Learning Science in an Intuitive and Fun Way Using Multi-touch Technology

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Abstract. This paper discusses the use of Tangible User Interface (TUI) systems to bring about a new era in Chemistry Education. The concept of integrating tactile and visual sensory information in an intuitive learning environment is explored. This learning environment encourages greater participation, and motivation to learn. Specific learning scenarios have been illustrated to explain how this application could be deployed in a real world environment. The development of a game environment, Virtual Atomic Model (VAM), is proposed to assist students to advance their understanding of the basic fundamentals of Chemistry Science in a natural and easily comprehensible manner. Use of a TUI is envisaged as an effective means to take abstract Chemistry concepts and present them to the student in a straightforward and comprehensible manner. Two software development environments are discussed as options for the implementation of this educational game concept.

Keywords: Tangible User Interfaces, Chemistry, Education, Virtual Atomic Model.

1 Introduction

Digital media is becoming more and more common in everyday life and it has been used widely for various purposes. Body gestures are a very natural and perhaps even essential element of how humans communicate and interact with each other. Human-computer interface research aspires to the “disappearance” of computers. By this we do not mean that we will not have computers, but rather that they will become “invisible” to us. Access to information from digital resources would be acquired through more natural modes of interaction, in an environment that is more natural and ”human”. Information technology has been changing dramatically, from typing commands like ”cd /” or “mkdir”, to computer screens with graphic user interfaces; but we still are required to slide a mouse, or to type things to provide the input and direction to the computer ... and these are hardly natural.

The latest technological breakthrough in using computers is user interaction, which is on the verge of a revolution. The next big transformation is that people will use computers by touch and by gestures. Graphical User Interfaces (GUIs) gave rise to a

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new mode of human-computer interaction, which provide a very practical replacement for the older command-line driven interfaces. More recently we find that Natural User Interfaces (NUIs) have made inroads in improving the experience of users, and now we may foresee a future in which multi-touch gesture technology provides a revolutionary way of interacting with computers, with new modes of use and new opportunities. It should be leveraged in the design of interactive design to replace typical mouse pointers in order to augment users' senses from direct interaction with the visual interface; Patten & Ishii [1], and Fitzmaurice & Buxton [2] have shown that TUI outperforms the standard keyboard & mouse interface [3].

In particular, information technology has become a central part of our every day lives and although we may not realise it, it has come to the point where parts of our daily activities are dependent on technology. Because of this, it has become important to pay attention to the needs of young students and their interaction with computers. These young students are part of an emerging user group who are learning to interact with computers from a very early phase. Lecturing is a typical and conventional mode of teaching at universities, however this mode of education is not effective in all cases at providing clear understanding of abstract ideas. Also, the mode of learning and perceiving the world is different to that of adults. There are cases where children require special motivation in order to use special learning tools, as compared to adults. Thus arises a new field of "Child-computer interaction". When creating technology for use with children, the idea of ubiquity arises quite naturally. Children interacting with technology in a manner that is so intuitive that one forgets its presence is ideal. This natural interaction can be achieved if it is based on an entity with which they are already familiar. This research focuses on ways of creating educational games in which children may use familiar and natural modes of interaction. This comes from a Learning-by-doing mode which is better suited to children, as researches have shown that children learn better when they are an active part of the learning process. Thus we find that children help us gain insight into building intuitive interfaces. The prototype, as well as being a examination of usability and design, is also intended to motivate and to engage them to play the game in a collaborative learning environment.

2 Background

In 1997 Ishii & Ulmer brought forth the concept of the Tangible User Interface (TUI), which was defined as augmenting the real world by combining digital data with real physical objects [4]. TUI allows computer interaction with physical objects by taking an everyday physical object and converting it into an input / output device for the computer interface [5]. By allowing everyday objects to become the mode of interaction with a computer, it provides a straightforward, natural, and flexible user interface [6]. After all, this is the natural way for humans to interact with the real world – picking up, rotating, and moving physical objects.

Thus we find humans do not need much by way of instruction on how to use TUI, as the interaction between the human and the digital world becomes seamless, effortless and intuitive [7].

2.1 Gaps

Existing science education is largely text book based and can have quite a bland way of presenting the subject matter (13). Flash card and quiz based learning systems also abound and are a modest improvement but still fail to captivate one's attention and imagination (12).

Within the normal learning environment a student deals with bland information and symbols that are difficult to understand. Being abstract, the student will often find the information difficult to relate to, as they do not share anything in common with their real world experience. Fjeld and his research group [14] developed the Augmented Chemistry system to compensate with the difficulty of learning the abstract organic chemistry concepts such as molecular forms. However, the comparative evaluation shows that it is not easy to learn the system compared to traditional "ball and stick" models since there are additional physical objects that have to be held by the learner.

The system being proposed here avoided the indirect manipulation of the virtual objects via a real-world counterpart, as this is a possible source of impediment and frustration in the learning process. The envisaged platform to be discussed in this paper provides direct interaction with the learning content. It is natural since users only need to use their familiar gestures to manipulate the Virtual Atomic Model (VAM). Hence, instead of students having to try and learn awkward and obtuse chemistry notation, they can, in the envisaged game, see how particles interact in a visual and easy to comprehend manner.

3 Aim

Much attention has been paid to leverage the design of interactive interfaces. The mouse input and desktop screen metaphors limit the information sharing for multiple users and also delayed the direct interaction for communication between each other. This paper proposes the innovative method by integrating game engine 'Unity3D' with multi-touch tangible interfaces. Unity3D provides powerful game development tools that are specially targeted at assisting users to focus on the task of building new games and 3D environments via its easy to use editor [9]. It creates Virtual Reality (VR) environments which can simulate places in the real world, as well as the virtual environments helping architects and designers to vividly represent their design concepts through 3D visualizations, and interactive media installations in a detailed multi-sensory experience. Stereoscopic displays advanced their spatial ability while solving issues to design e.g. urban spaces. The paper presents how a multi-touch tabletop can be used for these design collaboration and communication tasks. By using natural gestures, designers can now communicate and share their ideas by manipulating the same reference cooperatively using their own input simultaneously. Further studies showed that 3D forms are perceived and understood with greater ease via haptic and proprioceptive perception of physical forms, when compared to using visual stimuli only [10]. Based on the authors' framework the benefits of integrating 3D visualization and tactile sensory can be illustrated in this platform [11].

The VAM game play can potentially include: increasing levels of difficulty; competition to motivate students to excel and outdo their fellow students; co-operative play mode to allow friends to enjoy the game together, if they are not interested in out-competing each other; time-trial mode to increase the difficulty, pushing the student to think fast and put in an extra effort.

By giving the student an entertaining place to learn a student's interest will be captured, and they will be motivated to pay attention. The chemistry game that is envisaged will provide a fun and entertaining environment for students to learn about chemistry.

4 Concept

The Virtual Atomic Model (VAM) application to be developed provides a fun and entertaining environment for students to learn about chemistry. Students can learn practical information about chemistry, such as: the valencies of various atoms, eg. C^{4-} (Carbon) and H^{+} (Hydrogen); how atoms of different valencies interact, the various types of bonds that exist between atoms; the structure of various compounds, eg. CH4 is the structure for Methane; various reaction types, explosions, radioactive decay, equilibrium, redox reactions, etc.

4.1 Source of Inspiration

The application builds on a concept which is derived from an outdated and obscure game published in 1990 called "E-motion" by The Assembly Line (as shown in Fig. 1). The game E-motion places the player in a microscopic world in which the player bounces in to atoms, and manoeuvre atoms carefully in order to complete each task in the required time frame. A wrong move however can result in chaos (as atoms start reacting in something analogous to a chain reaction), thus adding to the difficulty of the game, and providing a challenge. Part of the games charm is that it is so unique, odd, and unusual. The game is somewhat addictive despite actually being quite a simple game in its structure.

As fun as E-motion may be, the authors of this paper would not describe it as educational in any significant way. Atoms exist and can be moved in the game, but here ends all similarity with real world atoms. The game fails to impart any actual useful knowledge about the behaviour of atoms and molecules, and focuses only on challenging the player with increasingly difficult scenarios.

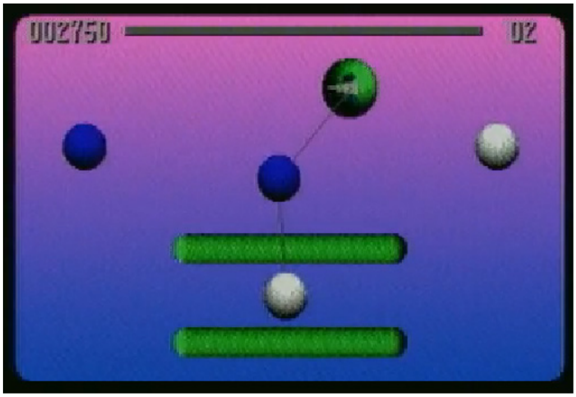


Fig. 1. The game E-motion [8]

4.2 Game Concept and User Interaction

In the envisaged game a user is presented with a task which they must accomplish in order to progress in the game (see Fig. 2 below). Here a user selects an atom using natural touch gestures by touching the desired atom and drags the atom over to a target molecule in order to create a bond. When atoms are joined to form a larger compound their valency information is updated on the screen.

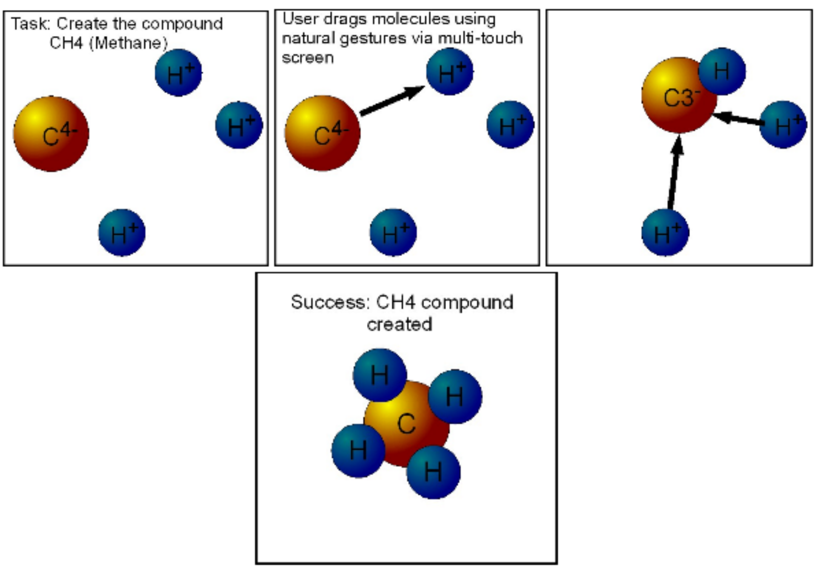
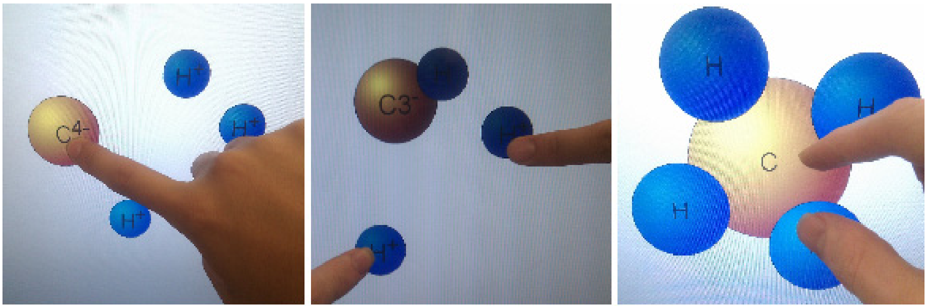


Fig. 2. User interaction with VAM

Multiple users as shown in Fig.3 may interact with the touch screen at the same time in order to move atoms around by using a dragging gesture as Fig.3.(a&b), and to zoom in and out, as in Fig.3 (c), by using a pinch gesture.



(a) (b) (c)

Fig. 3. Demonstration of user interaction with VAM

5 Implementation

5.1 Hardware Description

The following hardware options are suitable for our purposes: a) a multi-touch table; b) a normal desktop computer with a touch screen; c) an iPhone or Android phone. Flash and Unity3D are suitable development environments for hardware environments A and B. However if deploying to iPhone hardware then Unity3D must be used as the development environment.

5.2 Software Description

5.2.1. Development Environment - Option A: Adobe Flash

Benefits

Adobe Flash is a good choice here for the development environment as long as the choice is made to have a 2D only game. Indeed Flash is particularly well suited to creating fast, and fluidly animated 2D games that can be played in a web browser. Graphical objects can be easily created and modified within flash, thus making development simpler and more efficient. The action script programming language is quite easy to learn and not too cumbersome at all. It is easy to create and animate graphical sprites (game characters, atoms, and other moving screen objects). Creation of menus and buttons are also quick and straightforward.

Flash can run in a web browser on most operating systems such as MS Windows, Mac OSX, and Linux. This means that the potential user base is larger, a good thing from a commercial perspective. For experimental purposes this is useful too, as the experiment can be emailed to participants and completed at home using their personal computer.

Flash 10.1 supports multi-touch (15) allowing the creation of a game that allows the user to employ natural hand gestures. However, in order to use this multi-touch feature you must have the right operating system and hardware (eg. Windows 7 with touch screen, or Mac OSX 10.6 and a Macbook Pro)

Drawbacks

Adobe Flash is, at present, not well suited to the creation 3D games (the current version of Flash Player a the time this paper was written is v10.1). This is unlike Unity3D which was built from the start with 3D technology at its core.

The "iOS" operating system does not support Flash content in web pages. Adobe does provide tools to export Flash content to a format that is suitable for the iOS platform, but the game still would not run in a web browser on iPhones, iPads and iPods if built in Flash.

5.2.2. Development Environment - Option B: Unity3D

Benefits

Unity3D shares all the advantages of the Flash development environment, except that where Flash excels in 2D animation, Unity3D excels in creating 3D worlds.

Unity3D is capable of building, with relative ease, picturesque and compelling 3D worlds. Games built using the Unity3D development environment can be played via web browser, or on an iPhone or Android phone. Unity3D's easy to use 3D world editor gives a significant boost to productivity when building 3D environments, compared to having to hand code the entire world environment. Complex customised behaviours can be created using Unity3D's easy to use 3D scripting language.

Drawbacks

Applications built using Unity3D are comparatively large when compared to Flash games, due to the size of the 3D data and the Unity3D engine. This results in an increased load time due to larger application size, and greater complexity of the graphical world.

5.3 Choice of Development Environment

The authors of this paper have chosen to use Unity3D for our prototype since 3D technology is an important feature for our experimental purposes. Unity3D has: superior 3D support (fast rendering, easy to use 3D scripting, etc); has a built in 3D world editor; broader hardware compatibility (iPhone and Android support).

5.4 System Prototype Architecture

The prototype setup is described below in Fig. 4 describes the interaction between the student (actor), system hardware, and Unity3D. The student uses multi-touch gestures to interact with a device (eg. Multi-touch tabletop, or smart phone), the multi-touch gesture events are passed to Unity3D via TUIO (event handler and proxy). Unity3D takes the user input, and acts upon it according to the game logic and creates a representation of the 3D world database on the users device (visualization). The student, seeing the visualization in turn makes decisions, and uses gestures to signal this.

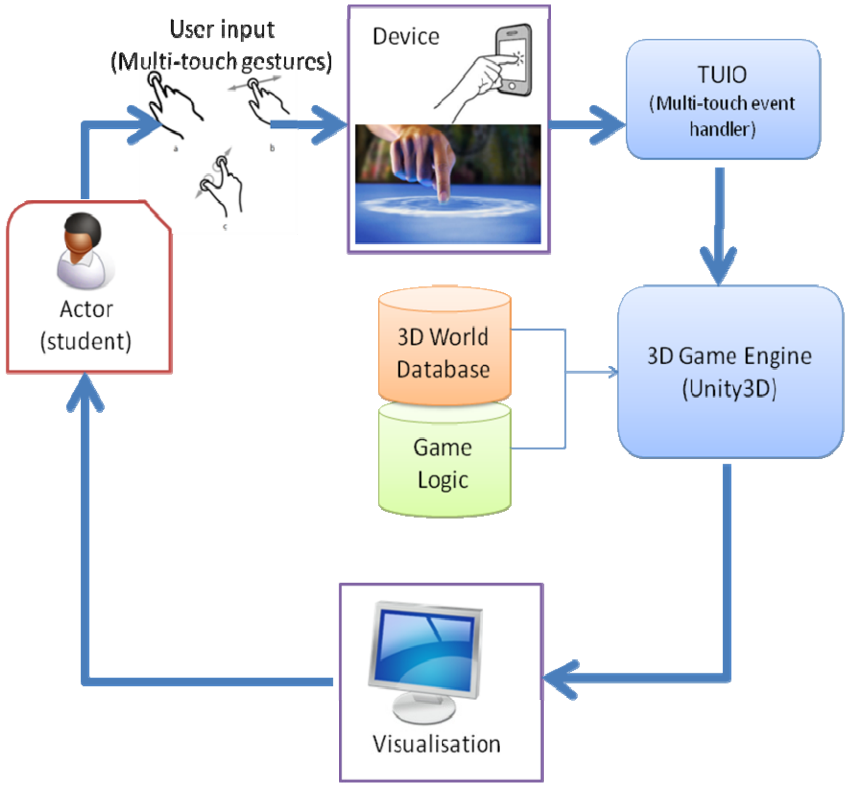


Fig. 4. Overview of system configuration and user interaction

6 Conclusion

The most fundamental point to come out of Tangible User Interface (TUI) systems is that the education sector is gaining significant advances throught the appropriate use of technology (including learning atomic models as has been demonstrated in this paper) and this is bringing greater satisfaction, retention and achievement. TUI systems provide learning environments which can facilitate learning in different domains, yet without requiring a greater footprint of the physical estate, and this is permitting education of a more diverse range of students. Students could learn anywhere and at any time, as is the case in ubiquitous computing, students can have the flexibility to learn anywhere and at any time using their mobile phones, netbooks, etc. The kind of high quality, accessible, flourishing higher education system sought by all is no longer possible without a deeper understanding of the abstract concepts in their course material. The proposed system provides a workspace for students to work either in the same or different locations. The tangible user interface can respond to the students with prompts, hints, and encouragement. This natural mode of interaction enables the students to learn more intuitively.

Furthermore, the TUI system endeavours to find new approaches for helping students to gain a greater understanding of science concepts, in which the computer enhances the learning experience without become a point of focus and distraction. With TUI technology the computer can "watch" as students work individually or collaboratively by sharing the same user interface. The TUI technology may become something like an assistant that provides the helpful motivation and encouragement that a teacher would. This acts on their natural cooperative spirit and their disposition to learn by doing. Such a system will not remove the role of teachers in education, rather it will help educators to motivate and encourage more students to learn cooperatively. If teachers are given the tools to create their own collaborative learning environments, then teachers will be further empowered in their role as educators.

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