「様式３」

課題番号 ：P-13

Space and Time Efficient Image Information Processing: Models and Algorithms

[1] Organization

Leader: *Reneta P. Barneva* (Department of Computer Science, SUNY Fredonia, USA)

Representative at RIE: *Kamen Kanev* (Research Institute of Electronics, Shizuoka University)

Participants:

Valentin E. Brimkov (Mathematics Department, Buffalo State College, State University of New York, USA)

José Ramón Dorronsoro (Telecommunications and Computing Department, Escuela Politécnica Superior, Universidad Autónoma of Madrid (UAM) and Instituto de Ingeniería del Conocimiento (IIC), UAM, Spain)

Kostadin Koroutchev (Universidad Autónoma of Madrid, Spain)

Alberto Suarez (Universidad Autónoma of Madrid, Spain)

Daniel D. Cunningham (Mathematics Department, Buffalo State College, State University of New York, USA)

Antoine Deza (Department of Computing and Software, Faculty of Engineering, McMaster University, Canada)

Elka Korutcheva (Universidad Nacional de Educación a Distancia, Spain)

Sergey Gagarsky (Quantum Electronics and Biomedical Optics Department, State University of Information Technologies, Russia)

Michael Vynnycky (Department of Mathematics and Statistics, University of Limerick, Ireland)

Francois de Vieilleville (Department of Mathematics, University of Savoie, France)

Robert Olson (Department of Computer Science, SUNY Fredonia, USA)

Andrew Speers (York University, Canada)

Akira Takahashi (Faculty of Informatics, Shizuoka University)

[2] Progress of the Research

The work on this project was a continuation of the previous successful project conducted from May 2010 to March 2011. In the period of the current project May 23, 2011 – March 9, 2012 the team performed several research tasks as outlined in project description. We had active communication through e-mail, Skype and on the phone which helped us performing part of the work. Another part was accomplished at face-to-face meetings, workshops, and seminars. The meetings and visits are listed at the end of the report.

The project members were also involved in organizing the 14th International Workshop on Combinatorial Image Analysis, which was held in May 2010 in Madrid, Spain. This was the 20th Anniversary of the workshop. General Chair of the conference was Prof. *Kostadin Koroutchev*. Prof. *José Ramón Dorronsoro* served as an Honorary Chair, Prof. *Reneta P. Barneva* was a Program and Publication Chair, Prof. *Valentin Brimkov* gave a keynote talk, and Prof. *Elka Korutcheva* served as Chair of the Organizing Committee. The Workshop Program Committee consists of 81 renowned experts coming from 26 different countries. Submissions to the symposium came from 20 countries from Asia, Europe, North and South America. The proceedings were published in Lecture Notes in Computer Science, Springer [1], [2]. Another volume devoted to papers from the Special Track on Applications was published by Research Publishing Services (Singapore) [2].

A special issue of Graphical Models (Elsevier), entitled “Computational modeling of objects represented in images” [4] edited by Profs. *Brimkov* and *Barneva* was published. The issue contains six papers devoted to various theoretical and practical issues such as surface-based analysis methods for high-resolution functional magnetic resonance imaging; connected distance-based rasterization of objects in arbitrary dimension; decomposition of nD-rotations: classification, properties and algorithm; thinning combined with iteration-by-iteration smoothing for 3D binary images; generalized perpendicular bisector and exhaustive discrete circle recognition; and direction-dependency of binary tomographic reconstruction algorithms.

Profs. *Barneva* and *Brimkov* also edited a book entitled “Digital Geometry Algorithms. Theoretical Foundations and Applications to Computational Imaging” (Springer) [7]. This contributed book contains thirteen chapters devoted to different (although interrelated) important problems of digital geometry,

algorithms for their solution, and various applications. All authors are well-recognized researchers, as some of them are world leaders in the field. As a general framework, each chapter presents a research topic of considerable importance, provides a review of fundamental results and algorithms for the considered problems, presents new unpublished results, as well as a discussion on related applications, current developments and perspectives.

A special issue of International Journal of Computer Mathematics (Taylor and Francis) edited by Profs. Barneva and Brimkov devoted to the latest theoretical findings in combinatorial image analysis and practical applications is in preparation [6].

The work on the project resulted in obtaining a series of results on space and time efficient computation based on different models. Respective algorithms were developed for solving the problems. Most of the project tasks have been successfully accomplished, and some new research goals were set.

[3] Results

(3.1) Research results

Nowadays we observe an expansion in the development of intelligent peripherals, smart phones, specialized embedded computers, and others, most of which are equipped with image acquisition devices and image processing functions. Developing specialized algorithms and software for these devices is becoming increasingly important. This is particularly challenging when the size of the problem input is huge since these devices are equipped with considerably smaller working space than the usual computers. We consider, in particular, CLUSPI technology which employs an unobtrusive layer of printed code and decoding software to provide a point-and-click functionality. Although the technology works perfectly with A4 surfaces providing real-time response, there are some challenges when it is applied to larger surfaces such as posters, wall papers, billboards and others, as well as non-planar surfaces. We proposed various improvements in [3] and [8].

In the time of exploitation of the encoded surface it becomes a subject of unavoidable wear and noise accumulation. This problem could be addressed by employing specialized techniques for more durable physical marking and laser encoding of tangible objects [10]. For reliable and robust decoding, however, physical methods should be complemented with suitable software-based techniques for code recognition in noisy environment. We developed a method of code restoration based on the information redundancy when capturing an area of the code. The method uses some particularities of the code generation algorithm. We obtained some theoretical results showing in which cases the code can be completely restored.

Another direction in which we worked was the implementation of algorithms for autonomous agent position determination [9]. We studied in detail various methods for indoor or outdoor localization, or for both of them aiming to determine the position of the agent in some coordinate system and its orientation. The position may be determined in the plane or in the space. A variety of devices may be used to gather information, such as digital, sonar, or infra-red cameras or various signal receivers, which may provide single or multiple inputs. As a rule, the autonomous agents have limited memory and processing capacity and the space efficiency in position determination is critical. In particular, we consider the following groups of methods:

• Mapping: the robot possesses prior information about the environment. The map can be two- or three-dimensional and may contain data about obstacles or landmarks. The agent receives signals allowing localizing of its position or may use an odometer allowing it to track its movement on the map from the initial position.

• Semantic surfaces: the agent does not possess prior information about the environment, but there is certain marking that it can recognize allowing it to determine its position in the coordinate system.

• Navigation in unknown environments: the agent detects static or dynamic obstacles and tries to localize some landmarks.

The important related problem of error accumulation is also discussed and approaches for its elimination are considered. The stereo-matching approach presented in [11] has been selected for practical experiments.

(3.2) Future work

The obtained results can be considered as an understructure for solving practical problems. At the same time, some new theoretical problems appeared requiring investigations and development of novel models and methods. The team is considering extending the work and

applying for a larger external grant to support the research effort.

During the research visits the members of the team met with administrative representatives – Deans, Vice Presidents, Directors of International Relations, and Department Chairs - and discussed ways to deepen the collaboration between the partner institutions. Apart from the research collaboration, ways to involve students in exchange opportunities were discussed. Students have always been invited to the talks given by the team members. An example of success story is the one of Ms. Kaori Sagawa, a former advisee of Prof. Barneva: the talk of Prof. Kanev to SUNY Fredonia encouraged her to apply for master's study at Shizuoka University. She is completing her degree requirements and we are looking forward to encouraging more students to follow her path.

[4] Publications

(1) Aggarwal, J.K., Barneva, R.P., Brimkov, V.E., Koroutchev, K., Korutcheva, E. (Eds.) Computational Image Analysis, *Springer Verlag*, LNCS 6636, Heidelberg-Berlin, 2011.

(2) Barneva, R.P., Brimkov, V.E., Koroutchev, K., Korutcheva, E. (Eds.) Advances in Image Analysis and Applications, *Research Publishing Services*, Singapore-Chennai, 2011.

(3) Barneva, R.P., Brimkov, V.E., Kanev, K. Direct-Access Pattern Interface: Theoretical Developments and Applications. Second New York Conference on Applied Mathematics, Buffalo, NY: University at Buffalo, 2011, pp. 41.

(4) Brimkov, V.E., Barneva, R.P., Computational modeling of objects represented in images, *Graphical Models* (Elsevier), Vol. 73 (6), pp. 311-312.

(5) Brimkov, V.E., Barneva, R.P., Connected distance-based rasterization of objects in arbitrary dimension, *Graphical Models* (Elsevier), Vol. 73 (6), pp. 323-334.

(6) Brimkov, V.E., Barneva, R.P. (Eds.) Selected papers on Combinatorial Image Analysis, *International Journal of Computer Mathematics* (Taylor and Francis), 2012, in preparation.

(7) Brimkov, V.E., Barneva, R.P. (Eds.) Digital Geometry Algorithms. Theoretical Foundations and Applications to Computational Imaging, *Springer Verlag*, Heidelberg-Berlin, 2012, in print

(8) Brimkov, V.E., Barneva, R.P., Kanev, K., Direct-Access Pattern Interface, *Pattern Recognition Letters* (Elsevier), submitted.

(9) Fu, Z., Methods for the Position Determination of Autonomous Agents, GT SUNY Fredonia, Barneva, R.P. (Advisor), Kanev, K. (Consultant), Fredonia, NY, 2011.

(10) Gnatyuk, V., Kanev, K., Gagarsky, S., Features of Transparent Material Marking with Nano- and Subnanosecond Laser Pulses, *The 9th Int. Conf. on Global Research and Education InterAcademia2011*, Sicevita, Romania, September 26-29, 2011, pp.26.

(11) Speers, A., Jenkin, M., Tuning Stereo Image Matching with Stereo Video Sequence Processing, In *Proceedings of The Joint Int. Conf. on Human-Centered Computer Environments HCCE 2012*, Aizu-Wakamatsu, Japan, March 8-13, 2012, pp.208-214.

Travelling report

Name:	Andrew Speers
Affiliation:	York University
Period of time:	March 6, 2012 – March 19, 2012
Destination:	Shizuoka University, Japan
Purpose:	To participate in joint experiments conducted at RIE, plan the future collaboration, and participate in the Joint International Conference on Human-Centered Computer Environments HCCE 2012 with a presentation entitled “Tuning Stereo Image Matching with Stereo Video Sequence Processing”
Name of receiver:	Prof. Kamen Kanev