ARtalet: Tangible User Interface based Immersive Augmented Reality Authoring Tool for Digilog book

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***Abstract*— A *Digilog Book* is an augmented reality (AR) based next generation publication supporting both sentimental analog emotions and immersive digital contents to improve a user's experience. This paper enhances the *Digilog Book* authoring tool, *ARtalet*. This is a tangible user interface based immersive AR authoring tool providing an intuitive non-programming based authoring methods using a 3D user interface in an AR environment. As novel authoring functions, we propose 3D object trajectory manipulation, real-time deformation, and audio/vibration feedback authoring functions to enhance a user's experience and interest. The ARtalet can be applicable to other Digilog application authoring, including posters, pictures, newspapers, and sign boards*.**

Keywords-component; Augmented Reality; Authoring Tool; 3D Object Trajectory Manipulation; Real-time 3D Object Deformation; Multisensory Feedback; Tangible User Interface

I. INTRODUCTION

A *Digilog Book* is a next generation publication combining analog sensibility of a paper book and digitized visual, auditory, and haptic feedback to readers by exploiting an augmented reality (AR) technology [1]. The *Digilog Book* consists of a conventional printed book, multimedia contents and a *Digilog Book* viewer software which acquires images of the printed book from the camera and augments the multimedia content on the book. As a learning tool, this allows the reader to experience the benefits of existing printed material enhanced by multimedia content through multi-sensory experiences like visual, auditory, and haptic. In other words, a *Digilog Book* maintains the original functions of a printed book, but adds the advantages of digital content.

A growing body of research has been conducted attempting to make AR authoring tools. Existing AR authoring tools are generally categorized as either programming based authoring tools, or non-programming based authoring tools [2]. The former targets the technical developer with professional knowledge of programming. On the other hand, the non-programming based AR authoring tools provide relatively intuitive direct manipulation through graphical elements. They involves a graphical user interface (GUI) based visual programming [3-5] or tangible user interface (TUI) based immersive authoring tool [6-10]. One characteristic of the immersive authoring environment is that the authoring of an AR application is congruent with the AR environment itself using a tangible object. Therefore, users are able to immediately and seamlessly modify virtual content registered from a printed book in the AR environment without any programming.

In this paper, we enhance a *Digilog Book* authoring tool called *ARtalet* [9], which is a compound word made up of the parts AR [augmented reality], Tale [story], and Let [booklet]. It targets average users with no professional programming skills, but limited in static properties authoring of 3D objects. The improved system supports novel visual/audio/haptic authoring functions such as 3D trajectory manipulation and real-time 3D object mesh deformation, as well as multi-sensory feedback authoring that includes auditory and vibration tactile feedback to enhance a user's experience and pique his interest more than affectless 3D object loading and arrangement.

Specifically, the existing 3D object trajectory insert method [10] has an advantage because it allows users to intuitively set the 3D trajectory in a 3D AR environment using their own hand movements. However, the following problems occur: ragged trajectory generation and difficult editing of the trajectory. To solve these problems, we adapted the Catmull-Rom spline curve model and exploited a trajectory editing method using the dynamic key point selection method. Considering the 3D object deformation in AR, the real-time process is a critical problem [11-12]. Therefore, we refined the Fast Lattice Shape Matching (FastLSM) method to enable rapid deformation. Finally, concerning the vibration tactile feedback, we extended the conventional 2D plane-based haptic interface [13-15] for a 3D space-based pen type haptic user interface for AR authoring of a *Digilog Book*.

The remainder of this paper is organized as follows. In Chapter 2, we mention technological details for *ARtalet* authoring functions and we then explain the implementation details in Chapter 3. Finally, our discussion and conclusions are given in Chapter 4.

II. ARTALET: DIGILOG BOOK AUTHORING TOOL

Figure 1 shows the overall *Digilog Book* authoring process using *ARtalet*, involving input images from a camera, computer vision based tracking conducted of a book, a menu prop and a pen-type manipulation prop. The collision detection process is conducted through collision detection

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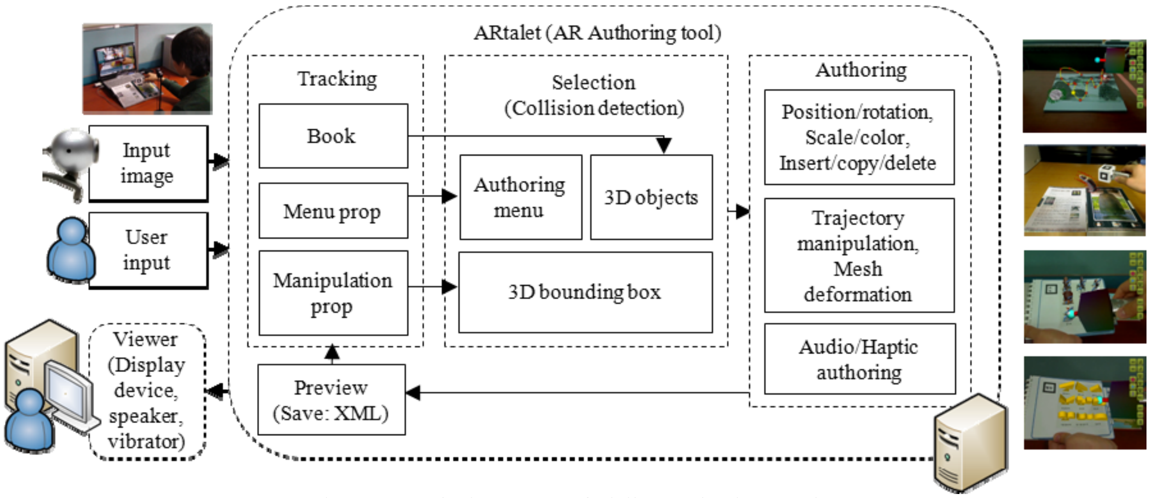


Figure 1. Authoring process of Digilog Book using ARtalet.

between the manipulation prop and a bounding box of the augmented 3D objects on the book or the menu prop. Using the tracked manipulation prop, the user can select the 3D object or choose authoring menus on a menu prop in the 3D environment. At this point, the user can conduct any of the incorporated functions, including canonical 3D object manipulation (e.g., positioning and rotating, coloring, scaling, coping, deleting), 3D trajectory manipulation, 3D object mesh deformation, and audio and vibration tactile feedback authoring manipulations. Finally, the *Digilog Book* viewer displays the authoring results.

A. *Novel AR Object Authoring Functions*

We design a cubical box attachable to a mouse input device and with multiple markers printed on the box. By using the mouse input buttons, a discrete input generates the event functions necessary for an authoring interface. Also, multiple markers enable prop tracking at arbitrary camera viewing angles and simultaneously provide continuous input for modifying the position/rotation matrixes of a 3D object. The 3D object trajectory manipulation function saves the transformation matrixes of a 3D object based on the page plane of the book while the user selects and drags the 3D object by using the manipulation prop. Then the created trajectory is modeled with a parametric key point curve equation. This fitting step makes the trajectory into a gently curved shape and reduces the number of trajectory points by saving only the key points. To do that, we first normalized the spatial interval between the points and adopted the Catmull-Rom spline model [16], which is a well-known model used in interactive camera path editing. In addition, we also exploited the dynamic 3D object selection method in VR [17] for the dense key point selection and manipulation of the trajectory in AR.

For realistic reactions of 3D objects, our authoring tool also supports physics based deformation. To satisfy real-time computation and stability, we use lattice shape matching (LSM) [18]. The dynamics of LSM are similar to that of a rigid case, except in the overlapping regions. The movements of the particle are calculated first and the translations and rotations of the shape matching regions are calculated later. However, the real-time computation of the deformation can frequently fail when we apply the LSM method to relatively complex models. Hence, the fast lattice shape matching (FastLSM) [19] method is used, which divides the region into many sub-summation regions and calculates the movements of the particle separately. Finally, the free form deformation (FFD) [20] method is used to connect the deformation of the lattice model with the deformation of the virtual model. The FFD method, which is relatively fast and stable, can smoothly deform both arbitrary topology models and variously shaped models. The user can increase and decrease the amount of lattice freely, so various deformable 3D objects can be generated.

B. *Multi-sensory Authoring Functions*

We suggest a vibro-tactile type haptic user interface. This is a mobile type vibration module used to enhance immersion when authoring and reading the *Digilog Book*. Considering its portable, light-weight design, it can be embedded in the manipulation prop and directly stimulates the user's skin by providing vibro-tactile feedback. The internal components of the manipulation prop contain a vibration actuator, a Bluetooth communication module for wireless communication, and a microcontroller for tactile feedback signal and the wireless communication process. The micro controller receives vibration commands related to the authoring task with a dedicated protocol using Bluetooth communication from *ARtalet* or the *Digilog Book* viewer. The micro controller then generates a corresponding vibration signal pattern and transfers it to a coin-type vibrator or linear-type vibrator. Additionally, we designed a DC motor driver to compensate for the slow response characteristic of the coin-type vibrator.

Using the immersive copy function in the *ARtalet*, the user can copy 3D objects from the menu prop to the book paper using a drag and drop function. The 3D objects visually present multisensory feedback. Specifically, visual (e.g., 3D object), audio (e.g., sound effect), and haptic (e.g., vibration pattern) preview functions enable the user to easily understand and preview the authoring-enabled multisensory feedback. The vibration patterns consist of various vibration waves such as a square wave, triangle wave, sin wave, and other shaped waves.

III. Implementation

A. Ruming Environment

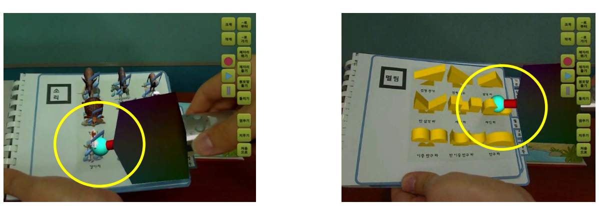
ARtalet was executed in a normal indoor environment with no dramatic lighting changes. The camera used was a general purpose USB camera, fixed on the camera arm and captured 30 images frames per second at 640x480 pixel resolution. The computer was equipped with a 2.40GHz CPU and 4GB memory. The osgART library[1] was used to support the rendering of scene graph structured graphic models and computer vision based tracking functions. In this demo, the setting, monitor, camera, and book were aligned together, shown in Figure 2, and were all in the direct view of the user. For the implemented manipulation prop, we adopted a commercial pen mouse[2] as a prototype, attached to a box with multiple markers fixed on the front of the prop.

(a) (b)

Figure 2. ARtalet running environment: (a) monitor, camera, and book were in co-line, manipulation prop, (b) manipulation prop.

B. Implementation Details and Results

Figure 3 outlines the copy function. Several 3D objects are aligned in a menu prop and are composed of static or animation enabled objects. The user can copy any them to a book page using the manipulation prop by selecting a 3D object and then dragging and dropping it. Audio or haptic feedback can also be copied and inserted with the 3D object on the book in same manner.



(a) (b)

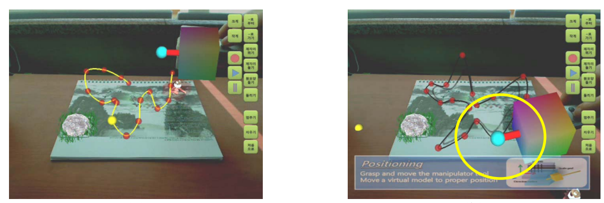
Figure 3. Copy function of a 3D object: (a) audio feedback, (b) haptic feedback. If user hits the 3D object with the manipulation prop in the *Digilog Book* viewer, then the audio and haptic effect can be played.

We did experiments to test the effect of audio and vibration feedback on 3D object manipulation (e.g., selection and translation). A total of 20 participants, 16 had previous experience in AR, participated in our evaluation and had an average age of 30. The task was composed of random 16 step trials of total 48 trials (4 sizes: 10, 20, 30, and 40 mm. 4 distances: 60, 120, 180, and 240 mm. 3 angles: 0, 30, and 60 degrees). We could get positive subjective evaluation results compared to the baseline (no feedback) as shown in Table 1.

TABLE I. User subjective ratings using Likert scales (0 ~ 6 score; 0 being most negative and 6 being most positive)

	Depth perception	Understand	Favorite
Audio feedback	3.92	4.63	4.11
Vibration feedback	4.68	4.60	4.50

Figure 4 shows the 3D object trajectory authoring process. The user can translate the 3D object by pressing and holding a button on the manipulation prop. If the user releases the button, the recording is stopped. The user can also edit the shape of the trajectory by dragging the key points in the same manner. Our experimental results suggested that the trajectory method generated a small amount of error (3~5mm) to the conventional non-curve model method for a primitive and a freeform trajectories. However, the number of key points is significantly reduced, approximately 92%, and the edit time using the dynamic 3D object selection method is also reduced about 22% compared to conventional method.



(a) (b)

Figure 4. 3D object trajectory authoring: (a) spline curve modeling, (b) edit of the shape of the trajectory.

Figure 5 shows the FFD and physics based deformation under AR environments. The deformation with a single lattice is indicated, where the user can freely increase and decrease the amount of lattice of the 3D model. Also the deformation module continuously checks a collision between the 3D model and the book page in order to simulate the deformation caused by the collision. In the implementation phase, we exploited the velocity and direction of the manipulation prop so that users could experience a realistic reaction from the 3D object when they throw the 3D object on the ground.

(a) (b)

Figure 5. The example of FFD and physics based deformation: (a) FFD with single lattice and (b) physics based deformation caused by collision.

[1] OSGART: www.artoolworks.com/community/osgart.

[2] Wireless presenter: 3M WP-8000, http://www.3m.com

IV. DISSCUSION AND CONCLUSION

A. Disscusion

We had the opportunity to conduct demonstrations at over 10 science and technology related exhibitions for average to the professional people in South Korea since 2007, including annual Korean Conference on Human Computer Interaction (KHCI) [3] exhibition, Korea Science Festival (KSF)[4], and a demonstration at the International Symposium on Mixed and Augmented Reality (ISMAR)[5] in UK, in 2008. We tested the feasibility of our prototype system and were able to receive a great deal of valuable feedback.

Many visitors were interested on immersive AR environments, many parents and teachers without programming skills showed positive interest. Especially an immersive direct manipulation technique is easily understandable for them. Some were able to easily execute the operation simply from their previous experience and knowledge of drag and drop method.

However, several problems remain unsolved. At first, additional equipment (e.g., computer camera, vibration module) is required to experience the *Digilog book*. We are expecting this problem to be solved in the near future through a smartphone device that has received widespread attention recently. The smartphone has an embedded camera for acquiring images and a vibration module for haptic feedback, as well as a display device for representing results.

Another problem in the immersive AR based authoring environment was computer vision tracking error. More robust, but inexpensive, tracking methods are needed for average users in a normal authoring environment. Depending on the book page's layout and contents, it may be difficult to extract good features and proper tracking for similar patterns (e.g., text majority), dark figures, and reflective material.

In considering the 3D object authoring, we need to understanding the context of a 3D object, requiring more diverse information in the authoring menu, such as the inclusion of a context sensitive menu. Also, simplifying the authoring process by exploiting the template and wizard concept can help the average user.

B. Conclusion

In this paper, we suggest a *Digilog Book* authoring tool based on a desktop metaphor and direct manipulation. By using the drag and drop technique with a manipulation prop enabling 6 DOF object manipulation, a user can perform 3D object trajectory manipulation, real-time deformation, and audio/vibration feedback authoring. Through several exhibitions, we confirmed the feasibility of our system and mentioned several unsolved problems. The ARtalet can be applicable to other Digilog application authoring, including posters, pictures, newspapers, and sign boards

As a future work, we are considering additional trajectory insert technique to enhance natural relations between a book and augmented 3D objects. For example, 3D objects can appear to be smoothly emerging from the book page plane or dropping from the air. Also the 3D object deformation and real-time optimization will require further study about representing natural phenomena such as fluids or fog. Lastly, we need an improved pen-type haptic device and a method to provide a more detailed resolution of vibrations for natural and immersive experiences (e.g., feeling the flowing, waving in a *Digilog Book* scenario).

[3] Korean Conference on Human Computer Interaction (KHCI): http://www.hcikorea.org

[4] Korea Science Festival (KSF): http://www.kofac.or.kr

[5] International Symposium on Mixed and Augmented Reality (ISMAR): http://www.ismar08.org

REFERENCES

[1] Y.Lee, T.Ha, H.Lee, K.Kim, W.Woo, "Digi-log Book - Convergence of Analog Book and Digital Con-tent," KIPS, 2007, pp.186-189.

[2] A.Hampshire, H.Seichter, R.Grasset, M.Billinghurst, "Augmented Reality Authoring: Generic Context from Programmer to Designer," OZCHI, 2006, pp. 409 - 412.

[3] BuildAR, HIT Lab NZ: http://www.hitlabnz.org/wiki/BuildAR

[4] B.MacIntyre, M.Gandy, S.Dow, Jay David Bolter., "DART: A Toolkit for Rapid Design Exploration of Augmented Reality Experiences," ISMAR, 2004, pp.172-181.

[5] Unifeye software platform, http://www.metaio.com

[6] H.Kato, M.Billinghurst, I.Poupyrev, K.Imamoto, K.Tachibana, "Virtual Object Manipulation on a Table-Top AR Environment," ISAR, 2000, pp.111-119.

[7] H.Kato, K.Tachibana, M.Tanabe, T.Nakajima, Y.Fukuda, "MagicCup: A Tangible Interface for Virtual Object Manipulation in Table-Top Augmented Reality," ART, 2003, pp.75-76.

[8] T.Ha, W.Woo, "Graphical Tangible User Interface for a AR Authoring Tool in Product Design Environment," ISUVR, 2007, pp.1-2.

[9] T.Ha, Y.Lee, W.Woo, "ARtalet for digilog book authoring tool - authoring 3D objects properties," KHCI, 2008, pp.314-318.

[10] G.Lee, C.Nelles, M.Billinghurst, GJ.Kim, "Immersive Authoring of Tangible Augmented Reality Applications," ISMAR, 2004, pp.172-181.

[11] A.Santhanam, C.Fidopiastis, F.Hamza, J.Rolland, C.Imielinska, "Physically-based deformation of high-resolution 3D lung models for augmented reality based medical visualization," AMI-ARCS, 2004.

[12] F.Hanmza, A.Santhanam, C.Imielinska, S.Meeks, J.Rolland, "Distributed Augmented Reality with 3-D Lung Dynamics A Planning Tool Concept," TITB, vol. 11, 2007, pp.40-46.

[13] K.Kyung, J.Park, "Ubi-Pen: Development of a Compact Tactile Display Module and Its Application to a Haptic Stylus," WorldHaptics, 2007, pp.109-114.

[14] J.Lee, P.Dietz, D.Leigh, W.Yerazunis, S.Hudson, "Haptic pen: a tactile feedback stylus for touch screens," UIST, 2004, pp.291−294.

[15] C.Liao, F.Guimbretiere, C.Loeckenhoff, "Pen-top feedback for paper-based interfaces," UIST, 2006, pp.291-220.

[16] E.Catmull, R.Rom, "A class of local interpolating splines," Computer Aided Geometric Design, Academic Press, 1974, pp.317-326.

[17] T.Grossman, R.Balakrishnan, "The Bubble Cursor: Enhancing Target Acquisition by Dynamic Resizing of the Cursor's Activation Area," CHI, 2005, pp.281-290.

[18] M.Müller, B.Heidelberger, M.Hennix, J.Ratcliff, "Position Based Dynamics," VRIPhys, 2006, pp.71-80.

[19] A.Rivers, D.James, "FastLSM: fast lattice shape matching for robust real-time deformation," ACM Graph, vol.26(3), 2007, pp.82-87.

[20] R.MacCracken, K.I.Joy, "Free-Form Defor-mations with Lattices of Arbitrary Topology," SIGGRAPH, 1996, pp.181-188.