I. ПОДАЦИ О КОМИСИЈИ
I. INFORMATION ABOUT THE EXAMINATION COMMITTEE

1. Датум и орган који је именовао комисију
Date and authority appointing the committee


2. Састав комисије са назнаком имена и презимена сваког члана, звања, назива уже научне области за коју је изабран у звање, датума избора у звање и назив факултета, установе у којој је члан комисије запослен:
Composition of the committee with the name and surname of each member, title, scientific field for which he/she was elected to the title, date of election to the title, and name of the faculty/institution where the member of the committee is employed:

1. Др Gert De Cooman, редовни професор, Моделовање несигурности и наука о системима, Универзитет у Генту.
   prof. dr. ir. Gert De Cooman, Full Professor in Uncertainty Modelling and Systems Science, Ghent University

2. Др Владимир Црнојевић, редовни професор, Дигитална обрада слике, ПМФ Нови Сад
   dr. Vladimir Crnojević, Full Professor in Digital image processing at Faculty of Science, University of Novi Sad.

3. Др Jan Sijbers, редовни професор, Биомедицинска реконструкција слика, Универзитет у Антверпену
   Prof. dr. ir. Jan Sijbers, Full Professor in Biomedical image reconstruction, University of Antwerp

4. Др Pim Pullens, научни сарадник, Когнитивне неуронауке, Универзитет у Генту.
   dr.ir. Pim Pullens, research associate, Cognitive neuroscience, Ghent University Hospital, Ghent University

5. Др Љиљана Платиш, Статистичка обрада слике, Универзитет у Генту.
   dr.ir. Ljiljan Platiša, research associate in Statistical image processing, Ghent University

6. Др Александра Пижурица, ванредни професор, Статистичка обрада слике, Универзитет у Генту.
   prof. dr. ir. Aleksandra Pižurica, Professor in Statistical Image Modelling, Ghent University

7. Др Дејан Вукобратовић, редовни професор, Телекомуникације и обрада сигнала, Универзитет у Новом Саду.
   dr. Dejan Vukobratović, Full Professor in Telecommunications and signal processing, University of Novi Sad.

II ПОДАЦИ О КАНДИДАТУ
II INFORMATION ABOUT THE CANDIDATE
1. Име, име једног родитеља, презиме:
   Name, name of one parent, surname:
   Марко, Невен, Панић
   Marko, Neven, Panic

2. Датум рођења, општина, држава:
   Date of birth, municipality, state
   24.04.1986., Шабац, Србија
   24/4/1986, Sabac, Serbia

3. Назив факултета, назив студијског programa дипломских академских студија – мастер
   и стечени стручни назив
   Name of the faculty, name of the study program of academic studies - master level and
   acquired professional title
   Факултет техничких наука, Енергетика електроника и телекомуникације, Мастер
   инжењер електротехнике и рачунарства
   Faculty of technical sciences, Power, Electronic and Telecommunication Engineering,
   Master of Science in Electrical and Computer Engineering

4. Година уписа на докторске студије и назив студијског programa докторских студија
   Year of enrollment in doctoral studies and title of the doctoral study program
   2010. Енергетика, електроника и телекомуникације
   2010 Power, Electronic and Telecommunication Engineering

5. Назив факултета, назив мастер рада, научна област и датум одбране:
   Name of the faculty, title of the master's thesis, scientific field and date of defense:
   Факултет техничких наука, Класификација слика заснована на AdaBoost
   алгоритму и стаблима одлуке са HOG и LBP обележјима, Електротехничко и
   рачунарско инжењерство, 16.09.2010.
   Faculty of technical sciences, Image classification based on AdaBoost algorithm and
decision trees with HOG and LBP descriptors, Electrical and Computer Engineering,

6. Научна област из које је стечено академско звање мастер:
   Scientific area from which the academic title of Master is obtained
   Телекомуникације и обрада сигнала
   Telecommunications and signal processing

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<th>III</th>
<th>НАСЛОВ ДОКТОРСКЕ ДИСЕРТАЦИЈЕ:</th>
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<td>III</td>
<td>DOCTORAL DISSERTATION TITLE</td>
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<td>Реконструкција сигнала из непотпуних мерења са применом у убрзању</td>
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<td>алгоритмама за реконструкцију слике магнетне резоначе</td>
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<td>Image Reconstruction from Undersampled Data with Application to Accelerated</td>
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<td>Magnetic Resonance Imaging</td>
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<th>ПРЕГЛЕД ДОКТОРСКЕ ДИСЕРТАЦИЈЕ:</th>
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<tr>
<td>IV</td>
<td>PhD DOCTORAL DISSERTATION REVIEW</td>
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<tr>
<td></td>
<td>Докторска дисертација је изложена на 176 стране, обухвата 43 графикаона,</td>
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<td>2табеле, 48 слика и 204 референце. Написана је на енглеском језику. На почетку</td>
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<td>дисертације дата је кључна документација, резиме, садржај.</td>
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The doctoral dissertation is presented on 176 pages, includes 43 charts, 2 tables, 48 figures and 204 references. It is written in English. At the beginning of the dissertation, key documentation, summary, and a table of contents are provided.

The dissertation contains seven chapters:

1. Introduction
2. Principles of MRI (Magnetic Resonance Imaging)
3. MRI recovery from partial data (Reconstruction of magnetic resonance imaging from incomplete data)
4. MRI reconstructions with MRF priors (reconstruction of magnetic resonance imaging with Markov random field as a signal model)
5. Greedy reconstructions with MRF priors (Greedy reconstruction process with Markov random field as a signal model)
6. Mult-coil MRI reconstruction (Reconstruction from multi-coil measurements)
7. Conclusions

The introduction motivates the development of algorithms for the reconstruction of magnetic resonance images and includes an overview of the existing literature on this topic. Chapter 2 gives the basic principles of magnetic resonance signal generation, an image acquisition model, and an overview of reconstruction methods from a complete set of measurements. The third chapter provides an introduction to the theoretical foundations of compressed sensing and wavelet-like transforms, which are necessary for the development of a reconstruction algorithm from incomplete measurements. The chapter also includes a literature overview of existing algorithms. Chapter four proposes four algorithms for reconstructing magnetic resonance images using a signal...
model based on a Markov random field model. The developed algorithms are based on two optimization approaches for image estimation, an approach with Lagrangian multipliers implemented as an ADMM-based method and an approach based on composite-splitting. Chapter 5 provides a proposal for a greedy algorithm that uses the adopted signal model based on a Markov random field prior. Chapter six provides an extension of the method from Chapter four to the problem of magnetic resonance image reconstruction from multi-coil measurements. The conclusion provides an overview of the dissertation contributions, as well as possible directions for further research.

The dissertation also includes: bibliography and a list of symbols and acronyms.

An efficient novel method for MRI reconstruction from partial Fourier data making use of a Markov Random Field (MRF) prior for the support configurations of sparse coefficients has
been developed. To our knowledge, this is the first elaborate study on CS-MRI with MRF priors, although the potentials of such an approach were earlier demonstrated with a heuristic method named lattice split-Bregman (LaSB). Compared to LaSB, the new method employs a different optimization technique, a more general MRF prior, and achieves consistently better results.

A constrained split augmented Lagrangian shrinkage algorithm (C-SALSA) is extended with an MRF prior. In particular, a new regularization step is introduced, which admits support configurations favored by the prior model. The resulting algorithm, coined lattice split augmented Lagrangian (LaSAL) outperforms consistently C-SALSA.

A new variant of the proposed method LaSAL has been developed with compound regularization (MRF prior + TV norm), which further improves the reconstruction performance. A thorough evaluation was performed on MRI data sets acquired on Cartesian and non-Cartesian grids for which different undersampling strategies were simulated. For the radially acquired k-space data on a non-Cartesian grid, undersampling was performed based on the golden ratio profile spacing in order to reduce the inevitable errors in the interpolation step on the Cartesian grid. MRF-based CS-MRI methods demonstrate a clear improvement compared to alternative methods.

The MRF signal model is extended to an anisotropic version and an efficient estimation of its parameters has been proposed. Based on the more general MRF prior, a soft-thresholding version of the regularization function is proposed. The estimated signal support in the transform domain separates the image coefficients into two classes: significant and insignificant, and different soft-thresholding rules are derived for each class. The proposed MRF regularization, together with the TV-regularization, is integrated and tested under the fast composite splitting algorithm (FCSA) framework, which earlier showed good performances in MRI image recovery problems.

A method for MRI reconstruction from undersampled multi-coil measurements has been developed, in the so-called CS-pMRI setting. Instead of reconstructing each coil image separately and then combining them to get the final MR composite image like most of the state-of-the-art algorithms in parallel MRI (pMRI) setting did, a joint reconstruction framework is proposed.

Undersampled measurements from all coils are taken together as an input to a nonlinear reconstruction algorithm. The proposed method is an extension of one of the single-coil reconstruction algorithms developed in this PhD thesis - the LaSAL optimization-based algorithm with a compound regularization (MRF prior + TV norm).

VI СПИСАК НАУЧНИХ И СТРУЧНИХ РАДОВА КОЈИ СУ ОБЈАВЉЕНИ ИЛИ ПРИХВАЋЕНИ ЗА ОБЈАВЉИВАЊЕ НА ОСНОВУ РЕЗУЛТАТА ИСТРАЖИВАЊА У ОКВИРУ РАДА НА ДОКТОРСКОЈ ДИСЕРТАЦИЈИ

VI LIST OF SCIENTIFIC AND PROFESSIONAL PUBLICATIONS PUBLISHED OR ACCEPTED FOR PUBLISHING ON THE RESULTS OF RESEARCH IN THE DOCTORAL DISSERTATION


Panić M., Vukobratović D., Crnojević V., Pižurica A. ‘Greedy MRI reconstruction using Markov Random Field prior,’ Proceedings of the IEICE Information and Communication Technology Forum (ICTF 2017), Poznan, Poland, Jul 4-6, Polish Association of Telecommunication Engineer, 2017. M33


Panić M., Vukobratović D., Crnojević V., Pižurica A. ‘Sparse MRI with a Markov Random Field Prior for the Subband Coefficients,’ Third International Traveling Workshop on Interactions between Sparse models and Technology (iTWIST’16), Aalborg, Denmark, Aug. 24-26, pp. 56-58, 2016.

VII CONCLUSIONS OR RESULTS OF RESEARCH

From a methodological point of view, there are a number of novel contributions presented in the thesis, mainly around the use of a Markov Random Field prior in the reconstruction process. Building on previous work, the candidate proposes improvements by generalizing the MRF prior that was earlier employed in LaSB and exploiting a different optimization strategy. Another interesting contribution relates to the development of a joint reconstruction method for parallel MRI with MRF priors. All proposed methods seem mathematically sound and have been thoroughly tested both with simulation and real data. The work has been published partly in IEEE TMI (top journal in the field) and partly in conference proceedings.

VIII ASSESSMENT OF THE METHODS OF DISCLOSURE AND INTERPRETATION OF RESEARCH RESULTS

Candidate Marko Panić completed the research that was foreseen by the plan given in his PhD application. The overall presentation of the dissertation is well-structured and clear. The results have been thoroughly and systematically evaluated and interpreted in comparison with the relevant methods in the field. A large number of graphical representations makes it easier to understand the results presented in the dissertation. Conclusions were drawn based on a large number of experiments and diverse data, which shows that the candidate masters the field and has gained profound knowledge in
In view of the above, the Committee evaluates positively the way the results of the research are presented and interpreted.

The dissertation was verified in the iThenticate plagiarism detection software. The coincidence report showed that the dissertation is the original copyright work of the candidate.

IX  FINAL ASSESSMENT OF THE DOCTORAL DISSERTATION:

1. Is the dissertation written in accordance with the reasoning given in the application form?
   The doctoral dissertation is completely written in accordance with the explanation given in the application form of the thesis.

2. Does the dissertation contain all the essentials elements of scientific work?
   The dissertation contains all the essential elements of scientific research. Topic, content, literature review, methodology, presentation and interpretation of the results meet the requirements of the doctoral dissertation level.

3. What makes a dissertation an original contribution to science?
   The PhD dissertation contains original contributions to sparse image reconstruction using Markov random field priors, development of new types of structured-sparsity regularization, and derivation of optimization and greedy based reconstruction algorithms with the proposed regularization approach. The derived algorithms have been thoroughly evaluated with different datasets and their performances showed improvements compared to the current state-of-the-art algorithms in the field.

4. The dissertation has no flaws that affect the research results.

X  PROPOSAL:

На основу укупне оцене дисертације, комисија предлаже:
Based on the overall assessment of the thesis, the committee proposes:

- to accept the doctoral dissertation entitled “Image Reconstruction from Undersampled Data with Application to Accelerated Magnetic Resonance Imaging” and to admit the candidate Marko Panić to the public defence of his PhD.

ПОТПИСИ ЧЛАНОВА КОМИСИЈЕ
(SIGNATURES OF EXAMINATION COMMITTEE MEMBERS)

Др Gert De Cooman, редовни професор, Универзитет у Генту

Др Владимир Црнојевић, редовни професор, Универзитет у Новом Саду

Др Jan Sijbers, редовни професор, Универзитет у Антверпену

Ментор: Др Александра Пижурица, ванредни професор, Универзитет у Генту

Ментор: Др Дејан Вукобратовић, редовни професор, Универзитет у Новом Саду

NOTE: A member of the committee who does not wish to sign the report because he or she does not agree with the opinion of the majority of committee members is obliged to include in the report a justification or reasons for not wanting to sign the report.