

Report on the outcomes of a Short-Term Scientific Mission¹

Action number: CA20111

Grantee name: Oana Andrei

Details of the STSM

Title: Evaluation and development of the Alk platform for enhancing students' algorithm design and analysis skills

Start and end date: 13/05/2024 to 20/05/2024

Description of the work carried out during the STSM

Description of the activities carried out during the STSM. Any deviations from the initial working plan shall also be described in this section.

This STSM was carried out to collaborate with Dorel Lucanu on investigating the algorithmic thinking skills fostered by the Alk platform.

The STSM provided the opportunity to carry out a literature survey on algorithmic thinking, identify algorithmic thinking skills in the ACM/IEEE curriculum guidelines, and work together on mapping them to the Alk platform for correctness proofs during algorithm design and algorithm analysis.

During the stay I have familiarised myself further with the Alk platform and the examples used by Dr Lucanu in published papers and the Algorithm Design course at the host institution.

One strand of work focused on understanding the Alk platform and rationalising to what extent its design principles and use helps enhancing algorithmic thinking skills. Algorithmic thinking is a central component of computational thinking [Wing, CACM 2006], essential for designing correct and efficient algorithms, and can be developed independently from learning programming [Futschek, ISSEP 2006]. Algorithmic thinking involves a range of cognitive skills, including decomposition and abstraction (describe, abstract, and decompose problem); designing algorithms; test solution with debugging (detect and fix errors), iteration (repeat algorithm design process), and efficiency optimisation [Lehmann, JMB 2023]. I have joined working on a paper on this topic, aiming to submit it mid-June.

Moving forward, I have conducted a comprehensive review of research papers on algorithmic thinking skills. This review, combined with the ACM/IEEE curriculum guidelines around competencies (as

¹ This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the GH for payment of the Grant.

knowledge, skills, and dispositions) and my expertise in competency-based learning, will guide the design of a competency framework for algorithmic thinking centred on ensuring correctness-by-construction. We have begun with using both Alk and Dafny on several small algorithm examples requiring correctness proofs as part of our research to validate this competency framework.

Description of the STSM main achievements and planned follow-up activities

Description and assessment of whether the STSM achieved its planned goals and expected outcomes, including specific contribution to Action objective and deliverables, or publications resulting from the STSM. Agreed plans for future follow-up collaborations shall also be described in this section.

The main achievements of the STSM are: (1) contributing to a paper on Alk's capabilities for enhancing algorithmic thinking (for submission to the Scientific Annals of Computer Science journal in mid-June 2024), (2) laying the foundations of a competency-based framework for algorithmic thinking, (3) identifying research questions to guide us in the immediate term as well as long term collaboration.

The integration of AI tools such as ChatGPT and Copilot for generating solutions to algorithmic problems requires strong code literacy skills to ensure correctness [Denny et al., CACM 2024]. While generative AI tools can rapidly produce initial solutions, learners must critically analyse and verify these outputs to avoid becoming passive consumers of potentially flawed or incorrect (pseudo)code. We have investigated the use of ChatGPT3.5 and ChatGPT 4o in conjunction with Alk to validate and prove the correctness of proposed solutions to given examples. This demonstrates how the Alk platform can help students understand and improve AI-generated solutions, while fostering design, decomposition, testing, and debugging skills in algorithmic thinking. While the latest ChatGPT performs better than previous versions, there are still issues (hallucinations) in its responses. This is something we will continue investigating on a wider range of examples of algorithmic problems and LLMs.

We will continue working together on the competency framework for algorithmic thinking using both Alk and Dafny. We will prepare a research study with rigorous methodology (including appropriate ethical application) to run with students enrolled in the Algorithm Design course at the host institution, a course taught using Alk by Dorel Lucanu and Stefan Ciobaca (with whom I have also had lengthy discussions during my STSM stay).