Mathematics.
- Donoho, D., (1999), Wedgelets: Nearly-minimax estimation of edges, Annals of Statistics, 27 (3), pp. 859-897., <http://dx.doi.org/10.1109/IEMBS.1995.575241>
- Donoho, D., Duncan, M. R., Huo, X. and Levi, O., (1999), Wavelab, available at: <http://www-stat.stanford.edu/~wavelab/>, [accessed 12 August 2011.]
- Führ, H., Demaret, L. and Friedrich, F., (2006), Beyond wavelets: New image representation paradigms. Chapter 7 in book: Document and Image Compression, ed. Barni, M., London: CRC Press.
- Gabor, D., (1946), Theory of communication, Journal of the Institute of Electrical Engineers, 93(26), pp. 429–457.
- Gagnon, L., Lina, J. M. and Goulard, B., (1995), Sharpening enhancement of digitized mammograms with complex symmetric Daubechies wavelets, IEEE International Conference of Engineering in Medicine and Biology Society, Montréal, Canada, September 20 - 23, 1995., IEEE Press, pp. 543 – 544., <http://dx.doi.org/10.1109/IEMBS.1995.575241>
- Golub, G. H., Loan, V. and Charles, F., (1996), Matrix Computations, (3rd ed.), New York: Johns Hopkins.
- Herley, C., Kovačević, J., Ramchandran, K. and Vetterli, M., (1993), Tilings of the Time-Frequency Plane: Construction of Arbitrary Orthogonal Bases and Fast Tiling Algorithms, IEEE Transactions on Signal Processing, 41(12), pp. 3341 – 3359., <http://dx.doi.org/10.1109/78.258078>
- Jansen, M. and Oonincx, P., (2005), Second Generation Wavelets and Applications, London: Springer - Verlag.
- Kingsbury, N. G. and Magarey, J. F. A., (1997), Wavelet Transforms in Image Processing, Proc. First European Conference on Signal Analysis and Prediction, Prague, Czech Republic, June 24 – 27, Birkhäuser, pp. 23 – 24., available at: <http://www-sigproc.eng.cam.ac.uk/~ngk/publications/ngk97b.zip>, [accessed 18 August 2011.].
- Kingsbury, N., (1998), The Dual-tree Complex Wavelet Transform: A New Efficient Tool for Image Restoration and Enhancement, Proc. European Signal Processing Conference, EUSIPCO 98, Rhodes, 8-11 September, 1998, University of Athens, pp. 319 – 322.

- Lina, J. M. and Gagnon, L., (1995), Image enhancements with symmetric Daubechies' wavelets, SPIE Aerospace: Wavelet Applications in Signal and Image Processing III, 2569(1), pp. 196-207.
- Mallat, S., (1999), A Wavelet Tour of Signal Processing, New York: Academic Press.
- Mallat, S., (2009), A Wavelet Tour of Signal Processing, 3rd Edition, New York: Academic Press.
- Melchior, P., Meneghetti, M. and Bartelmann, M., (2007), Reliable Shapelet Image Analysis, Astronomy and Astrophysics, 463(3), pp. 1215-1225., <http://dx.doi.org/10.1051/0004-6361:20066259>
- Misiti, M., Misiti, Y., Oppenheim, G. and Poggi, J. M., (1997), Wavelet Toolbox – User's Guide, For Use with MATLAB, Version 2, The Mathwork Inc.
- Pennec E. and Mallat, S., (2005), Sparse Geometric Image Representations With Bandelets, IEEE Transactions on Image Processing, 14(4), pp. 423-438., <http://dx.doi.org/10.1109/TIP.2005.843753>
- Peyre, G., Pennec, E. and Dossal, C., (2007) Geometric estimation with orthogonal bandlet bases, Proceedings SPIE Wavelets XII, San Diego, CA, August 26 – 29, 2007., SPIE, pp. 67010M.1-67010M.10., available at: [http://univ-paris-diderot.academia.edu/ErwanLePennec/Papers/607768/Geometric\\_estimation\\_with\\_orthogonal\\_bandlet\\_bases](http://univ-paris-diderot.academia.edu/ErwanLePennec/Papers/607768/Geometric_estimation_with_orthogonal_bandlet_bases), [accessed 18 August 2011.].
- Polikar, R., (2002), Lecturers notes, Rowan University, Glassboro, available at: <http://www.engineering.rowan.edu/~polikar/CLASSESS/ECE554>, [accessed 12 January 2010.].
- Proakis, J. G. and Manolakis, D. K., (2007), Digital Signal Processing, 4th Ed., New York: Prentice-Hall.
- Refregier, A., (2003), Shapelets: I. A Method for Image Analysis, Monthly Notices of the Royal Astronomical Society, 338(1), pp. 35-47., <http://dx.doi.org/10.1046/j.1365-8711.2003.05901.x>
- Rioul, O. and Vetterli, M., (1991), Wavelets and Signal Processing, IEEE Signal Processing Magazine, 8(10), pp. 14-38., <http://dx.doi.org/10.1109/79.91217>
- Selesnick, I. W., Baraniuk, R. G. and Kingsbury, N. G., (2005), The Dual-Tree Complex Wavelet Transform, IEEE Signal Processing Magazine, 22(6), pp. 123-151., <http://dx.doi.org/10.1109/MSP.2005.1550194>
- Strang, G. and Nguen, T., (1997), Wavelets and Filter Banks, Boston: Wellesly – Cambridge Press.
- Sweldens, W., (1998), The Lifting scheme: a construction of second generation wavelets, SIAM Journal on Mathematical Analysis, 29(2), pp. 511-546., <http://dx.doi.org/10.1137/S0036141095289051>
- Vetterli, M. and Gall, D. L., (1989), Perfect Reconstruction FIR Filter Banks: Some Properties and Factorizations, IEEE Transactions on Acoustics, Speech, Signal Processing, 37(7), pp. 1057-1071., <http://dx.doi.org/10.1109/29.32283>
- Vetterli, M. and Kovačević, J., (1995), Wavelets and Subband Coding, London: Prentice Hall.
- Wichmann, E. H., (1988), Quantum physics, Textbook of University of Berkeley, Croatian translation, Zagreb: Tehnička knjiga.
- Wickerhauser, M. V., (1994), Adapted Wavelet Analysis from Theory to Software, New York: IEEE Press.
- Wu, B. and Nevatia, R., (2005), Detection of Multiple, Partially Occluded Humans in a Single Image by Bayesian Combination of Edgelet Part Detectors, 10th IEEE International Conference on Computer Vision, Beijing, China, October 17-20, 2005., Springer, pp. 90-97., <http://dx.doi.org/10.1109/ICCV.2005.74>

# The Importance of Correct Punctuation and Capitalisation

Siniša Ninčević<sup>1</sup>, Željka Zanchi<sup>2</sup>

This paper concerns the correct usage of English capitalisation and punctuation. Devised as a sort of guide or manual, it is primarily intended for ESL learners. It lists a set of basic rules, as well as the accompanying examples, in order to facilitate their acquisition and to draw attention to the significance of the correct application of these rules since the failure to properly capitalise letters, omit, or to properly employ punctuation marks destroys the structure of the text and may lead to miscommunication between the writer and the reader, i.e., prevent the information from being properly conveyed, and your goals being properly met. Consequently, correct capitalisation and punctuation is an indispensable language tool in academic and scientific settings.

## KEY WORDS

~ Capitalisation  
~ Punctuation  
~ Rules  
~ Writing

## 1. INTRODUCTION

With the dawn of cutting-edge communication technology, the Internet slang, the SMS, and other novelties, the fundamental aspects of English punctuation and capitalisation, for years considered indispensable and essential to any intelligible and literate written communication, have almost sunk into oblivion. Not only does the failure to observe the basic rules, governing the correct use of capitalisation and punctuation, deprive the writer of properly expressing his thoughts, ideas and intentions, but it also mirrors the writer's professional profile and competence in general.

The ever decreasing awareness of the importance of correct spelling, punctuation, and capitalisation seems to be ubiquitous or, as some would prefer, global, and is certainly not limited to the correct usage of the English language – these tendencies may be observed in other languages as well, Croatian being no exception. There are apparently fewer and fewer people who still believe that a good command of spelling, punctuation, and capitalisation belongs to what may be called basic literacy, undoubtedly and infallibly indicating the person's educational, intellectual, and civilisation level, therefore extremely important and definitely worth an effort, to say the very least. On the other hand, there is, regrettably, an ever-increasing number of those who tend to dismiss these issues as unimportant, insubstantial, even a waste of time – more the pity that not a negligible number may be found among those who like to think of themselves as educated and enlightened, if not sophisticated. All things considered, one would not go too far in saying that the entire world seems to be heading towards illiteracy.

As has been said before, much of the problem may be attributed to the advent of modern communication technology (the internet, mobile telephones, etc.) where questions of style do not seem to matter – they have been long abandoned as superfluous or an indication of boring and useless pedantry

1, 2 University of Split, Faculty of Philosophy, Sinjska 2, 21000 Split, Croatia  
E-mails: sinisa.nincevic@ffst.hr, zzanchi@gmail.com



and would-be hypercorrectness that, with their 'unreasonable' demands, stand in the way of unimpeded communication. An overall neglect and carelessness are ever present and may be observed literally everywhere: in personal notes, letters, messages, primarily e-mails and other forms of electronic communication, as well as on billboards, shop-windows (even bookshops and libraries!), advertisements, TV-commercials, etc. It is for these very reasons why this problem needs to be addressed, drawing the attention of potential users of English, in our case the ESL students, primarily in higher education, but also all those who still believe in the proper, coherent, and literate use of Standard English.

In the reading process, capitalisation draws our attention to proper nouns such as names, places, time, addresses, at the same time amplifying the significance of keywords in the text. Punctuation, on the other hand, aids the reader to assimilate the thought expressed through the written word. There are no new sentences without a period, pauses without a comma, a change of thought without a dash, or additional information without brackets. Another writer tells us that punctuation marks are the traffic signals of language: they tell us to slow down, notice this, take a detour, and stop (Truss, 2005). Discussing the comma, Truss urges the writer to be aware of its potential ambiguity by giving a few examples where commas have been obviously misplaced, thereby obfuscating the meaning, causing confusion, and frequently resulting not only in misunderstanding, but in utter nonsense.

- (1) Leonora walked on her head, a little higher than usual.
- (2) The driver managed to escape from the vehicle before it sank and swam to the river-bank.

In the first example, the comma is to follow the preposition "on", otherwise the sentence would be meaningless, if not ludicrous, while the second example suggests that the vehicle swam to the river-bank, rather than the passenger. In this instance, the comma is to follow the past form of the verb "to sink", i.e., "sank" (Truss, 2005). The quoted sentences exemplify the consequences of mispunctuation which, surprisingly, even educated native speakers seem to be prone to, and, more often than not, in two minds about proper capitalisation, let alone the ESL learners. This paper is intended for the ESL learners as it concerns the proper usage of capitalisation and punctuation in order to help them properly convey information through the written word in terms of clarity and, ultimately, readability.

Since this paper has been primarily intended for the Croatian ESL students, and the problems discussed above are evident in the Croatian language as well, it might be useful here to mention, as far as written language is concerned, some problem areas due to an interaction between the two languages and possible confusion resulting from it.

Firstly, some of the punctuation marks, the colon and the semi-colon for instance, abundantly occurring in English written texts, are not as frequently used in Croatian. This might need some additional clarification in terms of making the students aware of this fact and encouraging them to use these punctuation marks wherever they are required, or wherever the particular situation calls for it.

The second problem is the one of capitalisation. Not only has it been almost completely eradicated by modern usage, primarily due to the design of book-titles, headings, captions, film posters, advertisements, etc., where capitals do not seem to figure at all – they are put (and omitted!) liberally and arbitrarily, almost at random, disregarding all rules and conventions of correct spelling. This has resulted in more and more people, especially the young ones, regarding the rules of writing as an unnecessary burden. Capitalisation in this respect needs particular attention since it considerably differs in the two languages (English and Croatian). It is also a segment in which the interaction and interference between the two languages becomes evident and actually goes two ways. In Croatian the separate segments of titles (books, films, etc.) are not capitalised, whereas in English they are. Also, the adjectives derived from proper nouns denoting nations and nationalities (Croatian, English, German, French, etc.) are always capitalised in English, while in Croatian they are not. Consequently, the most common mistakes arise from this, making Croatian students unnecessarily (and incorrectly!) capitalise the words in Croatian titles, while omitting the obligatory capitals in adjectives denoting nationalities and, conversely, using them in Croatian (e.g. \*english, french, italian vs. \*Engleski, \*Francuski, \*Talijanski).

Furthermore, the punctuation mark deserving particular attention and consideration is undoubtedly the apostrophe, hardly if ever used in Croatian (apart from the rare cases where it indicates contraction (elision or omission). In English, however, the apostrophe is extremely important because, apart from indicating elision in contracted forms of primary and modal auxiliary verbs (it's, isn't, aren't, can't, won't, etc.), it is also a mark of the possessive case (Paul's, Mary's, the Westons' house, children's, etc.), i.e., it has an important morphological and grammatical function which in no circumstances can be disregarded, not even for the sake of brevity and economy. Due to the failure to recognise this, the mistakes of this type are becoming increasingly frequent, sadly, not only among the non-native speakers of English:

**\*Its** a lovely day!

**\*Childrens'** toys sold here.

**\*He** bought some **CD's, record's** and **tape's** at a sale.



Naturally, when it comes to correct spelling and punctuation, many areas in the two languages are similar, if not identical: the cases where one would normally use a comma, an exclamation mark, or a full-stop, for instance, are perfectly compatible in both languages and foreign students of English can be comfortable and confident in using them properly. It is the areas where there are significant differences and departures that require more attention and care. In other words, in a paper of this type, particular emphasis should be laid upon the things that do not coincide in the two languages and where, in many respects, they considerably differ. It is also the aim of this paper to make the reader more aware of the differences in order to be able to adhere to the rules of proper spelling and punctuation, which, in our opinion, is still of utmost importance. It is a basic prerequisite for good writing, regardless of the register, all the more important when it comes to higher education and academic writing. Without a good command of the rules and standards, one could hardly aspire to achieve what is generally known as elementary literacy, let alone clarity, coherence, and elegance of style.

## 2. CAPITALISATION

Capital letters are employed to give emphasis to particular words, i.e. proper nouns and proper adjectives. This paper lists a number of rules and instances met daily.

### 2.1 Capitalise the first word of a sentence (a), of a direct quotation (b), and of a formally introduced series of items or phrases following a colon (c).

- (a) Always to be expressed in 360 degree notation from north (true north unless otherwise stated).
- (b) The captain said, "Fairway speed is...knots"
- (c) The analysis revealed the following: Carbon, six parts; oxygen; six parts.

### 2.2 Proper nouns, i.e., the names of particular people, countries, and cities are capitalised.

China

George Washington; but: the Washington family

Paris

Morocco

James

Cook

Venice

Italy

Walt Disney

Rome

### 2.3 Capitalise people's titles when they precede the name, or when the title is used alone instead of the name. In American English, people's titles are followed by a period (Ms., Mrs., Mr., Dr.). Shortened forms of capitalised titles normally have a period (Prof.), though this need not be so if the abbreviation ends with the last letter (Dr).

Mr Stewart

Dr Grey (Good morning, Doctor; but: She is a doctor).

Mrs Lincoln

President Kennedy

Ms Richardson

Queen Elizabeth II

Manager Smith

General Butler

Sir Edward (Can I help you, sir?)

Justice Roberts

### 2.4 Capitalise the d', da, della, van and von when not preceded by a title or forename.

De Maupassant; but: Guy de Maupassant

Von Tirpitz; but: Alfred von Tirpitz

Van Gogh; but: Vincent van Gogh

Della Robbia; but: Luca della Robbia

• In American and British names, these particles are usually capitalised, regardless of the said rule, but individual usage should be followed.

William De Morgan

Lucretia Van Zandt

Thomas De Quincey

Henry van Dyke (his own usage)

### 2.5 Capitalise the first sentence in a letter after the initial greeting, followed by either a comma (BrE, informal AmE) or a colon (AmE).

Dear Mr. Smith:

Dear Mr. Smith,

Following your notification of...

Following your notification of...

### 2.6 Capitalise words for members of a family when they precede a name, or are used alone instead of a name. These titles are not capitalised when they are preceded by possessive adjectives.

Uncle Paul; but: visit his uncle

a letter to Mother; but: I wrote to my mother

**A**unt Barbara; but: visit her aunt  
yes, **F**ather; but: he hasn't got a **f**ather

## 2.7 Words derived from proper nouns that retain a proper meaning are capitalised.

**C**hinese  
**P**arisian  
**D**isneyesque

**A**merican  
**V**enetian  
**D**isneyish

**M**oroccan  
**R**oman  
**D**isneyfication

## 2.8 Words that derive from proper nouns that are used as common nouns are set lowercased.

**r**oman (type)  
**m**acadam (crushed rock, dirt road)  
**f**rankfurter (meat)

**b**russels sprout (vegetable)  
**w**att (electric unit)  
**c**hina (crockery)

**v**enetian blinds (window covering)  
plaster of **p**aris (gypsum plaster)  
**s**cotch (drink)

## 2.9 Common nouns and adjectives which are part of a proper name, such as streets, buildings, and geographical names need be capitalised.

**E**lm **S**treet,  
**E**mpire **S**tate **B**uilding  
**R**ed **R**iver

**S**andy **L**ane  
**P**ort **A**uthority **B**uilding  
**B**iscayne **B**ay

**L**incoln **A**venue  
**C**hrysler **B**uilding  
**M**ount **S**t. **H**elens.

## 2.10 Descriptive place references are never capitalised.

the **v**alley of the Nile,  
the **r**iver Thames,  
the **g**orge of the Colorado

## 2.11 Common nouns used alone as a substitute for the name of a place are not capitalised.

**H**oover **D**am; the **d**am  
**S**tatue of **L**iberty; the statue  
**W**ashington **C**ity; but: the city of Washington; the city  
**C**ook **C**ounty; the county

**W**ashington **M**onument; the monument  
**C**ape **H**orn; the cape

## 2.12. Should an intervening common noun separate a common noun or adjective that forms an essential part of the name, then the expression is not considered a proper name and is therefore not capitalised.

**U**nion **S**tation: union **p**assenger station  
**E**astern **S**tates: eastern **f**arming states

## 2.13 If a common noun is used alone to refer to a well-known proper noun, it is capitalised.

**T**he **C**hannel (the **E**nglish **C**hannel)  
**T**he **C**hunnel (tunnel bellow the **E**nglish **C**hannel)  
**T**he **D**istrict (**D**istrict of **C**olumbia)

## 2.14 The plural form of a common noun preceding or following a proper noun is capitalised as well.

**L**akes **E**rie and **O**ntario  
**P**residents **W**ashington and **A**dams

**S**tate and **T**reasury **D**epartments  
the **P**otomac and **J**ames **R**ivers

## 2.15 Capitalise a noun followed by a number or a letter that indicates sequence, the nouns chart and table mentioned in the text and followed by numerals, as well as nouns followed by a number to name a section of a book or legal code.

**A**ccount 1220  
**A**rticle 2  
**R**oom 101

**A**ct 2  
**B**ook IV  
**F**igure 5

**A**ppendix B  
**C**hapter 6  
**T**able 6

• Exceptions: line, note, page, paragraph, size, step.

**2.16 The following terms are never capitalised, even with a name or number:**

aqueduct  
buoy  
ditch  
floodway  
lock  
slip  
tunnel  
watershed

breakwater  
dike  
drydock  
jetty  
pier  
spillway  
wharf  
weir

**2.17 The following common nouns are always capitalised when they form a proper name:**

(Kornati) **A**rchipelago  
(Blaca) **D**esert  
(Dalmatina) **H**ighway  
(Istra) **P**eninsula

(Savudrija) **B**ay  
(Plitvice) **F**alls  
(Marjan) **H**ill  
(Colorado) **P**lateau

(Carpenters) **B**ayou  
(Marča) **F**orest  
(Sechelt) **I**nlet  
(Krka) **R**iver

(Queens) **B**orough  
(Dobra) **F**ork  
(Island) of **H**var  
(Adriatic) **S**ea  
(Panama) **C**anal  
**F**ort (**K**lis)  
(British) **I**sles  
(Puget) **S**ound

(Cetina **R**iver) **C**anyon  
(Vratnik) **G**ap  
(Sit) **I**slet  
(Glenwood) **S**prings

Cape (**K**amenjak)  
(Hubbard) **G**lacier  
(Red) **L**ake  
(Neretva) **V**alley

(Brač) **C**hannel  
(Zrmanja) **G**ulch  
**M**ount (**P**apuk)

(Split-**D**almatia) **C**ounty  
(**G**ulf) of **M**exico  
(Biokovo) **M**ountain

(Medveščak) **C**reek  
(Split) **H**arbuor  
(Tacoma) **N**arrows

**2.18 Definite article in proper place nouns**

In English most countries and cities do not take the definite article, but some do. The definite article is capitalised when it is used as part of an official name or title.

The Dalles (OR); but the Dalles region  
The Gambia

The Hague  
British Council v. The Mermaid (court case)

• The definite article is not capitalised when it is used adjectively, i.e. when the state's name it precedes derives from a geographical reference, such as mountainous region, river, etc.

**t**he Congo  
**t**he Netherlands  
**t**he Lebanon  
the Second Hague Conference

**t**he Sudan  
**t**he Philippines  
the **H**ague **C**ourt  
the **S**ahara

**2.19 Capitalise the names of organised bodies and their members to distinguish them from the common meaning, as well as the names of organisations, associations, institutions, etc.**

Republican **P**arty, a **R**epublican; a republican (one who believes in a republican form of government).

**F**irst **N**ational **B**ank  
the **N**ational **B**asketball **A**ssociation  
the **U**S **A**rmy

## 2.20 Capitalise territory, state, nation, union, and empire only when these words refer to a particular political division.

the **U**nited **S**tates: the **R**epublic, the **N**ation, the **U**nion;  
but: a **r**epublic, a **n**ation, a **u**nion.

the **B**ritish **E**mpire: the **E**mpire; but: an empire, South Africa;  
but: countries of **s**outhern **A**frica, the **W**est; but: he drove **e**ast

## 2.21 Descriptive terms related to a definite geographical region or feature need be capitalised.

the **F**ar **E**ast  
the **C**ontinental **D**ivide  
the **S**outh **P**ole

the **N**ear **E**ast  
the **N**orth **P**ole  
the **W**estern **H**emisphere

## 2.22 Capitalise names of months and days of the year, historic events, eras, holidays, and ecclesiastical feast, fast days, all nouns and adjectives denoting the Deity, and all pronouns referring to the same.

**J**anuary  
**F**riday  
**W**orld **W**ar  
**M**iddle **A**ges  
**R**enaissance  
**A**llah  
**S**hrove **T**uesday  
the **L**ord  
the **V**irgin  
**S**on of **M**an  
the **H**oly **G**host  
**F**ourth of **J**uly  
**Y**ahweh  
the **A**lmighty

## 2.23 All names of creeds, religious bodies, and their adherents must be capitalised.

**C**hristian  
**B**uddhist

**M**ethodist **C**hurch  
**M**ohammedan

## 2.24 Capitalise the first and all the important words in the English title of a book, poem, play, essay, work of art, piece of music, report, publication (paper), court case, film, television programme, headlines in newspapers, etc.

The **W**ave: In **P**ursuit of the **R**ogues, **F**reaks, and **G**iants of the **O**cean (book)

The **R**ime of the **A**ncient **M**ariner (poem)

**M**utiny on the **B**ounty (film)

The **R**aft of the **M**edusa (painting)

**B**rown v. **B**oard of **E**ducation (court case)

• Little words (articles, conjunctions) within titles such as a, an, the, but, or, nor, as well as prepositions (to, from, on, etc.) are set lowercased.

## 3. PUNCTUATION

### 3.1 The comma (,)

The comma is used in writing to separate parts of a sentence showing a slight pause in the interest of clarity and ease of reading.

**3.1.1** A comma is used between each element of pairs and series unless the pairs are connected by a coordinating conjunction.

- (a) The voyage was interesting, eventful.
- (b) The voyage was interesting and eventful.

**3.1.2** A comma is used before the conjunction and in a series of a, b, and c.

When latitude and longitude are used, these shall be expressed in degrees, minutes, and decimals of a minute (if necessary).

**3.1.3** A comma is used before the conjunctions (and, for, or, neither, nor) when they join a pair of main clauses.

- (a) They will be there, or I am mistaken.
- (b) Many are called, but few are chosen.

**3.1.4** A comma is used to introduce a short, direct quotation in the form of a complete sentence and at the end of a quotation if it is followed by unquoted remarks. If the quoted sentence is long, a direct quotation can be followed by a colon.

- (a) The captain replied, "The creature is made of wood."
- (b) "The creature is made of wood", replied the captain.
- (c) "The creature", replied the captain, "is made of wood."

**3.1.5** A comma is used before and after such elements as for example, to be sure, however, nevertheless, and therefore, when they are used parenthetically.

- (a) Any offshore structure, in fact, may present a hazard to navigation.
- (b) The vessel will, therefore, proceed from harbour at six o'clock.

**3.1.6** A comma is used to enclose a geographical name explaining a preceding geographical name.

- (a) They lived in Split, Dalmatia, for a number of years.

**3.1.7** A comma is used to enclose a date explaining a preceding date.

- (a) In January, 1978, they moved to Zagreb.  
(b) On January 29, they decided to leave Zagreb.

**3.1.8** A comma is used between the parts of a name or phrase when they are written in reverse order.

Cook, James  
Punctuation, Use of

Navigation, History of  
Chemistry, Organic

**3.1.9** A comma is used to enclose appositives.  
Christopher Columbus, a fearless and dedicated explorer, grew up surrounded by the sea, ships, and sailors.

**3.1.10** A comma is used to enclose absolute phrases.  
Six boys came over the hill half an hour early that afternoon, running hard, their heads down, their forearms working, their breath whistling.

**3.1.11** A comma is used to separate two words or figures in order to avoid confusion.

- (a) In 1564, 23 Spanish ships were lost in Florida waters.  
(b) To Katharine, Spencer was the best actor of all times.  
(c) What will be, will be.

**3.1.12** Use a comma before the abbreviations or degrees.

Douglas Fairbanks, Jr.  
Christian Barnard, M.D.  
Rudolf Filipović, Ph.D.

**3.1.13** A comma is used to separate thousands, millions, billions in numbers of four or more digits.

8, 293  
87, 312  
8, 856, 345

• A comma is not used in telephone numbers, serial numbers, dates, and radio wave lengths.

Pacific Heights 6548  
A.D. 2011  
No. C83600854 K  
1170 kilocycles; 325 meters

**3.1.14.** A comma is used after a title or phrase in direct address.

- (a) Sir, we are ready to proceed.  
(b) Mr. President, we are waiting for your instructions.

**3.1.15** Use a comma between title and name of organisation where "of" or "of the" has been omitted.

Rector, University of Split  
President, Board of Directors

The comma has an important syntactic function: it is more than merely a punctuation mark because the overall meaning frequently depends on its proper use (or its omission).

The comma is used in complex sentences to separate the sentence elements (clauses).

If the main clause precedes the subordinate clause(s), no comma is used:

You must tell me all about it when you come back.  
Give me a ring if you should see anything unusual.

If, however, the subordinate clause precedes the main clause, i.e., the clause sequence is inverted, it is separated from it by a comma:

As soon as I have time, I'll deal with it.  
If you happen to see Jack, give him my regards.

The importance of the use of the comma (or its omission) becomes even more prominent in **relative clauses**, marking the distinction between **defining** (restrictive) and **non-defining** (non-restrictive) relative clauses.

In **defining relative clauses** the comma is omitted:

His brother **who lives in London** is an artist.

The omission of the commas in the above sentence indicates that the person has more than one brother, therefore the inserted clause determines which brother is meant, i.e., the one who lives in London.

Should, however, the commas be used, as in:

His brother, **who lives in London**, is an artist.

It would clearly imply that the inserted relative clause is not vital to the meaning: it merely contains a piece of additional information (the person has only one brother). The relative clause is in this case considered to be **non-defining** (non-restrictive).

After which, used as the sentential relativiser, the comma is obligatory. In this case, the relative sentence introduced by **which** refers to the whole previous clause:

We have received no reply to our proposal, **which** is quite surprising.

The unemployment rates are on the increase, **which** was only to be expected.

### 3.2 The Dash (-), the hyphen (-), and the slash (/)

The dash is used to introduce short sentence elements and has great force. It should be used only when other forms of punctuation are inadequate.

**3.2.1** Use a dash instead of a semicolon (;) when more effective grouping is desired.

The shouting ceased – all was quiet; evidently the mob had dispersed.

**3.2.2** Use a dash if you want put an emphasis on a word or group of words following it.

He works hard – too hard, in fact.

**3.2.3** Use a dash at the end of a long series to introduce material concerning that series.

With his persistence, with his positive attitude, with his determination – with all these, John should not fail.

**3.2.4** Use a dash to link letters, figures, years, days, months or letters and figures combined.

DO – X  
AB – 3  
1948 – 50  
February – June  
Monday – Friday

**3.2.5** Use a dash when there is repetition for additional emphasis.

We are now in financial trouble – the trouble that will cost us hundreds of jobs.

**3.2.6** Use a dash for summarising.

(a) John, Dean, Peter, James – all knew the solution to the problem.

**3.2.7** A hyphen is used to join part of a word at the end of one line with the other part which is continued on the next line. Divide a word by syllables, or the smaller units from which the

word is constructed (prefixes such as un-, dis-, im-in-, and suffixes such as -able, -ible, -ful, -fully, -less, etc.).

- (a) He was trying to chat up this girl, but you could see from her face that she was in- **different (next line)**.
- (b) Perspicuity and beauty of composi- tion (next line) are not to be sneezed at in this rotten world.

**3.2.8** A hyphen is used with compound adjectives preceding a noun (in the attributive position) (a), with a verb preceding an adjective (b) or adverb (c), with a verb preceding a preposition (d), with a past participle construction before a noun (e), as well as with a noun (f1), adjective (f2), or adverb (f3) preceding a present participle.

- (a) round-table discussion
- (b) feel-good factor
- (c) buy-now pay-later purchase
- (f) stick-on label
- (e) middle-aged lady
- (f) (f1) awe-inspiring personality
- (f2) long-lasting affair
- (f3) far-reaching decision

However, the hyphen is omitted in the compound adjectives predicatively used:

We felt that the decision was **far reaching**.

**3.2.9** A hyphen is used with prefixes.

A pre-war house  
Non-nuclear sources  
A self-employed builder  
Good co-operation

**3.2.10** A hyphen is used with numbers spelled out or as numerals.

Two-thirds of the population  
Twenty-three  
Five-sided polygon  
20th century-poem

**3.2.11** A hyphen is used with pairs of adjectives and nouns, as well as compounds including two geographical modifiers.

French-Spanish dictionary  
Afro-Cuban  
Father-son relationship  
Anglo-Indian

• **Slash mark** is also called the **stroke** or **oblique** (BrE).

**3.2.12** Use a slash mark instead of the conjunction “or”.  
Payment by cash /cheque /credit card only.



**3.2.13** Use a slash mark to show that two expressions have the same meaning.

Add 80z / 225g sugar and bake at 200° C / 400°F.

**3.2.14** Use a slash mark to separate the numbers when writing dates.

(BrE) 22 / 5 / 65 (22 May 1965)

(AmE) 12 / 4 / 83 (December 4 1983)

**3.2.15** A slash mark is used instead of for each (spoken per or a) with amounts and prices.

My car does not use much petrol. It does about 40 miles/gallon.

Car rental at \$50 /day

### 3.3 The Semi-colon (;)

The semi-colon is used in formal writing between two parts of a sentence, usually when each of the two parts could form grammatical sentences of their own, i.e., to coordinate main clauses.

**3.3.1** Use the semi-colon between main clauses which are not connected by a coordinating conjunction (and, but, for, or, neither, nor).

Rachel's eyes began to close; Dan, too, was feeling tired.

**3.3.2** Use the semi-colon between pairs of main clauses when a conjunctive adverb (therefore, nevertheless, however, otherwise) is present.

You may help him; however, I will not.

**3.3.3** Use the semi-colon with a coordinating conjunction if such clauses are long, contain commas, or if emphasis is desired.

It is not just to the people, the state, or the country; and although difficult, a proper decision must be made.

### 3.4 The Colon (:

**3.4.1** The colon is used to introduce a clause or phrase that explains a preceding clause.

(a) We have made a difficult decision: the company will close.

(b) We live on a planet, not on a star: a star is a sun.

**3.4.2** The colon is used to introduce a direct, lengthy quotation, or any other formal matter.

(a) The captain explained: "When the position is related to a mark, the mark shall be a well-defined charted object. The bearing shall be in the 360 degree notation from true north and shall be that of the position from the mark."

(b) These are his intrinsic motivations: personal growth and development; doing a good job; leading and organising others; and finding meanings from his efforts.

**3.4.3** The colon is used to express time.

9:30 A.M. 12:30 P.M.

**3.4.4** The colon is used after the salutation of a letter.

Dear Madam:

Dear Sir:

My dear Sir:

Gentleman:

**3.4.5** The colon is used in proportions.

1:3 :3:9 The ratio was 16:1.

### 3.5 Round brackets (BrE) / Parentheses (AmE)

**3.5.1** Use round brackets to enclose part of a sentence intended to be read as a side remark, given the removal of such part would not destroy the context. Complete sentences, intended as side remarks, may be given in round brackets.

Robert was playing great football (for the thrill of it; not merely to win). I'll see you on Tuesday (I can't come tomorrow, I am just too busy).

**3.5.2** Use round brackets in reference to tables, diagrams, charts, and to enclose figures or letters used in enumerations.

(a) Small business credit conditions depend on recovery in residential construction (see Chart I).

(b) (1) Insert a cassette. (2) Press the PLAY and RECORD buttons.

### 3.6 Square brackets

Square brackets are used in specialised writing, for example, textbooks. They are rarely, if ever, used in a business letter.

**3.6.1** Use square brackets to enclose an explanatory remark in a quoted passage.

"The rise of absolutism [Fascism, Hitlerism, etc.] has its roots in post-war conditions," the speaker said.

### 3.7 Quotation marks

Quotation marks may be single ( ' ') and double ( " "). Some writers prefer to use double quotation marks only to enclose words that were spoken.

**3.7.1** Use quotation marks to enclose all direct quotations. He said, "I am manoeuvring with difficulty. Keep clear of me."

**3.7.2** Use single quotation marks to enclose a quotation within a quotation.

Tom said: "I heard one of the passenger say, 'The ship is listing to starboard.'"

**3.7.3** The comma and period are always placed inside the quotation marks.

"I will join you," she said, "if you want me to."

### 3.8 The period (A.E) / The full stop (B.E.) (.)

**3.8.1** Use the period at the end of a declarative sentence.  
This ship will be built in our shipyard.

**3.8.2** Use the period at the end of an imperative sentence.  
Do not pass astern of me.

**3.8.3** Use the period after an indirect question.  
I asked him how it felt to see such a famous person.

**3.8.4** Use the period after an abbreviation.  
e.g. (for example)  
etc. (and so forth)  
i.e. (that is)

• A contraction (indicated by an apostrophe) is not followed by a period.

Ass'n (association)

M'g'r (manager)

Sup't (superintendent)

Assn.

Mgr.

Supt.

**3.8.5** Do not use a period after Roman numerals except in enumeration used in an outline.

Elizabeth II

I. The Colonial Period Henry VIII

II. The Ante-Bellum Period

III. The Post-Bellum Period

**3.8.6** Use the period within quotation marks.

He did not see the performance „Mourning Becomes Electra.“

### 3.9 The exclamation mark (!)

**3.9.1** Use the exclamation mark at the end of a declarative sentence or after an exclamation within the sentence to convey the idea of strong feeling, surprise, or irony.

(a) Here, get down from there!

(b) What! the only one we have! and I am not to use it!

### 3.10 The question mark

**3.10.1** Use the question mark at the end of an interrogative sentence.

(a) How much money did you spend yesterday?

(b) "How much money did you spend yesterday?" he asked.

**3.10.2** Use the question mark when it is desirable to emphasize each element separately.

Who is responsible for executing the plan? the coach? the coaching stuff? the players?

• Sometimes a question will actually end with a series of brief questions. When these brief questions are just follow-ups to the main question, each of the short questions can begin with a lowercase letter and end with a question mark (see exclamation mark **3.9.1**).

### 3.11 The apostrophe (')

**3.11.1** The apostrophe is used to indicate the omission of one or more letters from a verb, or figures from a number.

(a) We're (we are) his parents.

(b) It's their decision (it is).

(c) They've lived (have lived) in Split since 1975.

(d) The class of '75 met at the Marjan Hotel.

• Do not use an apostrophe with the possessive determiner *its*.

Split and **its** surroundings.

**3.11.2** The apostrophe is used to show possession with nouns not ending in an -s, with plural nouns ending in an -s, compound nouns, as well as with indefinite pronouns.

the girl's book, the children's bedroom

my brother-in-law's car

a girls' school, the Smiths' house

somebody else's coat

**3.11.3** Use the apostrophe and s to form the possessive of singular nouns of not more than one syllable, including those which end in an -s.

Fred's

James's

Mr. Jones's

• With the possessive of singular nouns ending in an -s, the *s* is preferable.

**3.11.4** Use the apostrophe alone with the possessive of plural nouns ending in an -s, but add an apostrophe with plural nouns which do not end in an -s.

sailors' wages

the Taylors' property

women's fashions

**3.11.5** Use the apostrophe and an -s to indicate compound possession.

John and Anthony's parents.

**3.11.6** Use the apostrophe and an -s to form the plural of a letter, a figure, a word used as a noun, or to indicate a decade.

- (a) No more if's and but's.
- (b) There are three 7's in your equation instead of two.
- (c) I liked the fashion of the roaring 20's.

In the plural of numerals the apostrophe is optional; therefore it is also possible to write **20s**.

#### 4. CONCLUSION

Since it is virtually impossible to give a comprehensive list of rules on this occasion, this paper's primary objective is to pinpoint a set of basic rules of capitalisation and punctuation, along with the accompanying examples, thereby providing the ESL students with a basis and a starting point for considering the issues presented and discussed, as well as to raise their sensitivity to and awareness of the relevant issues. The correct application of these rules is of the essence in formal writing, particularly in academic and scientific milieus. As this outline is not exhaustive, neither has it been its aim, the correct usage can be determined by analogy or application of the rules, by common sense, as well as by looking up other examples in textbooks, manuals, and dictionaries.

Furthermore, this brief guide is expected to encourage and motivate the ESL students, as non-native speakers and writers of English, to pay more attention to these issues and to make an effort to improve their spelling, punctuation, and capitalisation – their writing style in general.

In the present circumstances, where good writing style is practically on the verge of extinction, with fewer and fewer people giving more than a passing thought to issues such as these, and where illiteracy seems to be unstoppably spreading everywhere, encroaching even upon the academic territory (which does not seem to be immune to it), it is all the more important to warn of the pending danger. It is to be hoped that, in however small a way, this paper will make a contribution towards this goal.

#### REFERENCES

Curl, E., Luetar, J. and Zorović, D., editors, (1988), Standardni pomorsko-navigacijski rječnik, Zagreb: Školska knjiga.

Gillett, A., (2011), Using English for Academic Purposes: A Guide for Students in Higher Education, available at: <http://www.uefap.com>, [accessed 11 November 2011.].

Landau, S. I., (2000), Cambridge Dictionary of American English, Cambridge: Cambridge University Press.

McQueen, A. and Thatcher, S. V., The New Webster Dictionary of the English Language, Consolidated Book Publishers.

Procter, P., (1996), Cambridge International Dictionary of English, Cambridge: Cambridge University Press.

Quirk, R. and Greenbaum, S., (1977), A University Grammar of English, Longman.

Truss, L., (2005), Eats, Shoots, and Leaves: The Zero Tolerance Approach to Punctuation, London: Profile Books.

# Vela Luka

Gordana Burica

Stojidu sami naši kaići.  
Došli su na misto leuti, guci, gajeti.  
Samo more oko njih šumi  
I priča priču kako je u vali bilo ribari, svita.  
Kad se je svitlilo, potezala braganja, činila tramata.  
Kad su naši stari živili  
Na brujetu od stin, jili matar i spavali na konopima.  
Nihove vridne žene na glavan su nosile kašete ribe, uzbrdo.  
A danas, ja sama u Veloj Luci – pitan se i mislin kako će  
I moje vrime suncobrana i faktora 50  
Proć, zauvik.

# Vela Luka

(trans. Adelija Čulić-Viskota)

Alone stand our boats.  
To halt came leut, guc, gajeta.  
Only the sea around them murmurs  
And tells a story of fishermen, folks in the cove.  
While light fishing, hauling braganja, using tramata.  
When our elderly lived  
On a stew of rocks, eating matar and sleeping on ropes.  
Their agile wives wore crates of fish on their heads, uphill.  
And now, I alone in Vela Luka – wondering, and feeling that  
Even my time of parasol and factor 50  
Will go by, forever.



## NOTES:

Vela Luka – a small cove on the island of Šolta  
leut, guc, gajeta – types of traditional fishing boats  
matar – samphire  
braganja – a seine-net  
tramata ("ludara") – a type of surrounding net

# IMSC 2012: Upcoming Conference on Maritime Science



## Topics of interest

- Marine Engineering,
- Navigation,
- Safety Systems
- Marine Ecology,
- Hydrography,
- Marine Automation and Electronics,
- Transportation and Modes of Transport,
- Marine Information Systems,
- Maritime Law,
- Management of Marine Systems,
- Maritime Health,
- Marine Finance,
- Up-To-Date Technologies.

## Conference Proceedings

Authors are invited to submit abstracts on e-mail [imsc@pfst.hr](mailto:imsc@pfst.hr). Abstracts should be text only up to 250 words long, and should be written in English and Croatian language. The abstracts should be sent until 15th March 2012. After abstract, please provide at least 4 keywords. The authors will be informed about acceptance no later than 30th March 2012. All accepted abstracts will be published in the book of abstracts.

## Official Language of the Conference

Papers should be submitted in English. Presentation slides should be given in English, and oral presentation can be made in either English or Croatian.

## Registration

Conference registration deadline is 1st June 2012.  
Conference fee payments of 1 000 HRK or 150 EUR (VAT included).  
Registration form should be sent to [imsc@pfst.hr](mailto:imsc@pfst.hr)

## Contact

University of Split  
Faculty of Maritime Studies  
INTERNATIONAL MARITIME SCIENCE CONFERENCE  
Zrinsko-Frankopanska 38  
21000 Split, Croatia  
Tel: +385 (0)21 380-762;  
Fax: +385 (0)21 380-759  
E-mail: [imsc@pfst.hr](mailto:imsc@pfst.hr)  
[www.pfst.hr/imsc](http://www.pfst.hr/imsc)

## Location

University of Split Library (North building)  
Ruđera Boškovića 31  
21000 Split, Croatia



# Guidelines for Authors: Scope of Transactions on Maritime Science

The Journal is published in English as an open access journal, and as a classic paper journal (limited edition).

ToMS aims at presenting the best maritime research primarily, but not exclusively, from Southeast Europe, particularly the Mediterranean area. Prior to being accepted for publication, each article is reviewed by at least two reviewers. With the intention of providing an international perspective at least one of the reviewers will be from abroad. ToMS also promotes scientific collaboration with students and has a section entitled Students' ToMS. These articles also undergo strict peer reviews. Furthermore, the Journal publishes short reviews on significant papers, books and workshops in the fields of maritime science.

Our interest lies in general fields of maritime science (transport, engineering, maritime law, maritime economy) and the psychosocial and legal aspects of long-term work aboard.

## 1. GUIDELINES FOR AUTHORS: MANUSCRIPT PREPARATION AND SUBMISSION

### 1.1. Organization of the Manuscript

#### First (title) page

The first page should carry:

- (a) the paper title;
- (b) full names (first name, middle – name initials, if applicable), and last names of all authors;
- (c) names of the department(s) and institution(s) to which the work should be attributed. If authors belong to several different institutions, superscript digits should be used to relate the authors' names to respective institutions. Identical number(s) in superscripts should follow the

authors names and precede the institution names;

- (d) the name, mailing address and e-mail of the corresponding authors;

- (e) source(s) of research support in the form of financial support, grants, equipment or all of these.

#### Last page

The last page should carry:

- (a) ethical approval, if required;
- (b) authors' declarations on their contributions to the work described in the manuscript, their potential competing interests, and any other disclosures. Authors should disclose any commercial affiliations as well as consultancies, stock or equity interests, which could be considered a conflict of interest. The details of such disclosures will be kept confidential but ToMS urged the authors to make general statements in the Acknowledgment section of the manuscript.
- (c) a list of abbreviations used in the paper (if necessary);

#### Other pages

Each manuscript should follow this sequence:

- title page;
- abstract;
- text (Introduction, Methods, Results, Conclusions/Discussion);
- acknowledgments;
- references;
- tables (each table complete with title and footnotes on a separate page);
- figures and figure legends, and the last page.



## 1.2. Text Organization and Style

### 1.2.1. Abstract

The second page should contain the Abstract. ToMS requires that the authors prepare a structured abstract of not more than 250 words. The abstract should include (at least) four structures: Aims, Methods, Results, and Conclusion, not necessarily separated.

*Aim.* State explicitly and specifically the purpose of the study.

*Methods.* Concisely and systematically list the basic procedures, selection of study participants or laboratory/experimental/simulation setup, methods of observation (if applicable) and analysis.

*Results.* List your basic results without any introduction. Only essential statistical significances should be added in brackets. Draw no conclusions as yet: they belong into the next section.

*Conclusion.* List your conclusions in a short, clear and simple manner. State only those conclusions that stem directly from the results shown in the paper. Rather than summarizing the data, conclude from them.

### 1.2.2. Main text

Do not use any styles or formatting. All superscripts or subscripts, symbols and math relations should be written in MathType or Equation editor.

#### Introduction

The author should briefly introduce the problem, particularly emphasizing the level of knowledge about the problem at the beginning of the investigation. Continue logically, and end with a short description of the aim of the study, the hypothesis and specific protocol objectives. Finish the section stating in one sentence the main result of the study.

#### Results

Key rules for writing the Results section are:

- (a) the text should be understandable without referring to the respective tables and figures, and vice versa;
- (b) however, the text should not simply repeat the data contained in the tables and figures; and
- (c) the text and data in tables and figures should be related to the statements in the text by means of reference marks.

Thus, it is best to describe the main findings in the text, and refer the reader to the tables and figures, implying that details are shown there. The formulations such as "It is shown in Table 1 that the outcome of Group A was better than that of Group B" should be replaced by "The outcome of Group A was better than that of Group B (Table 1)."

The need for brevity should not clash with the requirement that all results should be clearly presented.

#### Discussion/Conclusions

The discussion section should include interpretation of study findings in the context of other studies reported in the literature.

This section has three main functions:

- (a) assessment of the results for their validity with respect to the hypothesis, relevance of methods, and significance of differences observed;
- (b) comparison with the other findings presented in the relevant literature; and
- (c) assessment of the outcome significance for the further research.

Do not recapitulate your results, discuss them!

### 1.2.3. Tables

Information on significance and other statistical data should preferably be given in the tables and figures. Tables should not contain only statistical test results. Statistical significances should be shown along with the data in the text, as well as in tables and figures.

Tables should bear Arabic numerals. Each table should be put on a separate page. Each table should be self-explanatory, with an adequate title (clearly suggesting the contents), and logical presentation of data. The title should preferably include the main results shown in the Table. Use tables in order to present the exact values of the data that cannot be summarized in a few sentences in the text.

Avoid repetitive words in the columns: these should be abbreviated, and their explanations given in the footnotes. Present the same data either in a table or a figure.

Each column heading for numerical given should include the unit of measurement applied to all the data under the heading.

Choose suitable SI units.

Place explanatory matter in footnotes, not in the heading. Explain in footnotes all nonstandard abbreviations that are used in each table.

### 1.2.4. Figures

Figures should be numbered in sequence with Arabic numerals. Legends to figures should be listed on a separate page, in consecutive order. The legend of a figure should contain the following information:

- (a) the word "Figure", followed by its respective number;
- (b) figure title containing major finding (e.g. Manuscripts which follow Guidelines for Authors had higher acceptance

rate, and not Relationship with manuscripts style and their acceptance rate).

Use simple symbols, like closed and open circles, triangles and squares. Different types of connecting lines can be used. The meanings of symbols and lines should be defined in the legend. Each axis should be labelled with a description of the variable it represents.

Only the first letter of the first word should be capitalized. The labelling should be parallel with the respective axis. All units should be expressed in SI units and parenthesized. Make liberal use of scale markings, directed outwards.

Graphs, charts, titles, and legends in accepted manuscripts will be edited according to ToMS style and standards prior to publication.

Preferred format for graphs or charts is xls or xlsx. Graphs and charts saved as image (raster) files such as JPG, TIF, or GIF and imported or copied/pasted into Word or Power Point are not acceptable.

The resolution for photographic images should also be at least 300 dpi, and minimum image width should be 6 cm. Please submit files in RGB format. For published manuscripts, image files will be posted online in their original RGB format, maintaining the full colour of your original files. Note that we will still need to convert all RGB files to CMYK for printing on paper and colour shifts may occur in conversion. You will not receive a CMYK proof. You can view an approximation of print results by converting to CMYK in Photoshop or Illustrator.

#### 1.2.5. Authorship Statement

All contributing authors must fill out and sign these statements and submit them to the Editorial Office. Accepted manuscripts will not be published until signed statements from all authors have been received.

#### 1.2.6. Acknowledgements

Technical help, critical reviews of the manuscript and financial or other sponsorship may be acknowledged. Do not acknowledge paid services, e.g. professional translations into English.

#### 1.2.7. References

References cited in the manuscript are listed in a separate section immediately following the text. The authors should verify all references.

Examples of citation in text:

It is well known fact (Strang and Ngyuen, 1997; Antoniou, 2006) that FT is not appropriate tool for analyzing non-stationary signals since it loses information about time domain. First group of authors (Vetterli and Gall, 1989) proposed Multiresolution Signal Analysis (MRA) technique or pyramidal algorithm. Second

group (Crochiere et al., 1975; Crochiere and Sambur, 1977) proposed subband coding algorithm.

References are cited according to Harvard style. Examples (for reference section):

Penne, E. and Mallat, S., (2005), Sparse Geometric Image Representations with Bandelets, IEEE Transactions on Image Processing, 14(4), pp. 423 – 438., <http://dx.doi.org/10.1109/TIP.2005.843753>

Donoho, D., Duncan, M. R., Huo, X. and Levi, O., (1999), Wavelab, available at: <http://www.stat.stanford.edu/~wavelab/>, (accessed 12 August 2011.)

Mallat, S., (2009), A Wavelet Tour of Signal Processing, 3rd Edition, New York : Academic Press.

Kingsbury, N.G. and Magarey, J.F.A. (1997), Wavelet Transforms in Image Processing Proc. First European Conference on Signal Analysis and Prediction, Prague, Czech Republic, June 24 – 27, Birkhäuser, pp. 23 – 24., available at: <http://www.sigproc.eng.cam.ac.uk/~ngk/publications/ngk97b.zip>, (accessed 12 August 2011.).

References are cited according to Harvard style. Examples:

Penne, E. and Mallat, S., (2005), Sparse Geometric Image Representations with Bandelets, IEEE Transactions on Image Processing, 14(4), pp. 423 – 438., <http://dx.doi.org/10.1109/TIP.2005.843753>

Donoho, D., Duncan, M. R., Huo, X. and Levi, O., (1999), Wavelab, available at: <http://www.stat.stanford.edu/~wavelab/>, (accessed 12 August 2011.)

Mallat, S., (2009), A Wavelet Tour of Signal Processing, 3rd Edition, New York : Academic Press.

Kingsbury, N.G. and Magarey, J.F.A. (1997), Wavelet Transforms in Image Processing, Proc. First European Conference on Signal Analysis and Prediction, Prague, Czech Republic, June 24 – 27, Birkhäuser, pp. 23 – 24., available at: <http://www.sigproc.eng.cam.ac.uk/~ngk/publications/ngk97b.zip>, (accessed 18 August 2011.).

#### 1.2.8. Language

Authors may use standard British or American spelling, but they must be consistent. The Editors retain the customary right to style and, if necessary, shorten texts accepted for publication. This does not mean that we prefer short articles – actually, we do not limit their size – but rather a resection of the obviously redundant material.

The past tense is recommended in the Results Section. Avoid using Latin terms; if necessary, they should be added in parentheses after the English terms. Real names rather than “levels” or “values” should refer to parameters with concrete units (e.g. concentration).

#### 1.2.9. Abbreviations

Only standard abbreviations and symbols may be used without definition and may be used in the title or the page-heading title.

Non-standard abbreviations should not be used in the title or page-heading title. They must be explained in the text in the following way: the term should be written in full when it appears

in the text for the first time, followed by the abbreviation in parentheses; from then on, only abbreviation is used in the text. This applies separately on the Abstract and the rest of the text.

### 1.3. Submission of manuscripts

All manuscripts should be submitted to:

#### Editorial office

Transactions on Maritime Science,  
Faculty of Maritime Studies,  
Zrinsko-frankopanska 38,  
21000 Split, Croatia  
[www.toms.com.hr](http://www.toms.com.hr)  
[office@toms.com.hr](mailto:office@toms.com.hr)

## 2. ETHICS POLICIES OF TOMS

Plagiarism is arguably the most complicated ethical issue. Our policies define plagiarism as “taking material from another’s work and submitting it as one’s own.” ToMS *holds authors — not the Publisher or its editors and reviewers — responsible* for ensuring that all the ideas and findings included in a manuscript are attributed to the proper source. We also refer to our role as steward of what constitutes ethical conduct. Ethical misconduct is the reason for our commitment to continue to strive to educate all the parties in the publishing process how to handle this matter.

As a member of Crossref, ToMS has a powerful weapon – iThenticate system, which is not perfect.

“Even if there were reliable and sensitive plagiarism-detection software, many issues would remain to be addressed. For example, how much copying is legitimate? Clearly, the reuse of large amounts of others’ text constitutes plagiarism. But what should one think about copying short passages from the author’s own earlier work, such as commonly occurs in the Methods section? In the *Nature* article it is suggested that some journals set a quantitative limit whereby the amount of text that can be reused is limited to about 30 percent. This may be utilitarian, but it seems curious and arbitrary that 25 percent of copied text might be deemed acceptable whereas 30 percent might not. Indeed, two authors who copied the same number of words could find themselves on opposite sides of that border if one author simply was more verbose and thus diluted their plagiarized content below the threshold! No, this is not a simple issue at all.” [cited from: <http://www.aspb.org/newsletter/ethicalstandards.cfm>]

### 2.1. Expectations for Publishing in ToMS

ToMS expects authors submitting to and publishing in its journals to adhere to ethical standards to ensure that the work they submit to or publish in the journals is free of scientific misconduct. Authors must:

- Take credit only for work that they have produced.
- Properly cite the work of others as well as their own related work.
- Submit only original work to the journals.
- Determine whether the disclosure of content requires the prior consent of other parties and, if so, obtain that consent prior to submission.
- Maintain access to original research results; primary data should remain in the laboratory and should be preserved for a minimum of five years or for as long as there may be reasonable need to refer to them.

All authors of articles submitted for publication assume full responsibility, within the limits of their professional competence, for the accuracy of their paper. Instances of possible scientific misconduct related to papers submitted to or published in the ToMS will be addressed by following the procedure outlined below.

### 2.2. Procedure for Addressing Allegations of Scientific Misconduct or Other Ethical Violations

Scientific misconduct in publishing includes but is not limited to:

- Fraud: fabricating a report of research or suppressing or altering data;
- Duplicate publication;
- Plagiarism and
- Self-plagiarism.

#### 2.2.1. Procedure for handling allegations of misconduct

- A. All allegations of scientific misconduct or ethical violation will be referred to the editor for research integrity or to the editor-in-chief. All allegations should be made in writing.
- B. Editor for research integrity will report the case in the meeting of the Editorial board and recommend the actions in 30 days.
- C. Except redraw of the paper, punishment could be inclusion in the black list of the journal and prohibition of further publishing in ToMS.