AMT-based Real-Time, Inter-Cognitive Communication Model

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Abstract: 3D technology has made remarkable progress in the last decade, considering the commercial successes and the availability of the technology. In this study we put emphasis on physical 3D visualization, which opens up a series of new possibilities, through the continuous development of AMT. The aim of our research is to develop an AMT-based, two-way and real-time, inter-cognitive communication model, which can be an effective tool for managers in the physical visualization of business information and in the determination of target values using different (strategic, tactical, operational) time horizons.

Keywords: AMT; 3D printing; information visualization; real-time communication

1 Introduction

Observing the growth of technological development and available performance, the development of the area of different visual presentations is becoming increasingly important. Within this area, 3D technology has made remarkable progress in the last decade considering the commercial successes and the availability of the technology as well. The attention of the cognitive infocommunication (CogInfoCom) research is also turning toward vision, especially toward 3D visualization; by way of example, systems based on virtual reality (VR), [10, 11, 12], holographic displays [14] or additive manufacturing technology [17]. It can be observed that one of the most significant areas of the last years' cognitive infocommunication researches is virtual reality connected to three-dimensional visualization and its various application opportunities [4]. In these systems, with the usage of different display types, sound systems and sensors such a sight and sonority can be produced which are able to offer an experience to users as reality would be built-up from those things they can actually see and hear. Three-dimensional virtual data visualization tools are also promising research topics that can be found in CogInfoCom [16]. In contrast, in this study, we put emphasis on physical 3D data visualization, which opens up a series of new possibilities by the continuous development of AMT (Advanced Manufacturing Technology).

Our research is mainly connected to the cognitive data visualization topic of CogInfoCom, but also has connections to HCI (human computer interaction). An important object of CogInfoCom is the examination of connections and connecting possibilities among actors involved in the infocommunicational process [2]. According to the definition of CogInfoCom, a cognitive entity is the co-operating combination of people, tools and infrastructure [3]. Therefore, in the following we will interpret cognitive entity as a triplet, which contains human, hardware and software tools and infocommunications technology.

2 Role of 3D Visualization and HCI in Cognitive Infocommunications

Cognitive informatics (CI) is such a new transdisciplinary research trend crossing over scientific fields which examines the inner information processing mechanisms and processes using engineering applications [21] building on the fields of computer science, information science, cognitive sciences and human and artificial intelligence. The cognitive infocommunication examines the connection between the research areas of infocommunications and cognitive sciences, as well as, the various engineering applications emerged by the synergistic combination of these sciences [2].

One of the main goals of cognitive infocommunication researches is efficient information processing and transmission; the various 3D visualization and HCI applications are relevant parts of this. The combination of the human and computer communication focuses on the complex mixture of human and artificial cognitive capabilities in human computer interaction processes. The cognitive infocommunication researches investigate the person and its knowledge along with the computing environment and information processing devices complemented with corresponding relations [20]; these things are the reasons and requirements of the involvement of many scientific disciplines.

Among the various communication modes, in our study, we are focusing on inter-cognitive communication, where the information transmission is established between two entities who have different cognitive abilities; in this case between human and an artificial cognitive system. Whereas, we can say that the human (and his knowledge) and the tools which have computing capacity and suitable for information processing are being examined with their existing connections as a single cognitive entity. So our further goal is to examine these as a compact system. Human computer interaction and 3D visualization will have special roles in developing the communication model.

3 Technological Background of AMT

3D printing is a type of manufacturing technology, which is basically about building up the final object in three dimensions, layer by layer, using raw materials (usually called "filaments", but the raw materials can be composites, resins, metals, glass or polymers) melted at a high temperature. The official term is Additive Manufacturing Technology – the word "additive" refers to the way of the printing process; the printer builds up the target object from layer to layer. "Manufacturing" suggests that this is a repeatable, plannable, automated and systematic line of actions [15]. During 3D printing – unlike other manufacturing processes – there are no wasted materials, and considering the method as a whole, it makes possible a faster, more economic and more complex production. On the other hand, AMT is not for mass manufacturing; it is more similar to the way jewelers, sculptors or painters create their artworks. But while these artists have to learn for a long time, the basics of 3D printing may be acquired quickly and relatively easily.

During the printing, the machine creates the objects by the coordination of "blueprints", which are the design schemes of 3-dimensional models. These models can be created and modified via a design planning software known as CAD (Computer Aided Design), built up from polygons, which are digital mapping of 3-dimensional points in the space. The final objects are usually saved in STL (StereoLithography) file format.

Figure 1

Conceptual Model of 3D Printing

STL is the standard industrial file type of printable 3D models, which contains the printable object's cross section in a structure built up from meshes (slices) [9]. Despite the fact that the technology has been available for more than 30 years, there were numerous major progresses in the area in recent years.

As in the case of this process complexity does not influence time and material costs, it is capable of visually representing any type of data from the simple elements to the complicated, composite objects – without the shape restrictions of industrial fabrication machinery. There is no need for complex rework or assembly when the printing is ready, so this procedure is more efficient than other means of production [6]. The unbelievable flexibility of raw materials (which means that almost any type of materials can be used even with different surfaces) is an important factor, when data visualization is built up on physical touch.

The main disadvantage comes from the size; objects larger than the machine must be made in modular structure, from more parts. The combining process of colors and raw materials also requires a multistage manufacturing technique – however, many developments have been made in this area over the years and in the term of multi-material printers some significant innovations are being expected. These machines are able to print simultaneously from more raw materials, without changing them during the process [19].

Overall, there is a significant, but still unused potential in 3D printing (at least in this area), which makes the technology suitable for the quick and efficient presentation of information transmission, in a way where not only spatial visual opportunities but the potential in physical touch and perception also can be harnessed to the fullest extent possible.

4 AMT-based Visualization

Taking into account this rapid innovation, it is plausible that the future is obviously the extension of sensations and interactive communication. By now users require not only seeing, but perceiving, holding and going around the tools of their work or the subject of their interest.

If education is taken as the basis, several experiments prove that students can learn more easily if they can tangibly experience information instead of merely reading or seeing them projected [18]. The same is true for the world of work; especially in professions where high precision and good spatial awareness are required. It should be specifically mentioned that the expansion of this technology is most prominent today in medical and industrial applications; the benefits of additive manufacturing technology are increasingly applied in the areas of implantable prostheses, implants, industrial prototype construction and functional testing [5].

At the same time, we must not forget about our fellow human beings with disabilities – the world of a blind or partially-sighted person can be widened significantly, if he can access information through other senses. In the area of technologies entitled for the extension of perception there have been a lot of progress in the last decades, for example the “sonification”, designed for presenting, “amplifying” visual data and images [11]. Other inter-cognitive solutions like vibration (haptic) feedback – being used primarily in mobile phones – and the “force feedback” – which is present in computer game controllers for many years – are also entitled to make the user’s experience more complete. In this area real-time transformation, dynamic mapping and tangible/perceptible interactive communication would be a further step forward.

3D printing provides us such opportunities we could not have imagined before. Compared to the industrial limitations of today’s design methods, huge potential lies in the more complex – yet more efficient – customizable process of 3D printing.

However, even if the technology has been available for many years, and it is constantly evolving, there are still many challenges and limitations to overcome.

5 Real-Time Inter-cognitive Communication via AMT

The aim of our research is to work out an AMT-based, two-way and real-time inter-cognitive communication model, which can be an effective tool for managers in physical visualization of information and in the determination of target values by different (strategic, tactical, operational) time horizons.

5.1 Real-Time Analysis of Corporate Data

As a result of growing analytical business needs, data visualization solutions are needed to provide reports and analysis, based on the business needs, for company managers and is now widespread. According to the conventional approach commonly accepted today, these studies are not based on the most actual of data, as these are replicated from the transactional system to the data warehouse – which is the basis for the analysis – only at certain intervals (monthly, weekly or nightly). Another disadvantage of this solution is that strategic managers do not have the ability to react to the results through the communication between the two systems. Due to these reasons, there is a “semantic wall” between the two systems (Figure 2).

However, using novel, in-memory-based database management techniques, it is possible to serve OLTP (online transaction processing) and OLAP (online analytical processing) requirements from a unified system and we are able to process analytical needs in real-time. As a result, for example, a management dashboard with this technology always displays analysis based on actual data, which can be a serious business value in certain decision situations. Strategic managers are able to join into day-to-day operations through real-time analysis of corporate data instead of waiting for a project to finish or waiting for the update of the OLAP system to evaluate efforts and make changes for the next interaction.

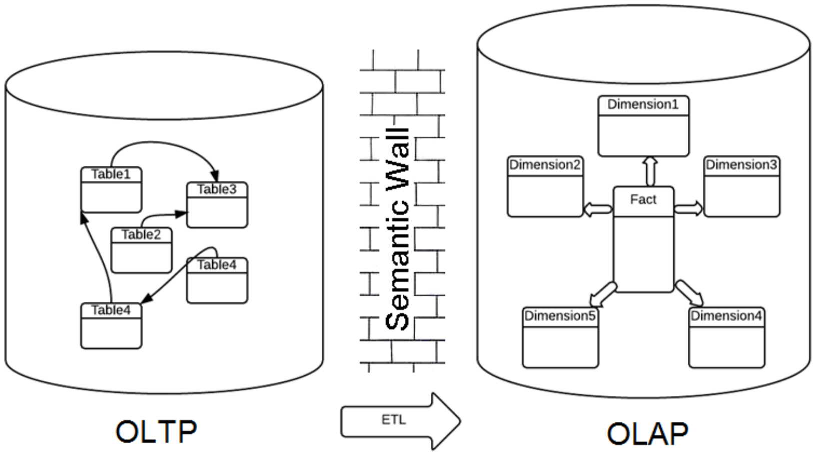

Figure 2
Separated OLAP and OLTP

5.2 Physical-Spatial Presentation of Information

Further key factor of the process we imagined, is the quick spatial and physical mapping of the previous (printed, drawn or projected) presentations of two-dimensional display units. This require a software and hardware environment which is able to map the real-time results of the analytical system immediately, in a tangible way, and continuously able to track changes that are updated by this analytical system. Of course, the process should include data conversion into a file format which is acceptable for 3D printers.

The raw materials we will use in the printing process have significant role in the model; the 4D printing technology is already under development and practically workable; it provides a new dimension for the process of 3D printing, which is time – it means that the object is able to change its shape after manufacturing. The main thing in this innovation is the production of flexible, memorable, shape-changing materials. Those objects which are produced by this way can be moved or changed; what is more, they are able to transform, change their structure, or fix their own failures and damages [1].

But for us, the most useful feature of these objects printed by 4D technology is that the given structures can take up multiple stable forms; these materials are able to respond to changing circumstances (for example temperature, humidity and touch) by changing their own configuration – and this might be a huge step forward in the case of interactive communication mapping.

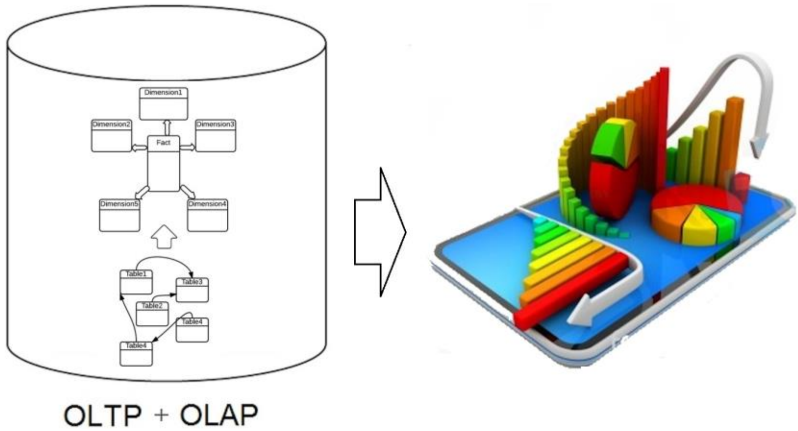

Figure 3
3D Printed Real-Time Reports

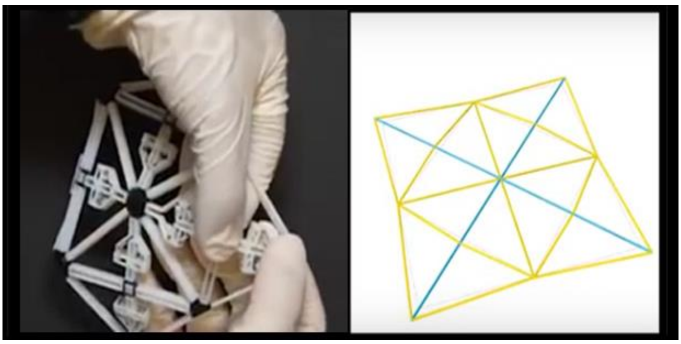

Figure 4
Flexible Object Created from 4D Raw Material

Moreover, the shape changing is a particularly fast process [7]. Thanks to the hydrogels used, with the impact of the heater medium, the change takes place within a few seconds and the printed objects are able to "multiply" their original size.

5.3 Updating Physical Visualization

The model is only viable if there is a surface which can generate and handle these changes. Maybe temperature changing appears to be the most reliable, so we are thinking about a platform, which – similarly to a chessboard's surface – consists of numerous separated fields – and these fields are individually heat-able or cool-able. There are a lot of methods for its technical implementation; because of its cost-effectiveness, easy accessibility and technological flexibility, the solution could be the integration of so-called "heat cells", which can be operated independently by microcontrollers.

In the model we envisaged that the temperature change needs for the shift of structure will be effectuated by Peltier-cells (semiconductor-based thermoelectric cooling cells). If DC input voltage flows through the terminals of the elements, one side heats up and the other side cools down. In practice, these modules are used among others, for soundproof cooling of microprocessors and electronic devices, as well as, in the construction of simple heating systems. The great advantage of this thermoelectric element – in addition to its relative small size (15.7 x 15.7 inches) – is the fact that it is able to warm up or cool down, according to the previously given configuration. Which is really important because in a real-time data visualization system the element performing the so-called "background work", the complementary activity cannot be, must not be the congestion in relation to execution time – in this case this element is the surface, which is able to change its temperature. This Peltier heat element can be placed on any smooth surface, and does not contain any moving parts, so their connection can be made easily and efficiently.

Figure 5
Peltier Heat Element

Because of the limited length of this study, we are not going to discuss deep technical details, but it is worth noting that the element responds to voltage change by changing its own temperature. The keys of the procedure are two counter-productive physical phenomena, the Seebeck and the Peltier effects. In a Peltier-effect device, the electrodes are typically made of a metal with excellent electrical conductivity. If there is a difference in temperature on both sides of the Peltier module, then the element generates electrical voltage because of the Seebeck effect; in that case it works in the thermos-generator mode. But if we apply electrical voltage to it, then – according to the Peltier effect – it works as a heat pump, and creates temperature difference [9]. For our model, the relevant point is the following: if we change the direction of the voltage, then the warm and cold sides are changed, and therefore it is able to produce the temperature-based control we need.

These elements will be connected in series during the practical implementation, and a chessboard-like, pre-defined matrix of any size will be created as a thermodynamic surface for 3D elements.

5.4 Management Interaction

In order to ensure a two-way, real-time inter-cognitive communication solution to corporate strategy managers, we have to provide feedback opportunity for the manager. In consequence, we have to make the created demonstration objects interactive; we have to reach that not only seeing or walking around, but changing them according to our demands also would be possible. By pressing of the given form of physically visualized data with appropriate force, the system is able to detect the shape change, and it will treat it as target value in terms of the given visualized data in the future. In this case the feedback means the input of the target value of the physically visualized information presented by AMT technology, on the basis of different time horizons desired by the management. Thereby, the feedback process specified by the human ensures the two-way inter-cognitive communication. Of course, after the specification of certain target values by physical impact, the chart will regain its original shape. This requires several conditions to be met at the same time. In our model the target object must be created per piece (with the coordination of the above-mentioned STL files, using AMT), ensuring that the moving of each piece would be able to provide an interactive experience.

As the printed model will be constructed from a material which is able to change its shape, in the case of physical pressure, the manager would convert certain presented data values to the desired target values. The monitoring of the shape change is ensured by sensors integrated into the physical model. Values recorded by these sensors will be stored and processed in the in-memory database.

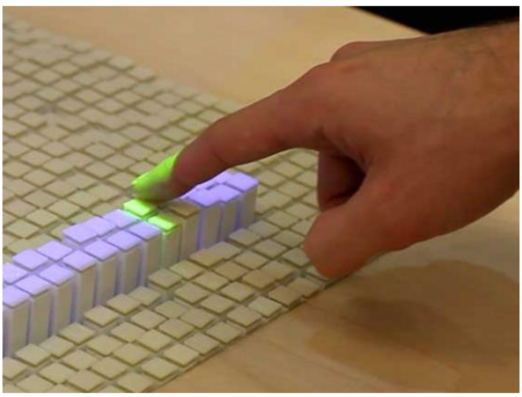

Figure 6

Tangible 3D Objects and Interaction

5.5 Conceptual Model of the AMT-based Real-Time Inter-cognitive Communication

Our model consists of four main elements. We need a business information system using an in-memory database management system for the sake of efficiency and fast data transmission – the aim is to transfer data in real-time. According to the pre-constructed analyzes and reports, we have to deliver a physical 3D printed model and refresh it at specified intervals. To achieve this goal for our physical model, we have to use the new generation materials. A surface, which is able to serve as the base of our 3D "display technology" is also required, built up from heat-able Peltier cells. And we will need a controller to change temperature, while the monitoring of the target values desired by the management will be ensured by sensors (these are integrated into the model). The sensors are constantly aware of the printed model's shape change initiated by the user, and these values will be forwarded and processed in the common OLTP-OLAP system. Data of shape change recorded by the sensors are interpreted by the system as target values of the appropriate time horizon (strategic, tactical or operative).

The elements and their connection are shown in Figure 7 below.

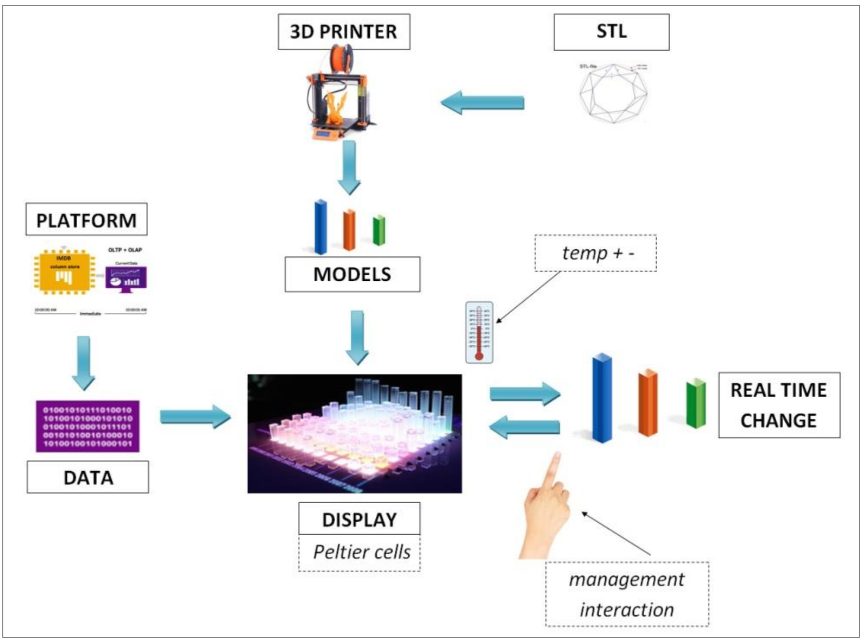

Figure 7
Real-Time Data Visualization System

Viewing the essence of the model, the process is quite simple; it uses the elements already discussed in the previous sections. Our objects are created with the coordination of STL files using new generation 4D raw materials by a 3D printer.

A platform, which is able to provide real-time data from the IMDB, transfers information to the controller. The controller sets up the temperature of each Peltier cells separately, based on the incoming data. Our models will respond to the temperature changes of the heat-able surface, by changing their shape.

Conclusions

In our research the cognitive entity is interpreted as a triplet that contains human, hardware and software tools and infocommunications technology. Looking at the entire picture of the research, we believe that the future is obviously the spreading of three-dimensional visualization – and not in virtual form only, but in its own tangible, physical reality. Visualization of information at a physical level can create novel solutions in many areas, including the field of strategic management that we have outlined. Expanding the three-dimensional capabilities of AMT technology with time, as the fourth dimension, provides additional opportunities for physical, tangible visualization. Complemented by the appropriate sensor technology, real-time AMT-based communication may be accomplished. To achieve this, the system we described herein can be an important step.

This subject, of course, requires further research. Our future efforts involve developing a functioning prototype, based on this work.

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