MMLA in non-classical learning environments

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Abstract. Multimodal Learning Analytics is part of Learning Analytics in the field of Educational Data Mining and Academic Analytics. MMLA gained popularity when researchers wanted to study the physical environment with the digital environment. This opened many new possibilities to research as now one could consider various environments such as the classroom, the student's own room, and even virtual environments. Collecting data in such environments was a new challenge and required an array of sensors. Having just one sensor to capture all this versatile data would seem like the ideal solution. On top of that, if we were to consider collaborative devices, we would need sensors capable of collecting multiple types of data from multiple users simultaneously. In this paper, an analysis of using the Microsoft Kinect sensor as a replacement sensor for video, audio, motions, gestures, and emotions is considered. Further, we also consider the possibility of using the Kinect sensor with collaborative devices to gather data. One such device that we have considered is the multitouch table. Some ideas and benefits to using the Kinect with the multitouch table are also discussed. Finally, a brief overview of using the Kinect in virtual environments is also discussed and the possibility of having collaboration in virtual environments is also explored.

Keywords: Learning Analytics | Education Data Mining | Multimodal Learning Analytics | Microsoft Kinect | Multitouch tables | Collaboration | Virtual Environments | Computer supported collaborative learning

1 Introduction

In this section a brief overview about learning technologies and various learning environments is given. How multimodal learning analytics gained popularity in the research community and the various environments in which we can apply MMLA.

1.1 Learning Analytics and Educational Data Mining

Learning Analytics (LA) and Educational Data Mining (EDM) emerged when Massive Open Online Courses (MOOCs) and Learning Management Systems (LMS) gained popularity and people started benefiting from these platforms. The main purpose of LA was to improve the experience of learning and the main purpose of EDM was to better understand how students learn [1]. But then why the need for MMLA? Researches wanted to extend LA and overcome the limitations of just focusing on digital trace-based analysis methods.

1.2 Multimodal Learning Analytics (MMLA)

There are various definitions of MMLA during the past years. As said by Ochoa and Worsley, the main objective of MMLA is to study collaborative, real world, non-computer mediated environments [2]. MMLA can also be defined in the context that students act with both the physical and digital world [3]. Worsley in one of his papers also defined MMLA as an open-ended learning environment [4]. He discusses about SPBL (student designed project-based learning) and inquiry-based learning and construction. This goes to show that the field of MMLA is still evolving and holds a lot of promise for the future.

As shown below in Fig. 1. MMLA is not a completely different field from LA and EDM but it is a part of LA. It follows the same principles of LA and uses the same algorithms for analysis, but the differentiating factor is the focus on different types of data from a variety of sensors and considering both the physical and digital environment.

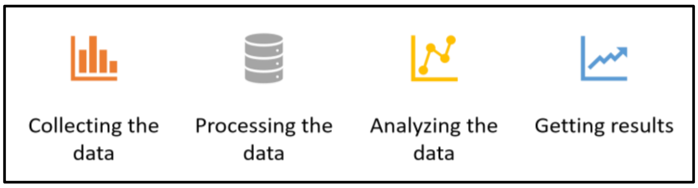

Fig. 1. Multimodal learning analytics

1.3 Definition of non-classical learning environments

The term non-classical learning environments gained trend when learning analytics and education data mining were gaining popularity. But to research on non-classical learning environments digital footprints were not enough. This led to the growth of MMLA.

MMLA and non-classical learning environments show a similar growth pattern. As video sensors, motion sensors and wearable technologies became popular and more importantly affordable, researchers wanted to study the impact of these new platforms on learning.

Fig. 2. Non-classical learning environments

As shown in Fig 2. Non-classical learning environments not only consist of virtual reality and augmented reality, but also multitouch games, multitouch tables and motions sensing. Sensors such as the Microsoft Kinect, VR headsets and simulation-based activities really helped push the domain of research into these environments.

1.4 Paper outline

In this paper we will be focusing on the non-classical environments and how sensors such as the Microsoft Kinect are being used to capture student's behavior. There are a lot of sensors that have been used in studies related to MMLA. The most popular ones are the audio and the video sensors. But now people have started using accelerometers, infrared sensors, motions sensors to name a few. This has led to tremendous amount of data being generated and the potential it holds for researches to use this data to improve students learning.

This paper will give an overview and analyze which sensors are best practices for non-classical learning environments. Furthermore, I will present an overview on how to use the Microsoft Kinect sensor with multi touch tables to get a better insight on users' behavior. To conclude, a discussion on the possibility of using the Kinect in virtual environments to study collaboration is shown.

2 State of the art research being conducted

This section highlights the sensors that are being used currently in the research community, describes the Microsoft Kinect in detail and talks projects being done with the sensor. Then multitouch tables are introduced with respect to collaboration and their importance in research in computer supported collaborative learning.

2.1 Sensors

A lot of research work and projects are being done at the Harvard LIT (Learning, Technology, Innovation) lab related to MMLA. However, gathering and collecting data for the projects remains a challenge. To overcome this, high frequency sensors as shown below in Fig. 3. (such as eye-trackers, motion sensors, wearables) have become affordable and reliable, thus opening new doors for capturing students' behavior [5].

Sensors gather data as time-based or activity-based (games, questionnaires, predefined tasks). The traditional approach is the time-based method which automatically collects data continuously or at predefined fixed intervals. Activity based data collection is data collected based on some event. This could be by means of games, or questionnaires and could be in some cases done without the use of sensors.

Educational researchers are now being able to collect significantly large amounts of data using these variety of sensors. An example of this can be the OpenGesture tool developed by Marco Worsley. OpenGesture is an open-source, low-cost, easy to author, application framework for collaborative, gesture, and speech-based learning applications. The platform is designed to enable students, teachers, researchers, practitioners, and parents to author innovative learning applications that are built on the cutting edge of human computer interface technology. The platform supports extensive opportunities to collect data about how users are engaging with the various applications [6]. This shows how easy it has become to collect data from all the various sensors available.

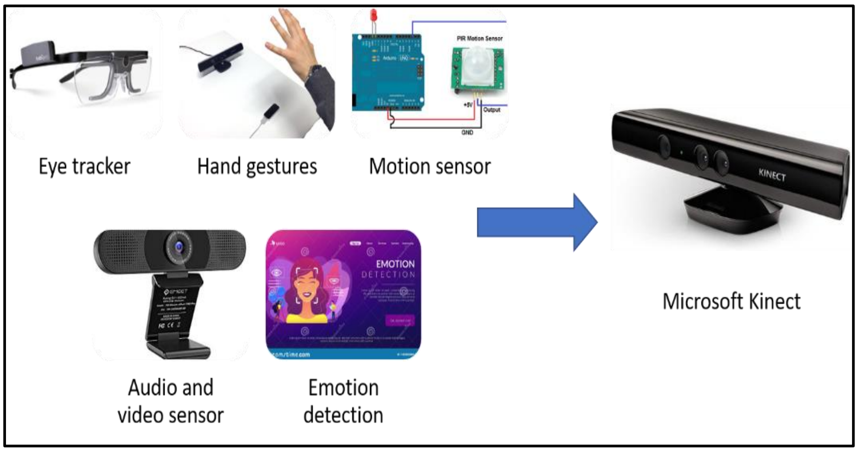

Fig. 3. Sensors

2.2 Microsoft Kinect

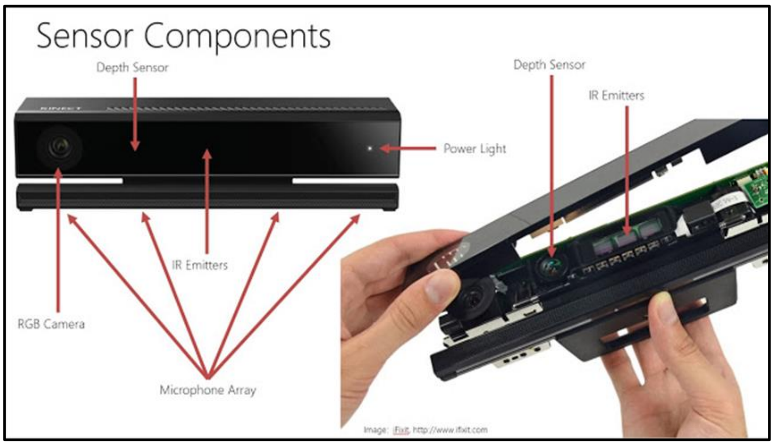

Fig. 4. Dissecting the Kinect

As shown in Fig 4 above, The Microsoft Kinect has multiple sensor components to collect multi modal data. The sensor collects information about a person's body joints (x,y,z coordinates), their facial expressions, and their speech at 30 Hz (i.e., 30 times per second). One can easily define approximately 100 variables that can be captured from the Kinect sensor [5]. A lot of projects have used the Microsoft Kinect as a tool to collect data.

Xinhao Xu in his research paper used Microsoft Kinect for a VR-based teaching simulation which enabled participants to project and embody real-time body movements and gestures onto their avatars in the virtual world. Specifically, it enabled embodied gesturing in virtual lecturing [7]. This shows that the Kinect is not only used for gathering data but now can be used to help create virtual environments for students to learn.

Another research paper by Noel Enyedy shows how to use the Microsoft Kinect cameras to track the motion of the students and feed it into a computer simulation, which depicts their movements as bees in the meadow [8]. This project was aimed at kindergarten students and to see if a virtual environment helps them learn and understand concepts better.

Referring to Fig. 3 the Microsoft Kinect can replace all the different sensors into one. For MMLA, the Kinect can be the one stop solution for the data needs and not only this, but it can also be used in virtual environments. Thus, for non-classical environments considering the Kinect is a smart choice.

2.3 Multi touch tables

When considering non-classical learning environments Multi touch tables also play an important role. They come under the umbrella of Computer-supported collaborative learning (CSCL) environments.

Fig. 5. Users collaborating on the multitouch table

Abro et al. defines multitouch tables in his research paper as follows; “Multi-touch tabletop displays provide a co-located collaborative workspace for multiple users around a physical table. They sit together and perform collaborative interaction to select and manipulate digital contents using their bare fingers.” This is shown in Fig 5 above. Multi touch tables use the Natural User Interface (NUI) that augments users to utilize their natural interaction capabilities to access the digital information as previously Graphical User Interface (GUI) facilitated the users to perform extraordinary interaction with computers as compared to Command Line Interface (CLI) [9].

Multi touch tables offer potentially valuable affordances to facilitate collaborative classroom learning by supporting group collaboration, direct face-to-face interaction and they allow to exploit the learning groups’ digital footprints [10].

3 Drilling down into the details

This part of the paper discusses the potential to use the Kinect sensor as a replacement for using multiple sensors for capturing the various data. Few projects are highlighted which show it is indeed possible to use the Kinect for this purpose but can also be used to study collaboration. Why multi touch tables are being used to study the gestures and emotions the users show when performing collaborative activities is shown.

3.1 Analysis of using the Kinect in MMLA

The Kinect sensor as a tool for gathering data is quickly gaining popularity for MMLA research. As shown below in Fig. 6 it helps to capture not only audio and video which are the two most used data for all research in MMLA but also helps in motion sensing and now researchers are also using it for creating virtual educational environments.

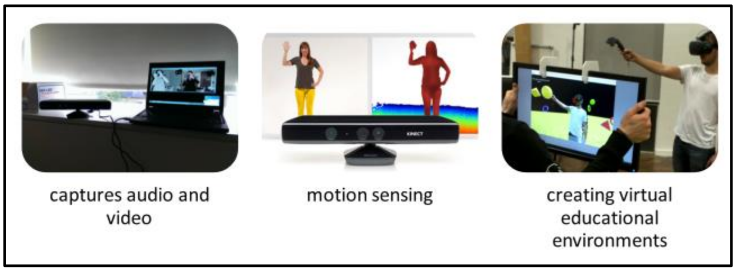

Fig. 6. Applications of the Kinect

Projects done using the Kinect

One of the projects by the Harvard LIT lab; *Augmented Electronic Sensing and Robotics,* used the Kinect along with physiological sensors for measuring learning, collaboration, and attitude change. This shows how student education of STEM concepts and processes can be enhanced by using these sensors and produce guidelines to help the design of innovative learning environments [11].

Another project by the Harvard LIT group; *Kinect Learning Analytics,* shows how Kinect can be used to study the collaboration between dyads (group of 2 people). The project is about the ability to rapidly assess and evaluate collaborative computational thinking tasks and focuses on measuring the quality of collaboration by analyzing participant movement and correlating a variety of measures with task performance and a coding scheme for assessing collaboration quality in dyads [12].

Looking at these projects we can see that there is potential to use the Kinect with CSCL devices, such as the multitouch tables, to better evaluate the responses and behavior of the users using the devices.

3.2 Findings

Researchers have used handheld devices, tabletop computers and multitouch tables to study how people think, perform, and analyze in a group. Multitouch tables for example are one of the devices currently being researched in the educational community for better understanding how users collaborate and achieve tasks together.

Multitouch tables in CSCL environments

In the paper by Martinez-Maldonado, Roberto; he explains how to capture multi-modal data about collaboration in a tabletop activity using a microphone array and a depth sensor [13]. Another paper by Martinez-Maldonado, Roberto; describes the design process to deploy multi-touch technology as a classroom ecology [10]. However, the paper further states that, having a classroom with multiple connected devices, sensors, a real time dashboard, lead to some interesting technical, educational and development challenges. Abigail C. Evans, states that in face-to-face group work at a tabletop, the computer can only access direct human-tabletop interaction, the verbal and gestural interactions that learners have with each other cannot be captured without the use of external sensors [14].

Considering these aspects and after further researching on the topic, multitouch tables are no doubt a great way for understanding and researching group collaboration but they are limited by only being able to access direct human-tabletop interactions. This is where the Kinect comes into play. It has the capabilities to capture multiple gestures at a time, recognize human interactions, can be configured to use face-detection, and has the potential to work in virtual environments as well.

4 Contribution

In this section of the paper, benefits of using the Kinect with multitouch tables is described. An approach on how to use the two together is shown and finally the potential to use the Kinect in collaborative virtual environments is highlighted.

4.1 Using the Kinect with Multitouch tables

Kinect can be a cost-effective, all-in-one solution to study the patterns observed when working in a group. Looking at the Harvard LIT projects it can already be seen that researchers have started using the Kinect to study collaboration [15].

Referring to the paper by Abigail C. Evans, adapting to support collaboration involves tackling several sub-problems:

1. detecting when a group is struggling?
2. determining when the system should provide support,
3. what sort of support it should provide?
4. and for how long [14].

These are the most interesting questions currently faced by the research community and using only multitouch tables, without external sensors, it will be quite some time before a solution is found. Therefore, it seems that the Kinect is a probable solution for the time being and maybe the one that can tackle all the sub-problems listed above.

If we consider the first problem of detecting when a group is struggling, using the face detection feature of the Kinect we can estimate when users are showing signs of frustration and to some extent conclude that the group is struggling.

For the second question of when the system should provide support we can use the motion detection feature of the Kinect, along with the audio sensor to see if the student request for help by either raising his hand or by detecting phrases like “this seems confusing to me", "I think I need help". Although this seems more of a natural language processing problem dealing with voice detection the Kinect is well equipped to cover the hardware aspect of this problem.

The next two questions are the follow up of the second question and require a software solution. To evaluate the response of the last two questions, the Kinect sensor can be used to detect the change in the emotions on the face of the users and see the change in gestures along with voice input to detect phrases which indicate that the problem is solved.

4.2 A proposed approach for using the Kinect with multitouch tables

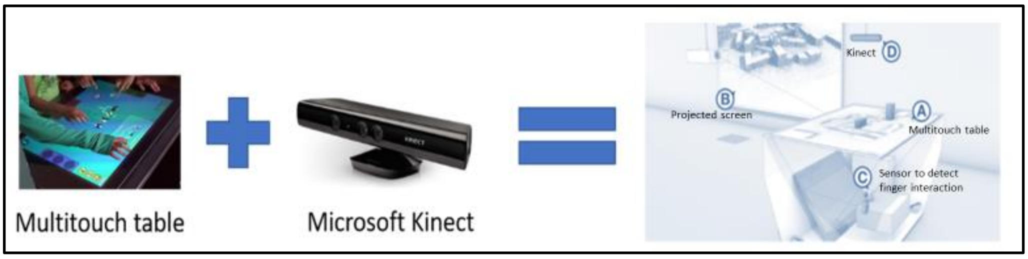

Fig. 7. Combing the Kinect with the Multi touch table

As shown above in Fig. 7. such an approach is possible where we combine the Kinect sensor with a multitouch table. The potential approach is taken from the research paper "Designing and Evaluating District Heating Networks with Simulation Based Urban Planning" by Bratoev in which he discusses the use of such a system for simulation based urban planning [16]. In Fig. 7. the labels are as follows: **A** - Multitouch table, **B** - Vertically mounted screen, **C** - Camera to anchor objects in the coordinate system to track movements of objects and fingers, **D** - IR depth camera to capture 3D geometry model of objects on the table.

It stands to reason that we can use a similar approach for MMLA in non-classical environments too. Using the Kinect sensors' camera and depth sensor, we can track movements of objects and fingers on the table and using the motion sensor, we can detect the user emotions. An explanation of how this works is given by Sebastian Anthony in his article [17]. He explains that the Kinect sensor analyzes the surface the user is pointing at which in this case is the multitouch table and works out how far away your fingers are and if they're the same distance as the table, the software knows you're making contact. The software can do this for any number of fingers (or other implements, such as pens/styluses).

With the data being gathered from the Kinect sensor we can then build models and apply different EDM techniques to interpret results from the data. Common techniques are same as machine learning techniques such as classifiers, decision trees and neural networks. Classifiers are commonly used to cluster body gestures to predefined gestures or to classify emotions. Decision trees and neural networks are used to evaluate sensor data which cannot be classified for example eye movement, student's attention etc. We can then derive interpretations from our analysis and improve the user experience of using multitouch tables.

4.3 Collaboration in the virtual world using Kinect

Another aspect for considering the use of the Kinect sensor can be the possibility to study collaboration in virtual simulations as show below in Fig 8. Xinhao Xu, in his research paper, showed that it is possible to combine the Kinect using a middleware interface with the OpenSimulator platform. In his experiment, the VR-based teaching simulation enabled users to project and embody real-time body movements and gestures onto their avatars in the virtual world. Specifically, it enabled embodied gesturing in virtual lecturing. His research paper shows that it is possible to implement VR-supported simulation in a physical co-located space and thus creating a hybrid space that allows users to engage in collaborative role-play in a virtual space through virtual avatar embodiment, while maintaining a real-world identity to do reflective and vicarious (or observational) learning of their virtual-world performance [7].

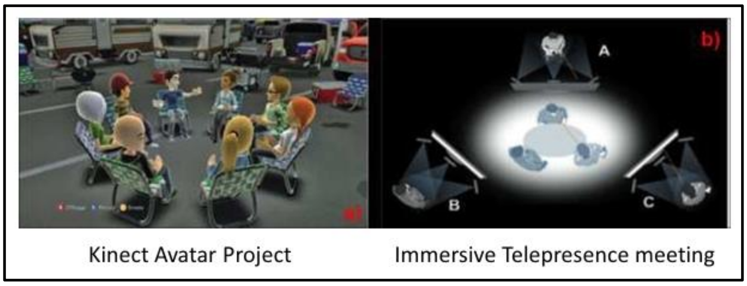

Fig. 8. Kinect simulated virtual environment

This shows that the Kinect sensor can become a major part of the CSCL environment and bring numerous benefits to the research in this field.

5 Conclusion

There has been continuous progress in the field of MMLA and researchers are investigating ways to study user's behavior in different environments apart from the classical digital trace-based scenarios. In doing so, the need for gathering and collecting data increased and researchers started using various sensors. Having to gather the data from each individual sensor is time consuming and significantly increases the workload. Using the Kinect as a replacement for all the most common sensors being used in MMLA right now is an efficient approach and as discussed above in the paper seems like the best choice.

When considering MMLA in non-classical learning environments we also must take into consideration the challenges of collaboration-based learning. Although there are various collaborative devices present, gathering data from these devices is done through external sensors most of the time. Again, this has the same problem that individual sensors are used to measure different entities independently. In the paper, the multi-touch table was chosen to highlight the advantages of the Kinect sensor to be used in replacement of the external sensors that are commonly used with the multitouch table. A proposed solution of how this would work is also presented in the paper.

Finally, discussion on applying MMLA in virtual environments is highlighted and how the Kinect sensor can be used in this scenario is explained as well.

Once the data is gathered, all that remains is to apply the various LA and EDM techniques to interpret results from the data. Either we want to cluster our results or classify them based on the type of sensor data. We can then derive interpretations from our analysis and improve the learning process.

6 Looking into the future

Using the Kinect sensor with the multitouch table can enable research in a lot of directions. One direction can be to incorporate the Kinect sensor with the multitouch table. This way the Kinect will not be an external sensor but a part of the multitouch table. Another direction can be using VR/AR technology to keep the users in different virtual environments and using the multitouch table in different scenarios. Another direction can be to completely make the environment virtual and the users make use of virtual multitouch tables and using various MMLA techniques we study this new approach.

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Fig. 2. Non-classical learning environments

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