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# Augmented Reality: Which Augmentation for Which Reality?

**Emmanuel Dubois[1,2], Laurence Nigay[1]**

(1) CLIPS laboratory, CHI research group,
BP 53
F-38041 Grenoble, Cedex 9

(2) TIMC laboratory, CAMI research group,
IAB, Grenoble University Hospital,
F-38706 La Tronche, Cedex

**ABSTRACT**

In this paper, we first present a brief review of approaches used for studying and designing Augmented Reality (AR) systems. The variety of approaches and definitions in AR requires classification. We define two intrinsic characteristics of AR systems, *task focus* and *nature of augmentation*. Based on these two characteristics, we identify four classes of AR systems. In addition our OP-a-S notation provides a complementary characterization method based on interaction. Using OP-a-S, an AR system is modeled as a set of components that communicate with each other. One crucial type of OP-a-S component is the Adapter that establishes a bridge between the real world and the virtual world. By defining a classification scheme, we aim at providing a better understanding of the paradigm of AR and at laying the foundations of future design principles according to the class of systems.

**Keywords**

Classification. Interaction characterization.

## INTRODUCTION

One of the recent design goals in Human Computer Interaction has been to extend the sensory-motor capabilities of computer systems to combine the real and the virtual in order to assist the user in performing a task in a physical setting. Such systems are called Augmented Reality (AR). The growing interest of designers for this paradigm is due to the dual need of users to both benefit from computers and interact with the real world. A first attempt to satisfy this requirement consists of reproducing the real world in the computer model and placing the user in this synthetic world (Virtual Reality, VR). Another approach consists of augmenting the real world with computerized information: This is the rationale for AR. Instead of reconstructing the real world, AR systems aim at augmenting it with additional computerized information. To do so several approaches are adopted:

- Adding 3D graphical information to the real world [1]
- Adding audio-information into the real world [2]
- Using force feedback, as it is argued in [3], is another possible method to augment the user's capabilities for interacting with the real world.



However, there is currently no consensus either on a precise definition of AR or on a design space. Consequently, the design of AR applications cannot currently refer to guidelines or AR-generic design principles. Every application domain of AR relies on its own methods and rules, if any. That is for example the case in Computer Assisted Medical Intervention (CAMI) domain. A CAMI system "augments" the physical world of the surgeon (the operating theater, the patient, the tools etc.), by providing pre-operative information including ultra-sound images, scanner and pre-planned strategy. In this domain, the classification and corresponding design principles are mainly based on the technology employed to design the system [5] and does not take into account the interaction between the surgeon and the system.

For a common understanding of the AR paradigm and for the establishment of design principles independent of the application domain, we identify here four classes of AR systems. We have defined these classes of systems on the basis of their intrinsic characteristics identified by first studying CAMI applications [4] and then different AR applications [1]. Coupled with the classification scheme, we also propose a notation for modeling an AR system at the interaction level.

## FOUR CLASSES OF AR SYSTEMS

We have identified two characteristics of AR systems, namely *task focus* and *nature of augmentation*, that enable us to define four classes of systems.

### Task Focus

The focus refers to the object involved in the user's task. Let us first consider the MIT "Media Blocks" project (tangible user interface) [5]. The user manipulates bricks to act on documents or on the menu of an application. The object of the task is thus the multimedia document or the application running on the computer. Consider now the Augmented Museum [6]. The user of this system wears a see-through head-mounted display, in which information about an exhibit is displayed. The user is thus able to perceive real objects (the exhibit) and added synthetic information. The object of the task here is the painting of the exhibit. Therefore, the task focus belongs either to the virtual world or to the real world. Indeed the user is performing a task in order to manipulate or modify:

- an object of the virtual world: Task focus = **virtual**,
- an object of the real world: Task focus = **real**.

### Nature of Augmentation

The augmentation provided by the system can take on a number of different forms. For example, the MIT "Media Blocks" system allows the user to act in a new way on the application: Instead of using a mouse or keyboard, the user manipulates a real piece of wood. A new interaction modality based on real objects (wood cubes) is provided to the user for acting on multimedia documents. In the "Augmented Museum" system, the user can perceive new information, unavailable in the world of the object of the task. Visual perception of the user is no longer limited to the real world. If we refer to the Theory of Action [7], augmentation can therefore be dedicated to the execution phase (action) and/or to the evaluation phase (perception). Consequently, the nature of augmentation can be:

- **Execution** (the user's actions): The number and/or the quality of tasks, that the user can perform, are increased.
- **Evaluation** (the user's perception): New or more realistic information is provided to the user.

### The Four Classes

The two characteristics, *task focus* and *nature of augmentation* define two orthogonal classification axes. Combining the two values of *task focus* with the two values of *nature of augmentation* leads us to define four classes, as illustrated in Figure 1.

| **Nature of Augmentation →** **Task Focus ↓** | **Execution** | **Evaluation** |
|---|---|---|
| **Virtual Object** | (**1**)Media Blocks | (**2**)Realistic Graphics |
| **Real Object** | (**3**)DigitalDesk | (**4**)Augmented Museum |

Figure 1: **Four types of AR systems**.

As explained above, media blocks and more generally tangible user interfaces (1) augment the execution phase by defining new modalities involving real objects. Such modalities enable the user to manipulate virtual objects such as multimedia documents. Augmented evaluation for interacting with virtual objects (2) refers to realistic graphics on screen and output modalities that mimic real world feedback. Augmented execution in the real world (3) corresponds to systems that enable the user to perform new actions in the real world that would not be possible without the computer. For example using the DigitalDesk [9], the user can perform a cut/paste operation on real drawings. Finally as explained previously, augmented evaluation in the real world (4) consists for example of superimposing visual information on real objects.

## OP-a-S FOR INTERACTION MODELING

In addition to these 4 classes of AR systems, we characterize each system by modeling it using our OP-a-S notation [8]. The principles of OP-a-S are firstly based on the identification of the different components of the interactive system and secondly on the relation between these components (that is the exchange of information). An OP-a-S model provides a better understanding of AR systems at the interaction level. The most important type of OP-a-S component is the Adapter that establishes a bridge between the real world and the virtual world. Adapters define the type of boundaries between the two worlds.

## CONCLUSION AND PERSPECTIVES

In this paper, we have shown how to differentiate between systems that enhance the user's interaction with his/her real environment, from systems that enhance the user's interaction with a computer by using everyday life objects as part of input/output modalities. This distinction helps us to better understand interactive systems that make use of a part of the real world. We believe that the classification scheme can be used for identifying design issues according to the type of systems, by studying and comparing existing systems of the same class. While the classification scheme is useful for establishing design issues, OP-a-S modeling can be applied for defining design principles.

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## REFERENCES

[1] Azuma, R., T., "A survey of Augmented Reality", in Presence: Teleoperators and Virtual Environments 6, **4**, (1997), p.355-385.

[2] Feiner, S., MacIntyre, B., Seligmann, D., "Knowledge-Based Augmented Reality",CACM n°**7**,(1993), p.53-61.

[3] Noma, H., Miyasato, T., Kishino, F.; "A palmtop display for dextrous manipulation with haptic sensation", Conf. Proc. on Human factors in computing systems, (1996), p.126-133.

[4] Troccaz, J., Peshkin, M., Davies, B., "The use of localizers, robots and synergistic devices in CAS", Conf. Proc. MRCAS'97,(1997), p.727-736.

[5] Ishii, H., Ulmer, B., "Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms", Conf. Proc. CHI'97, (1997), p.234-241.

[6] Rekimoto, J., Nagao, K., "The World through the Computer : Computer Augmented Interaction with Real World Environments", Conf. Proc. UIST'95, (1995).

[7] Norman, D., "Cognitive Engineering, in User Centered System Design, New Perspectives on Human-Computer Interaction", L. Erlbaum Associates, (1986), p.31-61.

[8] Dubois, E., Nigay, L., Troccaz, J., Chavanon, O., Carrat, L., "Classification Space for Augmented Surgery, an Augmented Reality Case Study", Conf. Proc. Interact'99, (1999), p 353-359.

[9] Wellner, P., "Interacting with paper on DigitalDesk", CACM, (36), 7, (1993).

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