# A Conceptual Framework of Augmented Design

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**Abstract**: Technology development influences design in two ways. First, it accelerates the emergence of many new products, systems or services that are digitally converged and interactive. New artifacts are becoming complex, intelligent and interactive. There has been more emphasis on creating new user experience which is satisfactory and enjoyable. Second, the introduction of new technologies has also influenced the design activities. New tools are developed and influence the design activities. The changed activities are reflected in the creative design process. One of the emerging technologies that are highly related to design is augmented reality. Augmented reality (AR) is a field of research which deals with the combination of real-world and virtual reality. Many researchers try to create tangible virtual worlds or virtually enhance the real world for better human experience. The main design issue of augmented reality is how to achieve a seamless integration between the virtual world and the real world. It is also about enriching products and environments for people. Augmented Design is defined as enriching the design activity and enriching products and systems by new augmented reality technology for people. This definition is based on the fact that the term design is used as a verb and a noun. In a narrow sense, Augmented Design is considered as an application of augmented reality. Augmented Design is based on the philosophy that the technology should augment the human mind and ability instead of replacing human. Augmented reality technologies have been around for some time in the technology domain, but little is studied on the value of this in design. This paper presents preliminary results of the research focusing on a conceptual framework, a survey of related works on Augmented Design and the introduction of case study projects.

***Key words: Augmented Design, Augmented Reality, Design Method, Design Tools, Interactive Product and System Design***

## 1. Introduction

To apply design for human centered innovation of new technology applications, it is important to understand the relationship between design and the development of technology. As known from the history of design, when new technology emerges, the design profession also changes. There is no field like design that requires quick adaptation to such changes.

With the rapid development of new technology, designers are now dealing with new products and systems as their subjects of design. In the past, hardware goods like chairs, tables and kitchen tools were the main design

subjects. Designers are now involved in the development of complex products and systems, such as mobile phones, digital cameras and other interactive products in ubiquitous computing environments. The characteristics of the design targets changed from static and hardware centered to interactive, dynamic, intelligent and complex. Products are interconnected with other services and software systems. Designers no longer focus only on the style of the hardware devices. More emphasis is given to the creation of holistic user experience with new technologies.

On the other hand, new technologies have influenced design activities, processes and tools. In the industrial design field, designers have used sketches with pen on paper, foam models, clay models and so on, to explore and evaluate early concepts. With the development of the computer technology, CAD(Computer Aided Design) tools are used for realistic visualization of early concepts. Rapid prototyping systems are used to create physical models. Interactive simulation is used to show and examine the usability of digital products. These tools plays a critical role in the creative design process.

The relationship between design and the development of technology raises two important questions. How can we achieve better human centered innovation of technology applications with design? How can we apply new technologies for the creative human activities like design, so that we receive benefit from more innovative products and environments enriching the human condition?

One of the emerging technologies that are highly related to design is augmented reality. It is a field of research which deals with the combination of real world and virtual world. Augmented reality started in the computer science field when early computer vision technologies developed the way to overlay a computer generated digital image on a real image from a video camera. Azuma[1] explained a framework to understand different levels of augmented reality environments.

Many researchers try to create new augmented reality worlds for better human experience. The interests are growing rapidly as we face the introduction of ubiquitous computing, physical computing and tangible media. The boundaries between real and the virtual worlds are becoming blurred. Augmented reality worlds are often considered as tangible virtual worlds or virtually enhanced real worlds.

New worlds created by augmented reality are becoming influential to people's lives. Technology researchers have been interested in technical challenges to build the new worlds. Industrial interests are also very high because it opens new business opportunities by creating different but seamlessly connected worlds from our real worlds. Although there have been studies on augmented reality, considering the life cycle of the technology, it is now time to address more important questions such as how to enrich human life with augmented reality applications, and how to augment human perception with augmenting technologies.

Although technology researchers start to understand the value of human-centered innovation, there are still gaps between the technology developers and the designers who should advocate the users of the technology. Technology researchers tend to focus on technical aspects without paying much attention to human aspects. For

example, in the augmented reality field, researchers have focused on technological issues, such as visualization of augmented worlds. They focus on developing better hardware systems, such as HMD (Head Mounted Display), projectors, tracking devices and cameras for augmented reality. They also focus on software systems that provide more realistic, fast and efficient algorithms that combine the images of the real world and virtual world. On the other hand, many designers still focus on visual aspects of artifacts, such as styling and packaging. In particular, designers do not contribute much to the human centered design issues for augmented reality applications that are interactive, complex and interrelated with other systems. The difficulties are also caused by the fact that design is young as an academic discipline, so the knowledge base of design is not sound. Technology researchers and design researchers need to understand each other better. Interdisciplinary research is required to fill this gap.

The goal of this research is to investigate human-centered design methods to enrich people, products and environments for augmented reality technology applications. Two important research questions are how to augment future things for human and how to augment future creative activities of design. The research aims to suggest a direction of the development of future digital products, systems and environment in ubiquitous computing worlds. It also aims to develop the next generation of tools, methods, principles and guidelines to support creative design activities by applying augmented reality technologies. To address these questions, this paper presents preliminary results of this research focusing on a notion of Augmented Design, a survey of research works on Augmented Design and case study projects carried out by the author.

## 2. Augmented Design

Augmented Design is defined as a method to enrich people, products and environments for augmented reality technology applications. This term can also be a new interdisciplinary research field to be formed in design research. The definition is based on the fact that the term 'design' is used as a verb or a noun. If design is considered as an artifact (noun), Augmented Design implies products or systems to enrich people, products and environments. It can be a new augmented world that combines digital and real words. On the other hand, if design is considered as an activity (verb), Augmented Design means methods, tools and processes to support creative design activities. In a broad sense, Augmented Design deals with the issue of how to enrich people, products and environment with new augmented reality technology. In a narrow sense, Augmented Design can be understood as applications of augmented reality in the design field.

The concept of Augmented Design is based on the philosophy that the technology should augment the human intellect, mind and ability instead of replacing them. This philosophy is originated from the research work of Engelbart[7] who invented the mouse and other pioneering interactive systems. This philosophy is different from the perspective of automation and machine intelligence. Many researchers have been working to achieve human-like artificial intelligence, but the history of the technology development shows that the philosophy of augmentation is more promising. It is believed that the reason is on the human-centered approach of that philosophy.

## 3. Survey on Augmented Design

Considering the definition of Augmented Design, a survey of related work in design and related fields was conducted. Related research work on Augmented Design could be classified into four areas; human-centered design methods, the development of augmented reality technologies, the development of augmented reality applications in a new ubiquitous computing environment, and applications of augmented reality in the design field.

### 3.1 Human-Centered Design Methods

A number of publications emphasized the importance of human-centered innovation of technology applications. Norman [21] described the psychology behind what he deemed 'good' and 'bad' design through examples. He also offered principles of 'good' design. He exalted the importance of design in our everyday lives, and the consequences of errors caused by bad designs. Norman continued emphasizing the importance of understanding humans in his later publications, including 'Emotional Design'[23], 'Invisible Computer'[20], and 'Design of Future Things'[24]. In the book 'Designing Interactions', Moggridge[18] and his interviewees discuss why some products are successful implying the importance of human-centered innovation. He also describes the story of his own design process and explains the focus on people and prototypes that have been successful at IDEO, how the needs and desires of people can inspire innovative designs and how prototyping methods are evolving for the design of digital technology.

There is also some published work on methods to achieve human-centered innovation, in particular in the field of human computer interaction. These design methods are mainly based on structured user research. For example, Beyer and Holtzblatt [4] proposed the contextual design method with five investigation models including: flow model, sequence model, artifact model, cultural model, and physical model. Other related models and methods are Spradley's [30] nine major dimensions of social situation, Pena's framework[26] for information gathering, Owen's [25] Structured Planning, AEIOU framework for observation, which was developed by the Doblin Group and Chayutsahakij's [5] analysis matrix.

The previous work in this area illustrates success stories and stresses the importance of human-centered approaches in developing new technology applications. In this respect, this research is built on the established work in this area. Some methods and models are proposed to achieve human-centered innovation. However, most work remains conceptual and abstract. The work could not be related to specific technology applications like augmented reality and ubiquitous computing. It is necessary to develop more practical methods and principles that can be applied in the real design practice. It is necessary to make advances in this respect by developing methods, principles, examples and case studies.

### 3.2 The Development of Augmented Reality Technologies

This research tries to augment the world and people. Therefore the work is directly related to research work on augmented reality. According to Barfield and Caudell [3], augmented reality is defined by a system in which a participant wears a see-through display (or views video of the real world with an opaque HMD) that allows graphics or text to be projected in the real world. Other modalities can be included in augmented reality and information can be subtracted from the real world using augmentation.

Augmented reality systems date back to the work of Sutherland[31]. Sutherland's work also fed virtual reality, where advances were made at a more rapid pace, principally due to limitations in augmented reality technology and requirements for fielding systems. Augmented reality emerged as a separate research program in 1990 when a team from Boeing created a prototype system for supporting aircraft wiring. Augmented reality systems have distinctive features that characterize their functionality. Barfield and Caudell [3] and Azuma et al. [2] describe these functional characteristics; blending the real and virtual in a real environment, real time interactivity, and 3D registration of information. Recently many researchers have studied technical issues that make more complete augmented reality world. These issues include tracking, computer graphics, displays, and packaging among others. Tracking is a major area of interest with respect to outdoor tracking methods, improvements in tracking precision, and techniques to take advantage of outdoor features. Computer graphics research generally involves rendering quality and lighting models that better match the dynamic range of the real world. Display technology programs involve packaging and accommodating variations in lighting and user needs. Packaging covers all areas of augmented reality, but is particularly focused on computing, data transmission, and power. Augmented reality is also able to leverage technical advances in other fields, such as virtual environments. Augmented Reality can also leverage methods for evaluating human performance from the human factors field.

Some work has tried to evaluate augmented reality's ability to enhance human performance. While some researchers have been oriented to perception, others have begun to look at cognitive and task performance in more realistic settings, characterized by the task and the variability that might be encountered in the real world. For example, Neumann and Majoros [20] illustrated that properly structured augmented reality offers the opportunity to reduce the user's cognitive load by extending the human sensory system and information processing. This research project shares the technological basis on augmented reality. The focus is however on human centered applications. Therefore the result will be complementary to the established work in this topic.

### 3.3 Visioning a New Ubiquitous Computing World

Augmented Design is also related to research work on the new world where the boundaries between virtual and real worlds become blurred. Augmented Design integrates the two worlds and tries to create meaningful and enjoyable human experience for everyday life and design activities.

Early work in this concept is the vision of 'ubiquitous computing' proposed by Weiser[34]. He predicted that computing would go beyond the desktop paradigm and begin to permeate our everyday environment. As microprocessors continued to get smaller and more powerful and networks became more prevalent, it would provide new opportunities for computing to become part of our everyday physical environment. Computing would no longer be confined to a virtual desktop accessed via a keyboard and a mouse. Instead, it would be embedded everywhere and in everything. Other work followed the idea of Weiser's vision. For example, Ishii and Ulmer[14] proposed Tangible User Interface (TUI) which is a type of user interface that uses physical form and physical attributes as a way to help people understand how to access, grasp and manipulate intangible digital information. Tangible interfaces provide physical handles to digital information by building on people's intuitive understanding and expectations of how physical objects operate in the real world.

One outstanding research project creating a new augmented world is 'Equator'. It is an interdisciplinary research project, supported by the EPSRC. It focuses on the integration of physical and digital interaction. The name, Equator, symbolized an ideal: the ability to cross the border between physical and digital experience without a thought, thereby enabling each environment to complement the other, as equals in a kind of dynamic balance. The ideal aimed at by the Equator project is in a similar track with this research project because one of the principles of augmented design could be to achieve a seamlessly integrated world for products, environments and humans.

A number of works have been published to create a new vision of augmented world. The applications are wide from personal mobile devices to architecture. The established work tends to focus on particular aspects of interaction between people and technology. These include impact of physicality and human sensation of the augmented world. Further investigation is needed to develop general methods and principles to create a humane augmented world.

### 3.4 Application of Augmented Reality in the Design Field

This research is directly related to the application of augmented reality technologies for design activities. The ongoing research work has focused on prototyping phase of design, often described as interactive augmented prototyping. It is believed that prototyping have a significant influence in a design process. In the design process, the act of creating visualizations is as important as its result; often new solutions emerge during this process. In the literature, a number of models are described, including sight models, cardboard mockups, working prototypes, and so on [12]. The prototypes are considered to act as a tool in the reflective dialogue between designer and artifact [28]. Furthermore, prototypes have an integrative character. The sense of engagement [16] seems to play an important role in creation and evaluation of prototypes [29]. Geurer[10] presented the four objectives of prototyping; exploration, communication, verification and downstream process specification.

The concept of augmented prototyping employs augmented or mixed reality technologies to combine virtual and physical prototypes. While creating product models with an embodied/tangible, high level of engagement can take place in the design process and can address four objectives of Geurer's work. In literature, a number of augmented prototyping systems have been found. For example, Built-it [27], 1998) and URP[32] were designed for architecture planning. These systems allow designers to interactively simulate different layouts of building plans and to support collaborative reviews with tangible control blocks in a augmented surface. Some systems were developed for automotive design [9] while others were for digital products and information appliances[19,33,13]. Augmented prototyping systems were often developed for CAD activities. [8,6]

There are also tools to support creating new design concepts of augmented reality applications and the ubiquitous computing world. ARToolkit is a software library for building augmented reality applications [15]. It uses computer vision algorithms to solve tracking and virtual image overlays on real images. The ARToolkit video tracking libraries calculate the real camera position and orientation relative to physical markers in real time.

This enables the easy development of a wide range of augmented reality applications. There are also similar extensions of ARToolkit for designers such as DART[17] and Flartoolkit [35].

Effective prototyping of physical interaction for designers is also important for creative design activities. Phidgets[11] are a system of low-cost electronic components, sensors and software library designed for this purpose. It helps designers implement physical representations of graphic user interface widgets. Arduino[36] is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments.

Established work remains in presenting a sub-optimal palette of devices and software that require a lot of tuning and craftsmanship. It fails to deliver optimized solutions for enriching design activities. Yet even in ideal technological situations, its adoption is disputable due to a lack of clear investment/turnover rules of prototyping in general and a lack of familiarity with the opportunities of mixed reality systems.

## 4. Case Studies

Case studies have been carried out by the author to show how the notion of Augmented Design can be applied in design. The projects can be classified into three sub-categories; i) designing new augmented products, ii) developing augmented design methods and tools to support early design activities; iii) augmented interaction techniques.

One of the augmented product systems is ARpost. It is an immersive tour experience system. It resembles a coin operated telescope that can be found in conventional tour sites. However, unlike the conventional ones, the users can see live scenes of history that are augmented on the current scenes through the AR post telescope. (Figure 1) The tourists can lively experience the historical scenes that occurred at the tour site, as if the tourist had travelled to the past.


Figure 1. ARpost : an immersive tour experience system

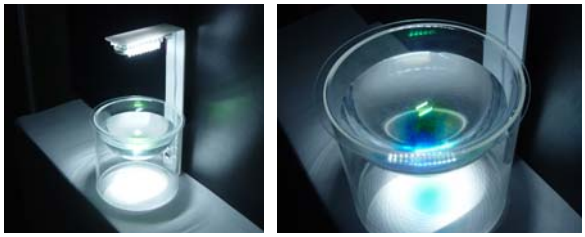

Figure 2. Liquid Music Therapy: Example application
of augmented reality and tangible interaction in product design

On the other hand, the core feature of augmented reality, seamless integration between virtual and real worlds, can create many interesting design applications. One of these example applications applying augmented reality and tangible interaction in product design was LMT(Liquid Music Therapy, Figure 2). The main concept of LMT was to combine a mood lamp, a device for aroma therapy and a media player. The device generates music and scent to make people relax biased on colored liquids dropped into the water of the device. Music and light for relaxation are automatically composed and played back according to the dissolution of the aroma liquid.

Squash-Art is another example of augmented reality application that was designed and patented to enrich a sports activity, squash play (Figure 3). Users can enjoy interactive art experience while playing squash. The location of the ball is traced and artistic visual effects are generated by a special sensor combined video projector.

Figure 3. Squash-Art combines sports and artistic experience(left) and a projector system(right)

Augmented design tools and methods includes ARBIS(Augmented Reality Based Integration System), STCtools and MIDAS. ARBIS is a designers' workbench to effectively integrate the hardware and software in the early phase of the design process. ARBIS provides new prototyping methods that allow digital product designers to effectively integrate the hardware and the software of the products from the early phase of the design process. The integration is accomplished by accurately overlaying a virtual display onto a quickly made functional hardware prototype using two AR techniques; i) using a video see through HMD (Figure 4 right) and ii) using video projection(Figure 4 left).

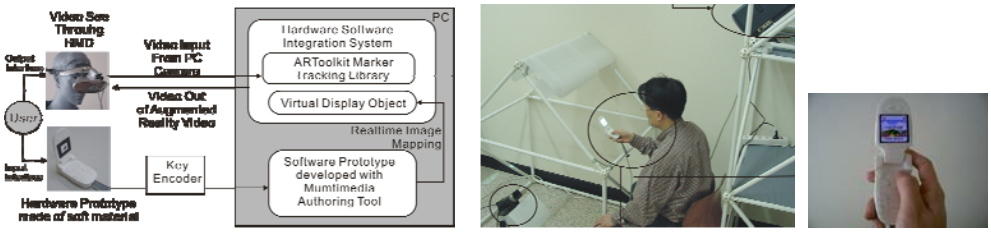


Figure 4. ARBIS(Augmented Reality Based Integration System) using a video see through HMD (right) and using video projection(left).

STCtools is a platform in which interaction designers can effectively and rapidly develop tangible interactive prototypes by sketching (Figure 5). The key concept of STCtools is to support effective sketching of state transition for designers' card sorting, scenarios and storyboards generation.

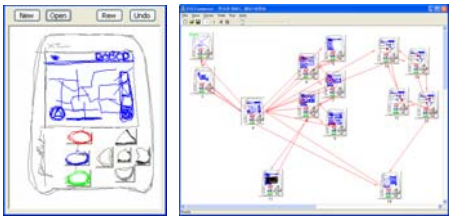

Figure 5. STCTools. Sketch based interactivity prototyping software solution

MIDAS is a design tool to support easy implementation of tangible media and augmented reality for designers and artists. MIDAS provides easier ways to manage external input and output and to support augmented reality with vision processing functionalities within typical multimedia design authoring tools, such as Director and Flash. This has been successfully used for design education and practice for several years.

An example of augmented interaction techniques is Spray modeling and Augmented Reality based shared 3D workspace. Spray modeling is an augmented reality based 3D spatial interaction technique. It employes physical sensation and a metaphor of air spraying for spatial interaction. In the research of augmented reality based shared 3D workspace, two new interaction techniques, Sync-Turntable and Virtual Shadow were developed and evaluated to support tele-presence in design review meetings. (Self-Citation will be added in the camera ready version of the paper)

## 4. Conclusions

This research attempts to lay down a new conceptual framework of Augmented Design. Although the idea is based on the philosophy of augmenting human intellect and earlier work on the applications of augmented reality technologies, the knowledge basis on this topic is not sound. The design discipline is young as a structured academic discipline. Sometimes the research outcome, for example the principles and guidelines of Augmented Design, can be difficult to generalize. The methods and principles to achieve human centered innovation may not be easily linked to proven ideas of evidence. In addition, it is also difficult to clarify the appropriateness of the framework and evaluate it. This problem comes from the nature of design research of this kind. Action research is situation specific. The ideas proposed in this paper can contribute to generating new design knowledge. This research also contributes to the development of design research. The Augmented design principles, methods, tools and systematic process model for human centered innovation of technology applications can be a good example of scientific basis on design knowledge. This is also very important for practice and education. This can contribute to the knowledge archive and transfer of other areas involving creative activities.

The life cycle of technology development is highly related to this work. In particular, implementation of augmented reality applications for a variety of human experience should be done in an effective manner. Emerging technologies such as tracking sensors, display hardware, solution solutions should be studied further to keep up to date the state of the art prototyping technologies.

This paper presented preliminary results on Augmented Design. The conceptual framework, the methods and principles should be further explored to show how to use design to enrich people, products and environments. These can also be studied to examine practical impacts of the methods on the innovative product design and development process.

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