様式２

平成２９年度　生体医歯工学共同研究実施報告書

受理年月日	
受理番号	2021

平成 30 年 3 月 15 日

生体医歯工学共同研究拠点 研究所長会議 議長 殿

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下 記 により、共 同 研 究 の 実 施 報 告 を 致 し ま す。

記

研　究　題　目	（和）医療及び生物医学用途イメージングデバイスと光符号 （英）Imaging devices and optical codes for medical and biomedical applications
研　究　領　域	1. 生体材料に関する基礎・応用研究 2. 生体工学に関する基礎・応用研究 3. 生体機能分子に関する基礎・応用研究 ④. 化学・電気・機械・材料工学の生体応用研究
研　究　期　間	平成 29 年 4 月 17 日 ～ 平成 30 年 3 月 31 日

研究組織

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Lisa Walters	School of Business, State University of New York at Fredonia, USA	Professor	Participant
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Antoine Deza	Department of Computing and Software, Faculty of Engineering, McMaster University, Hamilton, Canada	Professor and Canada Chair in Combinatorial Optimization	Participant
José Ramón Dorronsoro	Telecommunications and Computing Department, Escuela Politécnica Superior, Universidad Autónoma de Madrid and	Professor and Senior Researcher	Participant

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Remy Malgouyres	IUT Department of Informatics, Universite d'Auvergne (Clermont 1), France	Professor	Participant
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Vygantas Mizeikis	Research Institute of Electronics, Shizuoka University, Japan	Professor	Participant

生体医歯工学共同研究拠点内対応教員	（共同研究をした教員名を記載） Vygantas Mizeikis, Professor Research Institute of Electronics, Shizuoka University, Japan

研究成果

The team worked in the following directions of the project:

1. Task: "To investigate ways to assess risk in biomedical organizations to ensure proper distribution of resources for risk prevention and to guarantee safe functioning. Our goal will be to identify the processes, which may lead to serious potential problems and direct resources to prevent them."

   Results: We analyzed the data generated by a medical practice and proposed a data-driven decision making process within the framework of Six Sigma Quality, known as DMAIC (Define, Measure, Analyze, Improve, and Control) to diagnose and improve the inventory management process. To identify the issues and improve the performance, data mining approach was used. Further, the scope of the problem was identified using Critical-to-Quality trees, Supply-Input- Process-Output-Customer (SIPOC) diagramming, and prioritizing the focus on the problem using a prioritization matrix. The approach led to setting specific goals for the improvement and devising a plan [1]. The method could be applied to a broad range of medical practices.
2. Task: "Developing the theoretical background for imaging devices, and more specifically the efficiency – both time- and space-efficiency – of the algorithms. In most cases the data is structured in graph form and this is why our efforts are focused in this direction."
   Results: An injective coloring of a graph is an assignment of colors to the vertices of the graph so that any two vertices with a common neighbor have distinct colors. Injective colorings have applications in the theory of error-correcting codes and are closely related to other notions of colorability. We have shown that subcubic planar graphs with girth at least 6 are injectively 5-choosable. This strengthens previous results that subcubic planar graphs with girth at least 7 are injectively 5-colorable. It also improves several other results in particular cases [2]. We also investigated various algebraic and graph theoretic properties of the distance matrix of a graph. Two graphs are *D*-cospectral if their distance matrices have the same spectrum. We construct infinite pairs of *D*-cospectral graphs with different diameter and different Wiener index. A graph is k-transmission-regular if its distance matrix has constant row sum equal to k. We established tight upper and lower bounds for the row sum of a k-transmission-regular graph in terms of the number of vertices of the graph. Finally, we determined the Wiener index and its complexity for linear k-trees, and

obtained a closed form for the Wiener index of block-clique graphs in terms of the Laplacian eigenvalues of the graph. The latter leads to a generalization of a result for trees which was proved independently by Mohar and Merris [3].

3. Task: "A good model for autonomous devices, such as robots, is moving in a geometric network of straight-lines, which can represent, for example corridors in a hospital. We may assume that the geometric network is further extended by adding special facilities called controllers that are placed at certain locations. We assume that the moving objects are equipped with direct-access pattern interface imaging devices that provide dynamic environment-oriented information and/or static feature-related information. The goal is to develop algorithms for the movement of the autonomous robots."

   Results: We worked on the model described above and furthered our results deriving sharp upper and lower bounds on the number of intersections and closed regions that can occur in a set of line segments whose underlying planar graph is a cactus graph. These bounds can be used to evaluate the complexity of certain algorithms for problems defined on sets of segments in terms of the cardinality of the segment sets. In particular, we give an application in the problem of finding a path between two points in a set of segments which travels through a minimum number of segments [4].

4. Task: "Medicine is usually studied through hands-on activities and collaborative work. Thus, we examine imaging devices suitable for collaborative work and investigated their educational capacity and suitability for augmented learning."

   Results: We worked on a system that would stimulate collaboration among students through effecting grouping. Effective group organization is critical for the success of such collaborative learning, although many instructors would make arbitrary decisions about student grouping. This is mainly due to the lack of in-depth studies analyzing group setup in face-to face settings and providing recommendations and practical guidelines for group assignment and management. To address this problem, we conducted a series of experiments exploring the dynamic formation of collaborative groups among foreign language students at different proficiency levels. On the basis of the obtained results and the identified limitations of the current methods, we propose a novel technology-enhanced approach for optimized group setup and effective management. This approach provides a scaffold for integrating Tangible Technology Enhanced Learning and Computer Supported Collaborative Learning into an instructional system with advanced interaction capabilities for augmented learning and enhanced instructor support for dynamic group management [5].

Meetings/Presentations

1. Research Advancements in Imaging and Optical Encoding (K.Kanev, 2018.02.21, RIE 204)

使用した設備・資料・試料等	Research equipment available in the labs of Prof.Mizeikis (laser systems for surface and volumetric marking and digital encoding of transparent materials) and Prof.Kanev (computing systems, interactive tabletops, and specialized optical readers for code extraction and analysis)

本研究成果に関連する論文発表状況

1. Walters, L., R.P. Barneva, Drilling the data: Students use Six Sigma DMAIC to improve dental practice inventory management. The BRC Academy Journal of Education 7(1), 2017, pp. 57–74
2. Brimkov, B., J. Edmond, R. Lazar, B. Lidicky, K. Messerschmidt, S. Walker, Injective choosability of subcubic planar graphs with girth 6. Discrete Mathematics 340: 2538-2549 (2017).
3. Abiad, A., B. Brimkov, A. Erey, L. Leshock, X. Martinez-Rivera, S. O, S.-Y. Song, J. Williford, On the Wiener index, distance cospectrality and transmission-regular graphs. Discrete Applied Mathematics (2017).
4. Brimkov, B., On Sets of Line Segments Featuring a Cactus Structure. IWCIA 2017: 30-39.
5. Barneva, R.P., F. Gelsomini, K. Kanev, P. Bottoni, Tangible technology enhanced learning for improvement of student collaboration, Journal of Educational Technology Systems, Sage, Vol. 46(3), March 2018, pp. 284-302.

次年度の共同研究継続の有無	有（○印）・ 無	拠点内対応教員とご相談の上ご記入ください。 継続の場合には次年度の研究計画をご記入願います。

次年度の研究計画（継続の場合）

1. Cluster Pattern Interface (CLUSPI®) technology is a patented point-and-click technology based on optical codes, co-invented by one of the project participants [1]. It uses an almost invisible layer of optical code, a digital camera, and software for analyzing snapshots of the surface, detecting the code, decoding it, and performing various actions depending on the code. They could be determining the location the camera is pointed at, or changing the direction of an autonomous device, or displaying information, or performing another action. The code consists of cluster patterns and is specifically designed to be unobtrusive and still to provide a robust and reliable decoding and recognition. The digitally encoded layers become an integral part of the printed document and can be processed and printed along with the standard document content while staying practically indistinguishable to the human eye. They may be printed on paper, or on much larger surfaces, such as floors, ceilings, walls, or billboards, for example for the purpose of autonomous moving devices. In this case, the length of the code and the possible combinations becomes long and may not be processed in real time. Therefore, an important direction of research is improving the direct-access pattern interface imaging devices and point-and-click technology CLUSPI and their use in applications in medical and biomedical fields as well as in some related areas.
2. The theoretical models and the complexity of the respective algorithms play an important role in problem solving. Of particular importance is to develop space-efficient algorithms as the imaging devices have limited memory. We see, therefore, as another direction of possible research developing space-efficient algorithms in various space models – constant, logarithmic, linear or $O(n \log n)$. In particular, this is important when the code's length is large and it needs real-time processing performed at limited space. One of the most widely-used mathematical data structures with simple concept is the graph. Algorithms on graphs could be used in coding, machine vision, transportation, autonomous driving, robotics, and others. There exist numerous algorithms on graphs, but little attention is paid to space-efficiency. Our goal is to find a good trade-off between time and space and develop efficient algorithms for some of the above listed models. We have already obtained several results [2,3,4,5], and will plan to continue in this direction.
3. We will continue exploring scientific approaches for the smooth functioning of medical and biomedical organization. In particular, our objective will be to timely identify processes with the potential of seriously disturbing the work of the organization and direct the resources towards such processes.　An extra target will be optimizing the overall performance and minimizing the expenses. The approaches are based on the usage of point-and-click functionality and optical codes for the deviation processes. The results may be applied for optimization of the work in a wide range of organizations. We have already obtained some results [6,7,8], which we plan to further.
4. The applications of imaging devices in medicine and especially in education can be very beneficial. In previous works we considered student collaborative study from a nontraditional perspective [9,10]. We developed an interactive visually-enhanced educational environment and conducted experiments with it to stimulate student learning. In one of our setups, the traditional blackboard or table was replaced by a digitally enabled interactive surface such as a smart board or a tabletop computer. The information displayed on the digital surface can be further enhanced with augmented reality views through mobile apps on student smartphones. We also strengthened the instructional process through elements of game mechanics and outlined an experimental implementation. The proposed technological and pedagogical methods were applied to human anatomy training. We plan to continue working on enhanced learning through collaboration, involving imaging devices, computer graphics methods, virtual reality techniques, and data analytics.

References:

1. K. Kanev, Kimura, S., Digital Information Carrier, JP, Patent No 3635374.
2. B. Brimkov, A note on the clique number of complete k-partite graphs. CoRR abs/1507.01613 (2015).
3. B. Brimkov, R. Davila. Characterizations of the Connected Forcing Number of a Graph. CoRR abs/1604.00740, 2016.
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6. L. Walters, R.P. Barneva, Prioritization of Process Improvement Using Risk Evaluation in the Manufacturing of Biologics, Quality Management Journal, American Society for Quality, 2017 (to appear)
7. L. Walters, R.P. Barneva, Data Analytics for Risk Evaluation in a Biomedical Organization, reported at the International Conference Human and Computers, December 2015, Shizuoka University, Hamamatsu, Japan.
8. L. Walters, R.P. Barneva, Drilling the data: Students use Six Sigma DMAIC to improve dental practice inventory management. The BRC Academy Journal of Education 7(1), 2017, pp. 57–74
9. R.P. Barneva, K. Kanev, B. Kapralos, M. Jenkin, B. Brimkov, Integrating technology-enhanced collaborative surfaces and gamification for the next generation classroom, Journal of Educational Technology Systems, Sage, Vol. 45(3), March 2017, 309–325.
10. R.P. Barneva, F. Gelsomini, K. Kanev, P. Bottoni, Tangible technology enhanced learning for improvement of student collaboration, Journal of Educational Technology Systems, Sage, Vol. 46(3), March 2018, pp. 284-302.