Steady Steps and Giant Leap Toward Practical Mixed Reality Systems and Applications

Hideyuki Tamura
MR Systems Laboratory, Canon Inc.
2-2-1 Nakane, Meguro-ku, Tokyo 152-0031, JAPAN
HideyTamura@acm.org

"That's one small step for man, one giant leap for mankind." Neil Armstrong


1. Introduction

We have conducted the "Key-Technology Research Project on Mixed Reality Systems" (MR Project in short) from January 1997 to April 2001. In order to propel this project, the Japanese government and Canon Inc. jointly established Mixed Reality Systems Laboratory Inc. as a temporary research company. We have held the International Symposia on Mixed Reality (ISMR) to introduce the results of MR Project to the world on May 1999 as an interim report and on May 2001 as a conclusion.

At ISMR'99, an interim proceedings of MR Project was published as a book [1]. It was also the time when this appealing research area of mixed reality began to attract young researchers. It is remarkable that number of researchers joining this area is still increasing. Now, the mixed reality becomes a most livelier research theme in the Virtual Reality Society of Japan. ISMR was combined with the International Symposia on Augmented Reality (ISAR), which had been held in the USA and Europe, to form the International Symposium on Mixed and Augmented Reality (ISMAR). Note that ISMAR gathered record-high number of papers this year.

The ARVIKA Project in Germany is now in the final stage giving us a great forefeel of success. It is far more encouraging to us to hear that a new project called the VR-AR Project have already started before confirming the final results of ARVIKA. We have also heard that another project on mixed reality have launched sponsored by European Committee. It is our great pleasure if our MR Project has triggered these new promising projects.

Backgrounds, expected goals and results up to the mid-term of the MR Project were shown in [2], and the outline of final results was found in [3][4]. Besides the papers and reports in the academic society, the term “mixed reality,” more accurately a corresponding Japanese word, becomes popular to ordinary people due to extensive mass media coverage on our MR Project.

Put simply, the achievement of MR Project is in the fact that we have drawn augmented reality or mixed reality systems out of the laboratory to the show floor where everyone can visit. In other words, we have promoted these systems to the level where ordinary people can experience and enjoy. We have designed and manufactured see-through head-mounted displays (ST-HMDs), which were necessary to make these system enjoyable, by ourselves. We also have developed original geometric registration methods that brought a virtual object accurately to the real space. Note that we have set the greatest importance on organizing our research achievements into an actual system that one can interact in realtime, not just reporting primary technology.

The system is the result of piling up small steady steps. If people feels our result as a giant leap, that is because the system and underlying MR technology become a certain level that ordinary people feel it pragmatic. As a matter of fact, all the systems we have introduced through the MR Project cleared all the functional requirement for deployment. That is, technically available but economically unsatisfactory.

After the MR Project was finished, most of our member have been engaged in the development of practical MR systems and opening up MR business market at MR Systems Laboratory in Canon Inc. Especially, we have been studying the way to utilize the results of MR Project to a product that satisfy customers. Since the MR technology has great potential, its market is broad. Variety of customers have variety of needs and requirements. We know that we have to pile up a number of small steps in order to make people feel the next giant leap.

We have studied both on the augmented reality (AR) and the augmented virtuality (AV) through the MR Project. However, this paper deals only with AR and outlines some pragmatic systems utilizing the results of MR Project.

2. Competition on MR Entertainment

When planning the MR Project, we assumed the application area of MR technology to the medical area, architecture and city planning. However, from the partway of the project, entertainment and show business became to pay close attention to us. It was because “AR^2 Hockey” [5], implemented as a case study of collaborative augmented reality, was quite impressive to them (Fig.1). “AquaGauntlet [6],” a more real entertainment system we created, gave them stronger impact (Fig. 2). They said that the mixed reality technology caused a revolution in theme parks, exhibitions, museums, public information facilities of local governments and show rooms of private companies.

(a) Playing scene (b) Augmented view

Figure 1: AR^2 Hockey.

(a) Without augmentation (b) With see-through augmentation

Figure 2: AquaGauntlet: A multi-player shooting game in MR space.

Almost all the manufacturers of home video games and game software visited our laboratory to find out the possibility of MR entertainment. It is true that the MR entertainment has great potential to form a huge market by making MR-type games popular to home game machines if we can reduce the price of HMDs to a certain level. There may be two possibilities; natural growth of the market may reduce the price, or killer application or killer software may cultivate a new market in a short term. One may wait until the market grows naturally or one may exert an effort to create such a killer application.

In any case, it is manifest that we cannot expect maverick ideas as long as the party that owns decent HMD is limited only to us and we are a sole party that can develop a MR-type game content. At least we have to make creators and artists understand the MR technology so that they can create attractive contents. Thus we decided to prepare to coming waves of change.

As a first step of this preparation, we have established an organization called the Mixed Reality Entertainment Conference (MREC) that many companies, such as vendors of game software, CG animation studios, toy manufacturers and others who are interested in the MR entertainment, take part in. MREC annually held a competition from 2000 on new plans and scenarios of the MR entertainment and rewarded for excellent works. The third competition will be held this year. We can make inferences that the concept of the mixed reality is gradually accept by the people from the fact that many young creators enter this competition.

"Contact Water" is the work that was awarded the Grand Prize at the first competition called MREC 2000. The key concept of this work is to generate a surface of water on ones palm so that the player of this entertainment can breed an aquatic animal such as a dolphin and can exchange bread animal with other players to communicate each other (Fig.3). The media artist who think up this idea and programmers in Canon Inc. collaborate on realizing it as an interactive artwork that can be experienced by four players simultaneously (Fig.4)[7].

This system dose not require drastic advance from the innovative technology developed in the MR Project. However, we had a tough time to make it conformable to play. The system architecture is derived from "AquaGauntlet" implemented on SGI O2s, but ordinary PC is used and programmed in Windows environment using OpenGL library. A player wares a device to sense the position of head and hand. Sound of water comes from a speaker attached to the players hand. Since a sense of artistic design is required to respond to the subtle movement of palm and the adjustment of timing to exchange aquatic animals, we have polished up a technology to support such activity.

Figure 3: Concept of Contact Water.

Figure 4: Artwork of Contact Water.

"Contact Water" system presented in the art galleries of ISMR 2001 and SIGGRAPH 2001 was experienced with fun by a lot of participants of these symposiums. We have to add the fact that "Contact Water" won an outstanding performance award at the largest festival of media art in Japan.

3. MR Visualization of CAD Data in Automobile Industry

Most of the technical demonstrations at ISMR 2001 were to show the results of MR Project in the form of art and entertainment. However, we have also developed systems applicable to business in order to denote the power of MR technology. "Clear and Present Car" system [8] is the one of these systems. Academically, it is not a new system in any way, but the system has been continuously improved and now it starts spurring a great demand.

Almost all the automobile manufacturers introduce stereoscopic display systems of wall projection type to visually confirm the design of an automobile in real size. Our "Clear and Present Car" system has the following advantages to these systems.

- One can confirm harmonious balance of the size and form of a car against the real background since it can draw a virtual car onto the real world.
- One can walk around the car and even get into the car by opening a door.
- Since a real seat is prepared, one can sit in the seat and confirm the sight from the driver's seat through virtual windows.

This system was built up by applying our technology to "Virtual Car" system [9] developed by ART+COM in Berlin (Fig.5).

A company that gave an attention to the pragmatic significance of the system was not an automobile manufacturer but an automobile parts manufacturer, Denso Corporation, Japan. They wanted to use this system to check up design and function of a cockpit, not the external design of a car. The design department of Denso and MR Lab of Canon Inc. collaborated for more than a half year to make up the following system.

(a) A driver sitting on the real driver's seat (b) Virtual car in the real space, in real scale

Figure 5: MR Car. (The content data is provided by Daimler-Chrysler AG, Germany.)

(a) Without augmentation (b) Augmented image

Figure 6: Design review based on MR technology.

(a) Design of instrumental panel (b) Function annotation

Figure 7: Evaluation of Human-Machine Interface.

- The driver's seat and steering wheel are real objects used in a actual car and two devices for controlling audio, air conditioner and navigation system are also real objects. The instrument panel of the cockpit is skeleton only with frameworks (simple mock-up).
- Interior seen from the driver's seat, pillars, ceiling, doors, floor etc., including the instrument panel and meters that are to be confirmed are virtual objects of CG. A driver wearing a see-through HMD can see these virtual objects on top of the real objects. High precision registration is required to place the virtual steering wheel and control devices accurately onto the real ones (Fig.6).
- Not only the instrument panel is selectable to confirm its design, but the meters and other display on the panel also change its appearance as a driver changes the settings of controls. One can confirm the user-friendliness and visibility of the instrument panel (Fig.7).
- The outside scene from the driver's seat is also given by a video taken from the eye position of the driver. MR technology allows us to display any type of alert signal at the windshield, thus we could emulate the future head-up display, and its graphical design in any way. This is important to know how safety the design is.
- This system emphasizes on the feeling of mixed reality in that the driver can operate various controls by actually touching steering, switches, and other control devices. However, his/ her hands are masked by CG objects if you put these CG objects on top of real objects.

In order to avoid this problem and make the driver feel everything real, image of hands are extracted by the chroma-key operation and draw the results on the most front layer (Fig.8).

Figure 8: Composition of real scene, virtual instruments, and real hands.

The customer of this system is the design department of Denso, but the users who experience this system are members of automobile manufacturers. Therefore, we have to complete the system so that these users satisfy on the registration accuracy, response speed, operationability, etc. The system has already experienced by about a thousand of users and it is still utilized. In this sense, we have to say that the MR system put the great step for the pragmatic application from mere exhibition that came out of the laboratory.

The system gathered attention of people when we presented it at the Design and Manufacturing Solution Fair in Japan. 3D-CAD is now becoming more and more popular among manufacturers. They want to confirm product design by a digital mock-up without making an actual one. However, they also feel that something is missing in 3D-CAD or digital mock-up. Meanwhile, the MR experience might give them a great impact, since they can simulate the product design by changing its appearance while interacting with physical world. They may feel our pile of small steady steps as a giant leap. It is expected that almost all the 3D-CAD systems will have the MR visualization function in few years.

4. MR Platform and Its Application

We hope the MR technology is used in various fields so that the market becomes larger. For this, we decided to supply a platform that can be used as a base of AR/MR research and development to vitalize the research activity farther than now. We know ARTookit [10], developed by Prof. H. Kato (Hiroshima City Univ.) and distributed by HIT Lab., Univ. of Washington, is a powerful and easy-to-use tool and contributed to the improvement of this research area. It is good for introductory usage, however, the application is limited since available markers are limited. This is because we decided to supply an MR platform for research and development that can support broader application area.

Our MR Platform is the base of various AR/MR applications. The minimum set is called MR Platform/Basic Kit and consist of a video see-through HMD and a software library called MR Platform SDK. We also supply a platform called MR Platform System that includes PC and peripheral cards, CG libraries and a magnetic sensor for head tracking that are shown in the lower layer on Fig.9.

The HMD included in the MR Platform is based on COASTAR (Co-Optical Axis See-Through for Augmented Reality) technology that received great interests from AR researchers [11]. This HMD has a feature that the optical axes of the built-in cameras and displays coincide, thus providing true 3D sensation without a adverse effects (e.g., sickness or loss of balance). It takes over the base design developed in the MR Project, but decoration and appearance are improved as shown in Fig. 10. Not a few people wants to use this type of HMD, however, we cannot produce enough number of products because the lack of available parts.

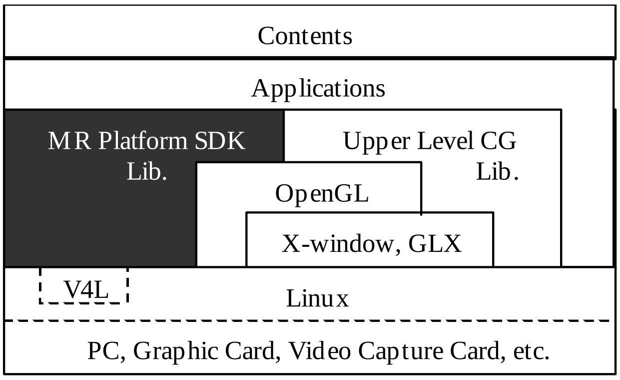

Figure 9: MR Platform library layer.

Figure 10: VH-2002 HMD.

MR Platform SDK is the fruit of historical assets of MR Project and has an architecture shown in Fig.11. We have written programs mainly for IRIX Operating System on SGI's Onyx and O2, and Open GL or DirectX on Windows environment. However we decides to use Linux as an operating system for our MR Platform SDK. Please refer to the reference [12] for its functions and specifications.

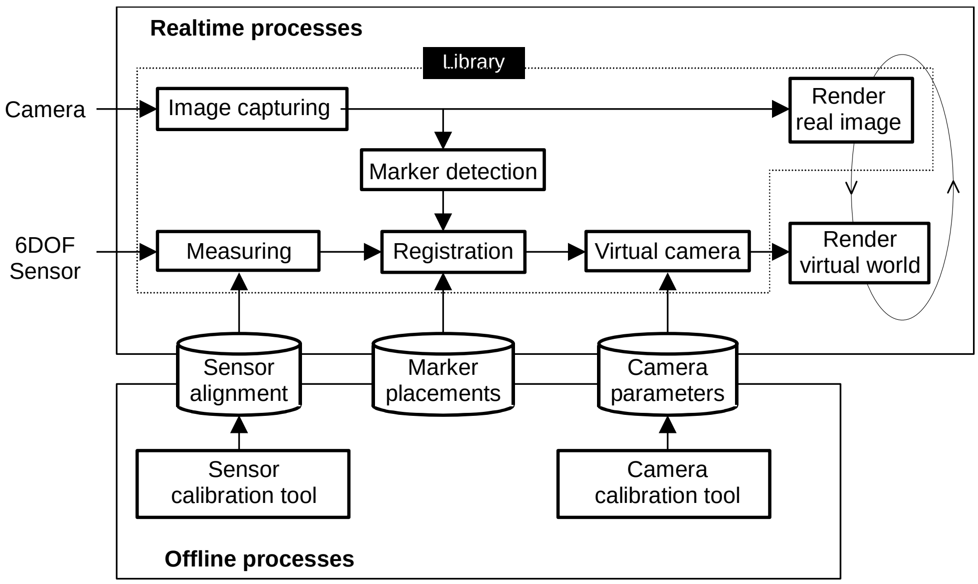

Figure 11: Processing elements of MR Platform system.

Figure 12: MR^2 system (Courtesy of Communications Research Laboratory.)

Finally, let us introduce one application of MR Platform System. Communications Research Laboratory (CRL) in Japan has a meeting room with various multimedia functions called MR^2 (Mixed Reality Meeting Room) [13]. This room was made as a prototype of emergency meeting room where multiple people share various information presentation functions. The 3D image presentation function of mixed reality type is one of these functions that make it possible for multiple people to proceed a meeting smoothly while freely referring to information given from both real and virtual spaces (Fig.12).

One of the features of the MR system build into this room is the HiBall system with dedicated transmitter placed on the ceiling as a head tracking system in order to satisfy the requirement to allow users to move around relatively broad area (Fig13). The standard head tracker of MR Platform System is Fastrak of Polhemus. However, the software is made flexible so that one can change the head trackers to satisfy customer's needs.

Figure 13: HiBall tracker at CRL. (Courtesy of Communications Research Laboratory.)

4. Concluding Remarks

This paper describes a brief introduction of several practical MR systems we have developed after the MR Project. Our MR Platform is merely a summary by discovering traits common to our small steps. It is our pleasure if a group exists that thinks this as a giant leap. Now, MR technology is gathering attentions from entertainment and industrial business. However, more research on basic and fundamental technology is required in order respond to various requirements from these business areas. We hope that we can vitalize the R&D community by improving our MR Platform and also hope that we can introduce attractive applications to cultivate potential market.

We are quite interested in the evolution of VR-AR Project in Germany expecting giant leap. The results must affect our research activity. Good mutual interaction should advance the MR technology as if we all are in the upward spiral.

References

[1] Y. Ohta and H. Tamura (eds.): *Mixed Reality-Merging Real and Virtual Worlds*, Ohmsha-Springer Verlag, 1999.

[2] H. Tamura, H. Yamamoto, and A. Katayama: “Steps toward seamless mixed reality, ” in [1], pp.59-84, 1999.

[3] H. Tamura, H. Yamamoto, and A. Katayama: "Mixed reality: Future dreams seen at the border between real and virtual worlds," *IEEE Computer Graphics & Applications*, Vol.21, No.6, pp.64-70, 2001.

[4] H. Tamura: “Overview and final results of the MR Project, ” *in Proc. ISMR 2001*, pp.97-104, 2001.

[5] T. Ohshima, K. Satoh, H. Yamamoto, and H. Tamura: “AR^2 Hockey: A case study of collaborative augmented reality, ” in *Proc. VRAIS'98*, pp.268-275, 1998.

[6] T. Ohshima et al.: “RV-Border Guards: A multi-player entertainment in mixed reality space, ” *SIGGRAPH 2000 Conference Abstracts and Applications*, p.96, 2000.

[7] T. Murakami: “Contact Water, ” *SIGGRAPH 2001 Electronic Art and Animation Catalog*, p.127, 2001.

[8] C. Stratmann, T. Ohshima, T. Kobayashi, H. Yamamoto, and H. Tamura: “Clear and Present Car: An industrial visualization in mixed reality space, ” in *Proc. ISMR 2001*, pp.199-200, 2001.

[9] C. Stratmann: “Virtual Car, ” *ACM SIGGRAPH 99 Conference Abstracts and Applications*, p.282, 1999.

[10] http://www.hitl.washington.edu/research/shared_space/download/

[11] A. Takagi, S. Yamazaki, Y. Saito, and N. Taniguchi: “Development of a stereo video see-through HMD for AR systems, ” in *Proc. ISAR 2000*, pp.68-77, 2000.

[12] S. Uchiyama, K. Takemoto, K. Satoh, Hi. Yamamoto, and H. Tamura: “MR Platform: A basic body on which mixed reality applications are built, ” in *Proc. ISMAR 2002*, pp.246-253, 2002.

[13] K. Kiyokawa, M. Niimi, T. Ebina, and H. Ohno: “MR^2 (MR Square): A mixed-reality meeting room, ” in *Proc. ISAR 2001*, pp.169-170, 2001.

[14] G. Welch, G. Bishop, L. Vicci, S. Brumback, K. Keller, and D. Colucci: “The HiBall tracker: High-performace wide-area tracking for visual and augmented environments, ” in *Proc. ACM VRST ’99*, pp.1-10, 1999.