MAIED21

Workshop on Multimodal Artificial Intelligence in Education

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Preface

Learning is a complex multidimensional process that involves multiple sources of data. In current Artificial Intelligence (AI) in Education research, however, many modalities of data are neglected to a large extent. Traditionally, the AI-based systems designed for education, typically Intelligent Tutoring Systems (ITS), rely on click-stream data generated from computer interaction with a mouse and keyboard or screen interaction in the case of mobile devices. The variety of interactions, multi-sensor devices and multimodal data can provide a more detailed digital representation of the learner. There is an increasing interest in the data-driven educational research communities in multimodal and multi-sensor interaction methods as an opportunity. The physiological sensors can provide a wealth of information that can be used further to contextualise the learning performance or strategies [3]. The analysis of multimodal data for learning, however, poses a series of promises [2] as well as challenges [1]. Multimodal data have low semantic value and increasing complexity. For this reason, it is harder for human intelligence to scout for patterns and regularities in multidimensional datasets.

Existing studies using Multimodal AI for education approaches can be divided into two groups. The first group aims at extending computer-based learning activities with physical sensors for tracking learners' behaviour, including, for example, learner's eye-gaze, facial expressions or physiological responses such as heart rate or neural activation (e.g. [3]). The second group is concerned with tracing learning activities "beyond mouse and keyboard" which belong to the domain of learning of *psychomotor learning*, i.e. practical learning activities that require levels of physical coordination. This emerging research direction was grounded in the Special Issue "The Next 25 Years: How Advanced Interactive Learning Technologies will Change the World" of the International Journal of AIED [5].

In AI, there is a philosophical discussion on whether AI systems are set to augment human abilities or replace them entirely. This discussion carries over to Multimodal AI in Education, across the degree of intervention that the AI assumes in the learning processes and to what extent it is set to replace human support and feedback.

On the "Multimodal augmentation" side, the AI algorithms are used for finding patterns and regularities in the data, which are then communicated to human actors in the learning process. This approach is advocated by the "CrossMMLA" community – learning across physical and digital spaces using multimodal learning analytics, a particular interest group within the Society of Learning Analytics Research [4].

The "intelligent tutoring" aims instead to the automatic provision of automatic feedback using intelligent and autonomous agents has been a longstanding discussion and topic of investigation within the Artificial Intelligence in Education (AIED) community. Although only recently, the community has started to look into more diverse data sources alternative to learner-computer interaction.

With this context in mind, in this first edition of the International Workshop on multimodal Artificial Intelligence in Education (MAIEd 2021), we have com-

piled ten research studies that go from early stages of developments to present empirical studies where novel experimental designs, theoretical contributions and practical demonstrations. MAIEd 2021 took place on June 14th, 2021 and was run virtually in conjunction with the 22nd International Conference on Artificial Intelligence in Education (AIED 2021).

In particular, at the MAIEd workshop, we have discussed which scientific, state-of-the-art ideas and approaches are being pursued and which impacts we expect on educational technologies and education, targeting the intersection of these two fields of AI and multimodal interaction. We tried to advance state of art in theories, technologies, methods, and knowledge towards the development of multimodal intelligent tutors with the following workshop topics:

- Multimodal Intelligent Tutoring Systems or User Interfaces
- Multimodality in Augmented, Virtual, and Mixed Reality
- Multimodal Learner Modeling and Affective Computing
- Adaptive Feedback, Guidance, and Process in Multimodal Learning
- Artificial Intelligence for Learning Analytics
- Big Data-driven Visual Analytics for Learning
- Error detection and classification for multimodal data
- Cognitive Load in Multimodal Interaction with Intelligent Tutoring Systems
- Explainability, Trust, and Safety in Multimodal Intelligent Tutoring Systems
- Multimodal data for Self-Regulated learning

The website of the workshop can be found here https://maied.edutec.science/. A video recording of the event is avaialble upon request.

Contributions

A peer-reviewed process was carried out to select the workshop papers. At least three members of the Program Committee with expertise in the area reviewed each paper. As a result, ten submissions were accepted (out of 13 submissions), which discuss ideas and progress on several interesting topics, such as multimodal analytics for affective computing, multimodal intelligent tutoring, self-regulated learning, multimodal intelligence augmentation.

Jiang et al. investigate if an ITS gives supportive, empathetic, or motivational feedback messages to the learner to alter the learner's emotional state and detect the change.

Huang, Fridolin and Whitelock carry a comparative analysis of holographic intelligent agents by analysing nine 'Holographic AIs' characters. They derive various design dimensions and principles for future research.

Zhou, Wannapon and Cukurova explore self-regulated learner clusters' engagement behaviours at individual, group and cohort activities. Their study analyses the relationship between students' SRL competence and their learning engagement behaviours observed in multimodal data. The results revealed that students with different SRL competence clusters might exhibit different behaviours in individual, group, and cohort level activities.

Lim and Leinonen propose an experimental design for fostering creativity with AI in multimodal and sociocultural learning environments. In the proposed Creative Peer System, humans and machines learn from each other in a multimodal learning environment and develop original artefacts.

Ronda et al. focus on simulated teamwork practice and how multimodal data processing can be performed to identify if the arousal levels matched the teachers' expectations regarding the students' emotional situation in the different phases in which the teachers' teamwork practice can be divided according to the instructional design.

Yang, Cukurova and Porayska-Pomsta focus on dyadic joint visual attention interaction in face-to-face collaborative problem-solving at K-12 Maths Education. Their results indicate that the multimodal approach can bring more insights into students' problem-solving. In addition, they propose a method for capturing gaze convergence by considering eye fixations, eye blinks, and the overlapping time between two eye gazes.

Echeverria and Santos introduce KUMITRON, a multimodal psychomotor intelligent learning system that can provide personalised support when training karate combats.

Howell-Munson et al. move preliminary steps towards detecting proactive and reactive control states during learning with fNIRS brain signals. They distinguish between proactive and reactive control using fNIRS brain imaging in a controlled continuous performance task. They also propose integrating the fNIRS datastream with the ITS to create a multimodal system to detect the user's cognitive state and adapt the environment to promote better learning strategies.

Gupta et al. focus on multimodal and multi-task stealth assessment for reflection-enriched game-based learning. They present a stealth assessment framework that takes as input multimodal data streams (e.g., game trace logs, pre-test data, natural language responses to in-game reflection prompts) to predict post-test scores and written reflection depth scores jointly.

Lee-Cultura, Sharma and Giannakos propose a multimodal AI agent to support students' motion-based educational gameplay. The AI agent identifies and delivers appropriate feedback mechanisms to support a student's play learning experience. A Dashboard visualises the measurements to keep teachers informed of a student's progress.

Conclusions

MAIEd 2021 workshop aimed at gathering new insights around the use of Artificial Intelligence (AI) systems and autonomous agents for education and learning leveraging multimodal data sources. It built upon the CrossMMLA workshop series at the Learning Analytics & Knowledge Conference and called for new empirical studies, even if in their early stages of development. As a result, ten papers have been accepted for presentation at the workshop that consists of novel experimental designs, theoretical contributions, and practical demonstrations which can prove the use of multimodal and multi-sensor devices "beyond

mouse and keyboard" in learning contexts with the purpose of automatic feedback generation, adaptation, and personalisation in learning. Through the organisation of this first edition of the workshop, we sought to engage the scientific community in opening up the scope of AI in Education towards novel and diverse data sources.

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