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Space and Time Efficient Image Information Processing: from Theoretical Models to Practical Implementation

[1] Organization

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

Participants:

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Akira Takahashi (Faculty of Informatics, Shizuoka University)

[2] Progress of the Research

In the nine month project period (May 2010 – March 2011) the team worked on the research tasks outlined in project description. The work was continuation of the successful previous project conducted from June 15, 2009 to March 16, 2010. Part of the work was coordinated and done through electronic communications on Skype and through e-mail. Another part was accomplished in face-to-face meetings. Some of the project members gave talks at seminars and conferences. A detailed description of the meetings and visits is given at the end of the report.

Project members were also involved in organizing the International Symposium on Modeling of Objects Represented in Images, which was held in May 2010 in Buffalo, NY. Its Program Committee members are renowned experts coming from 25 different countries. Submissions to the symposium came from 22 countries from Africa, Asia, Europe, North and South America. Overall, representatives of 32 countries contributed to the symposium in different capacities. Profs. Barneva and Brimkov were general chairs, Prof. Kanev was a member of the Program Committee, and Prof. Cunningham was a member of the Organizing Committee. A special guest of the symposium was Dr. Herbert Hauptman, Nobel Laureate. He also served as an editor of the proceedings published in Lecture Notes in Computer Science, Springer [1]. Another volume devoted to papers from the Special Track on Object Modeling, Algorithms and Applications was published by Research Publishing Services (Singapore) [2].

A special issue of IJIST Entitled "Combinatorial Problems and Algorithms in Image Analysis" edited by Profs. Barneva and Brimkov was devoted to the latest theoretical findings in combinatorial image analysis and practical applications appeared in March 2011 [3]. Eight papers presenting new structural results and algorithms in digital geometry and topology and addressing various applications of image analysis and processing were included in the volume.

In the course of the research, both theoretical and experimental studies have been carried out. This effort resulted in obtaining a series of results on space and time efficient computation regarding the theoretical foundations of this research area as well as related applications. Overall, most of the project tasks have been accomplished, and some unexpected new results have been obtained.

[3] Results

(3.1) Research results

We worked in two main directions:

A. Time- and space-efficiency of embedded software of intelligent peripherals. We are currently working on improvement of the

efficiency of CLUSPI technology using methods intrinsic to the applied coding. In particular, we are constructing algorithms that would reconstruct missing information due to noise or surface wear and defects. [4]

Another research task was dedicated to visual encoding of surfaces for absolute positioning and global navigation by optical means. Special attention was paid to seamless coded patterns suitable for interior decoration. Single figure type patterns over equally and non-equally spaced grids were constructed and figure directional vector calculation tests were implemented.

Experiments were carried out for integrating the Cluster Pattern Interface (CLUSPI) for blockless encoding and the Seamless Coded Pattern (SCP) methods in a more flexible, unified surface marking and localization system. [7]

B. Computation of topological image invariants

We introduced a special type of digital objects called *digital stars* with special points from which all other points can be "seen." The continuous counterparts were studied since the early 20th century, but there was no research in the field of digital stars. Problems on stars are closely related to convexity issues. We initiated a study on digital stars particularly motivated by possible applications in computer vision. We defined the notion of digital star, derived several basic properties, and consider relations between digital starshapedness, continuous starshapedness, and digital convexity. In particular, we showed that Krasnosel'skii's theorem does not hold for digital stars, in general. We also conjectured that computing the surveillance/star decomposition number is NP-hard. Future work is aimed at constructing a time and space-efficient algorithm for finding a center of a digital star. Extending the considerations to higher dimensions is seen as another important task. [6]

Another trend of our work was the investigation of the properties of a digital object obtained by taking the integer points within an offset of a certain radius of the object. Our considerations apply to digitizations of arbitrary path-connected sets in an arbitrary dimension *n*. Interesting corollaries were derived for the important special case of surfaces, as well as for offsets of disconnected sets. [5]

(3.2) Future work

Some of the results, already reported at international conferences will be extended and submitted for consideration and publication in special issues of reputable scientific journals. (See, e.g. [4].)

The obtained results are groundwork for developing various implementations and solving practical problems. They can also be used as a seed results for future projects for which the team will apply for external funding and support.

In the framework of the research meetings and visit exchange, ways to deepen the collaboration were outlined. In particular, formal exchange agreements between RIE-Shizuoka University and the partner universities were discussed. There is already a former undergraduate student from SUNY Fredonia, Ms. Kaori Sagawa, who is currently pursuing her master's degree at Shizuoka University as a result of the visit and presentation of Prof. Kanev. We are looking towards more opportunities.

[4] Publications
(1) Barneva, R.P., Brimkov, V.E., Hauptman, H.A., Natal, R.J., Tavares, J.M.R. (Eds.) Computational Modeling of Objects Represented in Images, *Springer Verlag*, LNCS 6026, Berlin-Heidelberg, 2010.
(2) Barneva, R.P., Brimkov, V.E., Natal, R.J., Tavares, J.M.R. (Eds.) Object Modeling, Algorithms, and Applications, *Research Publishing Services*, Singapore-Chennai, 2010.
(3) Barneva, R.P., Brimkov, V.E., Wiederhold, P., Combinatorial Problems and Algorithms in Image Analysis, *International Journal of Imaging Systems and Technology* (*Wiley*) 21 (2) March 2011.
(4) Barneva, R.P., Brimkov, V.E., Kanev, K., Theoretical Developments for Direct-Access Pattern Interfaces, (in preparation).
(5) Brimkov, V.E., Connectedness of Offset Digitizations in Higher Dimensions, In: Computational Modeling of Objects Represented in Images, *Lecture Notes in Computer Science* (*Springer Verlag*), 6026, Berlin-Heidelberg, 2010, pp. 36-46.
(6) Brimkov, V.E., Barneva, R.P., Digital stars and visibility of digital objects, In: Computational Modeling of Objects Represented in Images, *Lecture Notes in Computer Science* (*Springer Verlag*), 6026, Berlin-Heidelberg, 2010, pp. 11-23.
(7) Kanev, K., Kato, H., Koroutchev, K., Encoding of Surfaces for Global Positioning and Navigation, *The Journal of Three Dimensional Images*, Vol. 24, No. 3, 2010, pp. 51-57.

Travelling report

Name:	Kostadin Koroutchev
Affiliation:	Universidad Autónoma of Madrid, Spain
Period of time:	June 8, 2010 – August 10, 2010
Destination:	Shizuoka University, Japan
Purpose:	To participate in cooperative research and the preparation of joint publications and to give a talk on "Figures Design for Coding with Orientation" at the 190th Monday Moring Forum (MMF) organized at RIE.
Name of receiver:	Prof. Kamen Kanev

Name:	Alberto Suarez
Affiliation:	Universidad Autónoma of Madrid, Spain
Period of time:	January 23, 2011 – January 30, 2011
Destination:	Shizuoka University, Japan
Purpose:	To discuss the cooperative project organization and research, to participate in research meetings, and to give a talk entitled "The Arrow of Time in Time Series".
Name of receiver:	Prof. Kamen Kanev and Prof. Akira Takahashi

Name:	Michael Vynnycky
Affiliation:	University of Limerick, Ireland
Period of time:	November 15, 2010 – November 18, 2010
Destination:	Shizuoka University, Japan
Purpose:	To discuss the cooperative project organization and research and to give a talk entitled "A New Look at the P3P Problem".
Name of receiver:	Prof. Kamen Kanev

Name:	Reneta Barneva
Affiliation:	Department of Computer Science, SUNY Fredonia, USA
Period of time:	February 25, 2011 – March 6, 2011
Destination:	Shizuoka University, Japan
Purpose:	To plan the future collaboration, coordinate the ongoing research, and participate in a collaborative research seminar organized at RIE with a presentation entitled "Space and Time Efficient Image Information Processing: Computation of Topological Image Invariants"
Name of receiver:	Prof. Kamen Kanev