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# Theoretical Developments and Practical Applications of a Direct-Access Pattern Interface for Imaging Devices

［1］**Organization**

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［2］**Research Progress**

The project includes participants from three continents who communicated actively through electronic means on the research topics. On December 11, 2015 a Cooperative Research Seminar was held at Shizuoka University, RIE, at which some of them met and reported the achieved results, exchanged ideas about future join work, and possibilities for further cooperation between the respective institutions.

The team members were involved, apart from the activities described in the next section, in active dissemination of the results. Some of them participated in the organization of three major international conferences and in the publishing of a special issue of a reputable journal, both of them devoted to the topics of the project.

- Profs. Barneva, Brimkov, and Korutchev were involved in the organization of the 17th International Workshop on Combinatorial Image Analysis, held in Kolkata, India, November 2015. Prof. Reneta P. Barneva was the Program and Publication Chair. Profs. Valentin Brimkov and Kostadin Koroutchev were members of the Steering Committee [1].
- Profs. Barneva, Brimkov, and Koroutchev are also playing key roles in the 18th International Workshop on Combinatorial Image Analysis, to be held in June 2017 in Plovdiv, Bulgaria. Profs. Barneva and Brimkov are chairs, and Prof. Koroutchev is a member of the Steering Committee.
- Profs. Kanev, Barneva, and Brimkov are

playing leading role in the International Symposium Computational Methods for Objects Represented in Images, which will be held in Niagara Falls, USA in September 2016. Prof. Kanev is invited tutorial speaker and Profs. Barneva and Brimkov are symposium chairs.

- Profs. Barneva and Brimkov serve as guest-editors of a special issue of Discrete Applied Mathematics (Elsevier) devoted to graph-theoretical problems [2]. Many of the articles have already been edited and posted online. The issue is expected to be published soon in paper form.

**［３］Results**

**（３－１）Research results**

Below is a brief explanation of the following results achieved:

I. Imaging devices possess limited memory. It is very important, therefore, to develop space-efficient algorithms for them. In [3, 4] we developed space efficient graph algorithms, particularly under the log-space computational model. This model entails algorithms which use a read-only input array and $O(\log n)$ working memory; the model is advantageous in settings involving large, distributed, or read-only datasets, or involving computation on devices with limited storage space. We developed deterministic log-space algorithms for several restrictions of various graph problems such as finding the shortest path, clique number, circumference, girth, number of blocks, and chromatic polynomial of a graph. The different restrictions on the problems we considered include structural assumptions on the biconnected components, parametric bounds on the maximum vertex degree and biconnected component size, and use of a log-space oracle for certain special tasks. The problems considered have a wide range of applications; for example, the shortest path problem is used in machine vision, robotics, transportation, and autonomous guidance.

II. Imaging devices work with appropriate geometrical primitives. Since the computer models are discrete, it is important to have the right discretization model for the main primitives.
A discrete spherical circle is a topologically well-connected 3D circle in the integer space, which belongs to a discrete sphere as well as a discrete plane. It is one of the most important 3D geometric primitives, but has not been studied up to its merit. We have researched some of its important properties, and have clarified its theoretical prospects in the framework of digital geometry. We have shown how different types of discretization can lead to forbidden and admissible classes, when one attempts to define the discretization of a spherical circle in terms of intersection between a discrete sphere and a discrete plane. Several fundamental theoretical results have been presented, the algorithm for construction of discrete spherical circles has been discussed, and some test results have been furnished to demonstrate its practicality and usefulness [5].

III. With respect to imaging and image devices, pose estimation or the perspective 3-point problem play an important role. It has its origins in camera calibration and is of great importance in many fields such as computer animation, automation, image analysis and robotics. In a previously published article we worked on formulating it mathematically in terms of finding the solutions to a quartic equation. Since in general, the equation does not have a unique solution, and in some situations there are no solutions at all, we concentrated on some special cases. In [6] we extended our considerations to the case where the three marker points are not equally spaced; in addition, the quartic polynomial derived by Grunert was used. The two approaches were reconciled and the probability of finding two and four solutions as a function of the marker spacing was determined. The manuscript is in preparation and is planned to be submitted to the International Journal of Computer Vision.

IV. Various real-life problems involve networks that can be modeled by a set of straight-line segments. These may be networks of the streets in a city; corridors in a building; tunnels in a mine, nuclear plant, or a military facility; a complex system of pipes in a factory;

a map of possible routes for a robot motion in certain environment, or similar. In many cases, modeling is extended by considering moving objects along the edges of such a geometric network. These may represent cars running on streets; humans walking in a city or along corridors or tunnels; mobile robots, or other entities. Geometric networks are further extended by adding special facilities called controllers that are placed at certain locations. Controllers usually represent specialized imaging devices such as cameras and motion sensors but may also stand for guards or policemen (possibly equipped with proper technology.)

We proposed a novel approach for identification and monitoring of moving objects within a geometric network modeled by straight line segments based on CLUSPI. The approach can also be used for supplying the objects with directions or other useful information about the surrounding environment. The moving objects are equipped with direct-access pattern interface imaging devices that provide dynamic environment-oriented information and/or static feature-related information. Within the framework of the proposed model, a number of real-life interrelated tasks are considered and possible applications are discussed [7, 8, 9].

V. In two- and three-dimensional graphical models involving imaging devices, we may include digital marking, indicating specific object voxels. One way is to do this is optically, through laser-induced marks. The local area with optical properties different from those of the matrix (bulk), i.e., with a permanent micro-defect can be considered as an information carrier. Spatially controlled laser-induced volumetric formation of marking centers (information carriers) offers novel opportunities for creation of digital recording areas or images in a variety of materials. We have evaluated various laser-assisted technological approaches and techniques suitable for 2D or 3D optical recording of digital data or images by creation of micro-marks (data bits, pixels, and other information carriers) in the bulk of different materials, transparent for a selected laser wavelength. The features of laser-induced damage in solids, that are applicable to the creation of various parameterized marking centers with controlled geometric parameters (size, shape, orientation, etc.), are discussed. Different marks can be obtained by varying the laser focal area, wavelength, duration and energy of laser pulses, temperature of the object and also applying general external or local internal compressive or tensile stresses in the irradiated objects. The laser-based technologies for creation of colored marks in transparent glasses and polymers with special inclusions are considered and physical and photochemical processes, which take place in the bulk of such transparent dielectrics under tightly focused short laser pulses, are analyzed. Different types of materials, which are promising for the formation of colored and dark marking centers, have been identified and extensive experiments have been carried out [10, 11, 12].

VI. We studied imaging devices suitable for collaborative work and investigated their educational capacity and suitability for augmented learning. As a result, we identified tabletop computers, possessing a large touch-sensitive display placed in a horizontal position and controlled by a computer as very efficient and psychologically stimulating for collaborative activities. In this setting, the interactive surface is equally accessible to all collaborators that are seated around the tabletop facing each other.

We conducted studies to determine how to design effective interfaces for learning that couple mobile devices with interactive stereoscopic 3D visualizations. In our experimental setup, an instructor and a group of students are positioned around the interactive tabletop so that they can comfortably observe the presented content and access the surface for interactive feedback. In contrast to a vertically positioned presentation surface (e.g., an electronic whiteboard) where the up-direction is common for the entire audience, in our scenario the farther edge of the table will differ, depending on the position of the observer with respect to the tabletop. As a test bed case, we have employed Computer

Graphics and Virtual Reality techniques from traditional Computer Science courses to create and present an augmented reality model of a human eye. In the course of such work, students can put in practice a range of methods and technologies from their core Computer Science studies and follow up with hands-on experience in a collaborative ICT setup [13, 14].

**（3－2）Ripple effects and further developments**

The obtained results laid out the ground for solving various problems with theoretical and practical significance. The team is considering extending the work on new models and paradigms as of special interest will be the results for mobile devices.

The research meetings and visit exchange helped deepen the partnership and outline new ways of scientific collaboration.

**［4］Achievements (List of Publications)**


（1） R.P. Barneva, B. Bhattacharya, V.E. Brimkov, Combinatorial Image Analysis. Heidelberg-Berlin, Springer Verlag, LNCS 9448, Berlin-Heidelberg, 2015.

（2） V.E. Brimkov, R.P. Barneva (Guest Editors), Graph-theoretic issues (Special Issue). Discrete Applied Mathematics (Elsevier) (to appear).

（3） B. Brimkov, I.V. Hicks: Memory efficient algorithms for cactus graphs and block graphs. Discrete Applied Mathematics, Elsevier (2015) doi:10.1016/j.dam.2015.10.032.

（4） B. Brimkov, A note on the clique number of complete k-partite graphs. CoRR abs/1507.01613 (2015).

（5） R. Biswas, P. Bhowmick, V.E. Brimkov, On the connectivity and smoothness of discrete spherical circles. Combinatorial Image Analysis, Springer, Heidelberg-Berlin, LNCS 9448, 2015, 86-100.

（6） M. Vynnycky, K. Kanev, On the P3P problem (in preparation). International Journal of Computer Vision.

（7） R.P. Barneva, V.E. Brimkov, K. Kanev, Direct-access pattern interface for geometric networks modeling, Japanese Journal of Applied Physics Conference Proceedings, 2016 (in print).

（8） R.P. Barneva, V.E. Brimkov, K. Kanev, Direct-access pattern interface for geometric networks, Proc. Inter Academia, 2015, 128-129.

（9） V.E. Brimkov, Monitoring and Identification Issues of Motion in Large Networks (invited paper), Proc. Humans and Computers 2015 (in print).

（１０） V.A. Gnatyuk, O.I. Vlasenko, S.N. Levytskyi, T. Aoki, V. Mizeikis, S.V. Gagarsky, K.S. Zelenska, D.V. Gnatyuk, Laser-induced creation of marks as information carriers for digital recording, Proc. of LAMP2015 - the 7th Intern. Congress on Laser Advanced Materials Processing, (2015) in press.

（１１） V. Mizeikis, K. Kanev, Sub-surface Laser Encoding of Physical Objects for Enhanced Privacy and Digital Security, The 14th Int. Conf. on Global Research and Education InterAcademia2015, Hamamatsu, Japan, September 28-30, 2015, pp.126-127.

（１２） K.S. Zelenska, S.E. Zelensky, L.V. Poperenko, K. Kanev, V. Mizeikis, V.A. Gnatyuk, Thermal mechanisms of laser marking in transparent polymers with light-absorbing microparticles, Optics & Laser Technology, Vol. 76, (2016) 96-100.

（１３） A. Uribe, B. Kapralos, A. Hogue, K. Kanev, M. Jenkins, R.P. Barneva, A multi-user tabletop display with enhanced mobile visuals for teaching and collaborative training. ACM Journal of Computing Sciences in Colleges 2016 (in print).

（１４） R.P. Barneva, R. Banerjee, K. Kanev, B. Kapralos, Enhanced student engagement using cell phones and tabletop computers or smart boards, Proc. CIT 2016 - Conference on Instruction and Technology, Potsdam, NY, 2016 (in print).

（１５） A. Deza, K. Huang, M. Metel, Imperfect demand estimation for new product production planning. AdvOL-Report 2015/4, McMaster University (2015).

（１６） M. Vynnycky, S.L. Mitchell, On the numerical solution of a two-phase Stefan problem with phase formation and deletion, J. Comp. Appl. Math. 300 (2016) 259-274.

Travelling Report （Mention each travel by CRP budget.）

Name：Reneta Barneva
Affiliation： SUNY Fredonia, USA
Period of time：December 4-13, 2015
Destination：Shizuoka University, Hamamatsu, Japan
Purpose：Research meetings and participation in a Cooperative Research Workshop at which a presentation titled "Theoretical Developments and Practical Applications of a Direct-Access Pattern Interface for Imaging Devices: Medical Imaging Paradigms" was delivered.
Name of receiver：Prof. Kamen Kanev and Prof. Vygantas Mizeikis

Name：Valentin Brimkov
Affiliation： SUNY Buffalo State, USA
Period of time：December 4-13, 2015
Destination：Shizuoka University, Hamamatsu, Japan
Purpose：Research meetings and participation in a Cooperative Research Workshop at which a presentation titled "Theoretical Developments and Practical Applications of a Direct-Access Pattern Interface for Imaging Devices: Medical Imaging Models" was delivered.
Name of receiver：Prof. Kamen Kanev and Prof. Vygantas Mizeikis