China Scholarships Council Project

PROJECT TITLE:
Ancient knots – Bringing together the complexity of real knots and mathematical knot theory

SUPERVISORY TEAM:

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PROJECT SUMMARY:

Knots are considered one of the first tools of humankind, and have been used in many different areas such as for making clothes, for sailing and fishing, for construction, in arts and craft and in medicine. In particular, surgical knots have a rich history in medicine and the development of their usage throughout the centuries has been well-documented. Learning how to make knots of varying complexities is part of the education of surgeons as their usage is an important necessity in surgeries.

Mathematicians have also investigated knots since the 18th century, especially in the area of topology. Recently, mathematical knots have also been studied by computer scientists, who develop algorithms to determine the similarity of different knots.

In this project, we will compare the complexity of knots from two viewpoints: a mathematical one and a historical and anthropological one, using the example of surgical knots. We will try to find alignments between the results from these two areas. In particular, we will define measures for the complexity and classification of knots that would be valid for "both worlds". We will use algorithms to classify the knots according to the defined criteria and determine whether the classifications coincide.

The research conducted in this project will start to establish the link between the historical development of surgical knots w.r.t. their structure and the complexity of their mathematical representation. The ultimate goal is to develop a phylogeny of known surgical knots. On the one hand, this will contribute to the development of algorithmic techniques for classifying mathematical knot diagrams. On the other hand, this leads to a better understanding of the variety of existing surgical knots and enhances various approaches in the education of knot-making. Furthermore, the systematic data- and computation-intensive research might lead to design of brand new surgical knots better suitable in real-life robotic surgeries, e.g., better one-handed-robot knots, simpler multi-handed-robot knots, faster and simpler knot-making techniques.

Especially for the data science community, we create an extensive benchmark library/ dataset of surgical knot diagrams in different dimensions and projections. Next to the dataset, we create a repository of algorithms visualizing and comparing the knot diagrams, animating optimal knot construction with one or multiple hands, designing evolution trees/ networks of knots.

KEYWORDS:
Knot theory, complexity, algorithms, crafting skills, surgical knots.

REQUIREMENTS:
Applicant should have a degree in mathematics, computer science, operations research or a related area. He/she should be open minded and willing to work on a multidisciplinary project that involves discussions with colleagues and using research methodologies from other disciplines, e.g., medicine, health science, history and anthropology.

RECENT PUBLICATIONS OF THE SUPERVISORY TEAM:

Berger, A., Grigoriev, A., Panin, A., Winokurow, A., 2017. Location, pricing and the problem of Apollonius. *Optimization Letters*, 11(8), pp.1797-1805.

Berger, A., Grigoriev, A., Winokurow, A., 2017. An efficient algorithm for the single facility location problem with polyhedral norms and disk-shaped demand regions. *Computational Optimization and Applications*, 68(3), pp.661-669.

Berger, A., Gross, J., Harks, T., Tenbusch, S., 2016. Constrained Resource Assignments: Fast Algorithms and Applications in Wireless Networks. *Management Science*, 62(7), pp.2070-2089.

Harris, A., Wojcik, A., Allison, R.V., 2020. How to make an omelette: A sensory experiment in team ethnography. *Qualitative Research*, 20(5), pp.632-648.

Harris, A., (2016). Listening-touch, affect and the crafting of medical bodies through percussion. *Body & Society*, 22(1), pp.31–61.

Approved by the academic department (DAD): Alexander Grigoriev