Hand gestures during collaborative problem solving

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ABSTRACT
In this paper we present the need for analyzing (hand) gestures in learning environments and particularly in collaborative problem solving tasks. Based on experimental user studies, we analyze gestures and their impact on technology-based assessment, 21st Century skills as well as on collaboration and cognition.

Author Keywords
Gesture analysis; PISA; speech; tangible user interface.

ACM Classification Keywords
K.3.2 Computer and Information Science Education H.5.2. User Interfaces.

INTRODUCTION
Schaper et al. (2015), among others, regard embodiment as an alternative perspective in human-computer interaction (HCI). Gestures have been indeed analysed often in the literature, both from a philological foundation and also an HCI perspective. In the project Gestures in Tangible User Interfaces (GETUI) we focus on gestures on a specific application field of HCI: Tangible User Interfaces (TUIs). The term TUI has been established by Ullmer & Ishii (2000) as follows: "[TUIs] give physical form to digital information, employing physical artifacts both as 'representations' and 'controls' for computational media. We will also explore gestural interaction with TUIs in the context of technology-based assessment (TBA).

RELATED WORK
As far as gesture taxonomies are concerned, the most prominent philological taxonomy is that of McNeill (1992). McNeill (1992) categorized the gestures into *gesticulation*, *emblems*, *pantomimes*, and *sign language*. We focus particularly on *gesticulation*, i.e. hand-and-arm movements that are almost always accompanied by speech. A gesture taxonomy in HCI is created by Quek (1994); he classified meaningful gestures into *communicative* and *manipulative* gestures. Communicative gestures are meant for visual interpretation, whereas manipulative are not subject to such constraints. Moreover, Lao et al. (2009) defined *tapping*, *pressing*, and *dragging* gestures and showed that a variety of hand gestures can be constructed through these three basic movements.

MOCO'16, July 05-07, 2016, Thessaloniki, GA, Greece
ACM 978-1-4503-4307-7/16/07.
http://dx.doi.org/10.1145/2948910.2948913.

COLLABORATIVE PROBLEM SOLVING AND PISA
Collaborative problem solving is the capacity to recognize the perspective of other people in a group, participate, contribute knowledge, recognize the need for contributions, and build knowledge and understanding as member on a collaborative setting. Most of the research in TBA of collaborative problem solving skills dealt with the improvement of assessment of traditional skills (Binkley et al. 2012). However, the focus in the future should be on the so-called 21st Century skills. 21st Century skills encompass an array of competencies that can be classified into cognitive, intrapersonal and interpersonal skills (National Research Council, 2012).

The international large-scale educational *Programme for International Student Assessment* (PISA) is a programme that offers insights for education policy and practice. PISA is run by the Organization for Economic Cooperation and Development and is the most important and most comprehensive international large-scale assessment. Complex and collaborative problem solving was a major domain in PISA 2012 and 2015.

USER STUDIES

Setup
At the Luxembourg Institute of Science and Technology (LIST), a TUI realised as a tangible tabletop (75x120 cm) is used for the study. Physical objects, like widgets or pawns, can be manipulated on the table in order to explore different factors. The table provides visual feedback in real-time and displays the effects with changing pictures and animations. We recruited 60 participants between 15-18 years old through public schools in Luxembourg.

Task
The task of the participants is based on a microworld scenario; the three pupils are provided with physical objects that represent industrial facilities which produce electricity: a wind park, a solar park and a fossil fuel power plant. By installing the objects on the TUI, there are two parameters changing: i) the power generation and ii) CO_2 emission. The pictures depicted on the tabletop are accordingly adapted to the output values: a city has smog due to CO_2 emission. After an experimental phase, the pupils are then

asked questions to distinguish between the industrial facilities, e.g. which emits CO_2, which produces more electricity power, etc. Moreover, they are asked to reach a target goal, ca. 5,5 GW emitting maximum 2 million metric tons of CO2. In this case they discuss more and perform more gestures, resulting in more active collaboration. We follow the MicroDYN framework of Greiff et al. (2012), an approach for computer-based assessment of CPS based on linear structural equations.

Recognition and analysis

A multimodal corpus of video volume≈9 h and 200GB is currently collected. The Kinect 2.0 depth sense camera is used for recognition of the spatial position of the participants, proximity between users and between users and tabletop, and their gestures. It has been found in the past that the contextual social factors (age; proximity to other people) influence the choice of multi-touch gestures (Hinrichs and Carpendale, 2011). Julià et al. (2013) examined the gesture recognition and disambiguation on TUIs and created a framework which is device agnostic (multi-touch interfaces or depth-perceptive cameras) and does not enforce a specific gesturing technique or library for gesture recognition.

As for the manipulative gestures on the TUI, such as placing/removing, tracing, rotating objects, etc., they are logged by the light-weight and extensible software framework TULIP (Tobias et al. 2015) which uses an abstraction layer to receive information from computer vision frameworks, such as reacTIVision and a widget-model based on model-control representations (Ullmer and Ishii, 2000) to enable rapid application development.

DISCUSSION AND CONCLUSION

Within the project GETUI, experimental user studies with 60 participants are currently being conducted. The participants are asked to solve a collaborative problem solving task, similar to that of PISA. Our goal is to analyse the amount, frequency, and repetition of gestures and their impact on learning as well as 21st Century skills. A preliminary study (Anastasiou et al. 2014) proved that problem solving task on the TUI encouraged the use of rapid epistemic actions by lowering cognitive load by simplifying thinking processes. In this pre-study, the gestures were manually annotated, but the future goal is to reduce the time-consuming task of manual annotation through gesture recognition. However, this task is challenging for such a context, as there are many users crossing in front of others or placing hands on the top of other hand(s). We decided against sensor-based technologies, such as hand gloves, so that pupils do not feel constrained through the technology during their collaborative task.

For the current studies in GETUI, we developed an application that can automatically analyse object manipulation in real time with regards to *which object* has been manipulated *when*, *by whom* using *which hand*. Our application converts the TUI's screen coordinates to Kinect coordinates system; hence the location of all active objects is continuously controlled by the application to check that the hand coordinates of the participants fit with the objects' coordinates.

ACKNOWLEDGEMENT

This research is funded by the Marie Curie IF project *GEstures in Tangible User Interfaces* (654477).

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