In-Place Sketching for Content Authoring in Augmented Reality Games

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ABSTRACT

Sketching leverages human skills for various purposes. In-Place Augmented Reality Sketching experiences build on the intuitiveness and flexibility of hand sketching for tasks like content creation. In this paper we explore the design space of In-Place Augmented Reality Sketching, with particular attention to content authoring in games. We propose a contextual model that offers a framework for the exploration of this design space by the research community. We describe a sketch-based AR racing game we developed to demonstrate the proposed model. The game is developed on top of our shape recognition and 3D registration library for mobile AR.

KEYWORDS: In-Place Augmented Reality Sketching, Tangible Interaction, User Interface, Sketch Interaction.

INDEX TERMS: I.3.3 [Computer Graphics]: Interaction Techniques; H.5.1b [Information Interfaces and Representation]: Artificial, augmented, and virtual realities.

1 INTRODUCTION

Augmented Reality (AR) opens new avenues for developing novel immersive digital experiences that are visually tied to the world surrounding us. Over the last decade, various user interface paradigms have been researched to explore the possibilities offered by AR, such as gesture-based interfaces, haptic devices, and Tangible User Interfaces (TUI). These are intuitive to humans because they draw from our everyday skills, such as grasping and spatially manipulating objects.

One such common human skill is sketching on all kinds of surfaces using different physical tools like pencils. Sketching provides flexibility through creative processes and allows us to rapidly and visually convey concepts to each other, as well as clarify them to ourselves. Sketching is widely used by engineers for prototyping, by designers for brainstorming, and by many of us for communicating ideas. Sketch-based interfaces have been the focus of different HCI groups for over a decade. Since AR offers the ability to see the real world combined with virtual content, it is interesting to investigate the uses of traditional sketching combined with AR. Namely, the user can sketch and see virtual content generated accordingly on top of the drawing (see Figure 1). Sketch-based experiences can be developed for a wide range of surfaces, such as napkins, whiteboards, and pavements.

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In this paper we describe our exploration of *In-Place Sketching*, which refers to sketching in the real world. We define a visual language to generate virtual content for 3D augmentation from hand sketches. This exploration is an extension of previous work on In-Place Augmented Reality [1][2]. We focus here on design space concepts and aim at providing a context for the study of In-Place Sketching interfaces and applications.

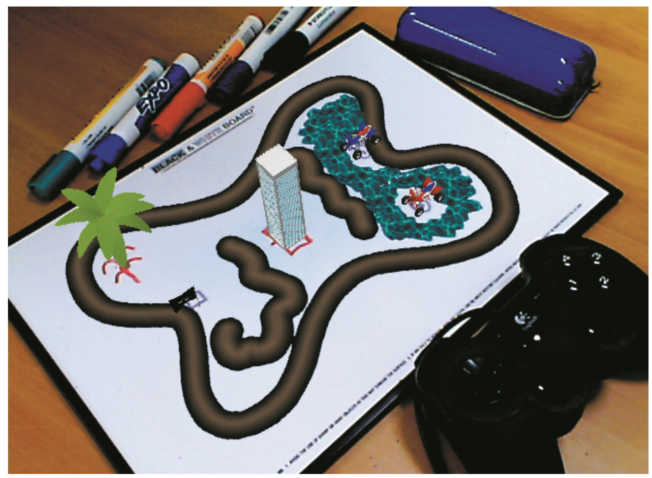


Figure 1. Sketchaser: An In-Place Sketching Capture the Flag game.

The aspects discussed here are geared towards virtual content authoring in sketch-based AR gaming, which we find one of the most intriguing directions in this scope. To demonstrate the concept, we describe an AR game we developed. The game is designed to provide non AR users intuitiveness and flexibility in creating virtual content.

In the next section we describe related background. We then describe an example of an AR sketching game. We then discuss the details of the design space. Finally, we conclude and discuss future work.

2 BACKGROUND

In this section we review relevant work on sketching in digital environments. We discuss the digital acquisition techniques that have been used, as well as several sketch-based games.

2.1 Sketching Systems

One of the first computer systems that used digital sketching is the famous SketchPad system [3], designed by Ivan Sutherland. Another pioneering work done by Zeleznik et al. is the SKETCH system [4], which introduced a new form of interaction for manipulating 3D objects. Balashrinkna et al. [5] recently proposed sketching for creating 3D manipulator interfaces in-situ. On the application side, some notable works are MathPad^2 [6] and

ASSIST [7], which aimed at assisting in learning maths and mechanical engineering using a tabletPC and a digital whiteboard.

Several researchers have focused on sketching in 3D space using dedicated devices and immersive virtual reality technology [8][9][10]. Other efforts have been made to allow virtual sketching using different real artefacts [11][12][13].

A small number of works combining AR and sketching can be identified in the literature. AR researchers have considered possible views of the real world and the dimensionality of the physical space used for sketching [14][15][16][17]. Seichter et al. [18] proposed the usage of sketching for the design of extruded architectural models, which can be overlaid on real architectural mock-ups. Xin et al. [19] presented Napkin Sketching and Anabuki et al. [20] proposed the usage of a dedicated tangible user interface for creating 3D virtual meshes in the real world. More recently, Sareika et al. [21] presented the Urban Sketcher system for exploring the in-situ AR sketching in the context of urban design.

Recently, Bergig et al. [2] presented a sketch-based AR system for reconstructing and augmenting mechanical experiments from webcam images of sketches made using pencil and paper. 3D models were reconstructed from sketches of isometric projections and interaction was allowed by modifying sketch elements.

In summary, most of the previous work on sketch-based interaction has focused on sketch interpretation of input retrieved using digital tablet-based systems and 3D tracking devices. The value of traditional sketching in the scope of AR still remains to be explored, which forms the motivation for this work.

2.2 Sketching in Games

Sketching has gained much attention in the scope of gaming recently. Some of the popular sketch-based games in this context are LinerRider[1], Phun[2], Crayon Physics Deluxe[3], and PenWars[4].

In the scope of AR gaming, Haller et al. [22] presented a Mixed Reality domino game. In Purple Crayon, Xin et al. [23] explored the transition of virtual sketched content from a tabletPC into the real environment. Petzold et al. [24] addressed real world sketching in an AR setup. Using projector phones, Löchtefeld et al. [25] described a mobile AR game for exploring the transporting of sketch-based games into the real world. More recently, Huynh et al. [26] developed Art of Defense (AoD). They discussed the value of sketching for creating virtual game content.

To conclude, we identify a movement of games in the direction of tangible sketching interaction. In this work we study the design space of such game interfaces in AR.

3 Sketchaser

We begin by describing a game called *Sketchaser*, which is a collaborative In-Place Sketching game based on the traditional Capture the Flag concept. In Sketchaser two players compete with each other using their All Terrain Vehicles (ATV) by capturing and maintaining hold of a single flag.

Sketchaser is played on the real world, over real paper or a whiteboard located in front of the two players (see Figure 1). The game arena is designed by sketching according to a set of visual rules, which are used to author virtual game elements. The sketched elements are automatically analyzed by the system and translated into 3D virtual game elements. For example, the symbols in Figure 2(a) define the starting positions of the players' vehicles and the flag. Areas of the sketching surface painted in blue and green, as depicted in Figure 2(b), turn into grass patches and slippery water ponds. Different symbols, such as the ones depicted in Figure 2(c), introduce 3D virtual objects, such as buildings and trees, into the virtual arena. Sketching black lines, as depicted in Figure 2(d) causes virtual brown hills to rise from the ground along the sketched lines.

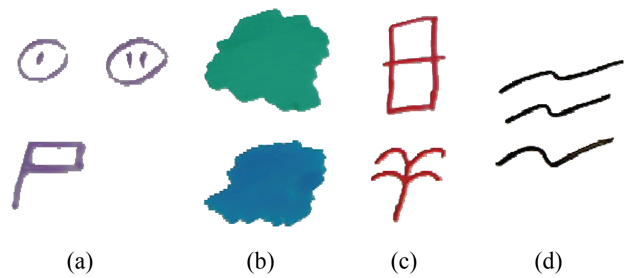


Figure 2. Several of the symbols used in Sketchaser: (a) player 1, player 2, and flag starting positions (b) grass patch and water pond (c) building and palm tree (d) hills.

The generated virtual content is spatially registered in 3D over the sketching surface, which the players can move around to change viewpoint on the game. We use the tracking system presented in [27] to maintain 6DOF registration of the sketch. When the system detects the occlusion of parts of the sketch, it renders the virtual content semi-transparently to allow the players to see the underlying sketch while sketching.

An In-Place Sketching game like Sketchaser can be played on different surfaces, such as napkins and whiteboards, use different types of displays, from a mobile phone to a Head Mounted Display (HMD), involve a wide range of game content types, from basic objects to complex behaviours, and use different tracking solution. This forms a motivation for the development of the design space presented in the next section.

4 Design Space

In-Place Sketching refers to interactively authoring AR content by drawing according to a visual language. The resulting experience is derived from both sketching and Augmented Reality elements. In this section, we discuss these elements as game factors.

4.1 Environment

In-Place Sketching refers to sketching on any surface in the real world surrounding the user, which is also where the user sees the result overlaid. This unifies the real world not only with the virtual world, as generally done in AR, but also with the interaction mechanism. The interaction points between the user and an In-Place Sketching system are the input sketching tools, e.g., pen and paper, and the output display device, which shows the user the result of his creativity. These play fundamental roles in designing user experience and interact with other design concepts.

Sketching Tools

While various types of *active surfaces* exist, such as digitizing tablets and tabletPCs, we are more interested in traditional *passive surfaces*, which can be practically any surface in the real world. To perform sketch interpretation, the passive surface is imaged by a camera and the resulting image is analyzed in real time. Various surface properties have implications on user experience, such as the *surface material*. For example, a game provides a whole different experience depending on whether it is played on a notebook page, a napkin, a whiteboard, or wood.

[1] http://www.linerider.com
[2] http://www.phunland.com
[3] http://www.crayonphysics.com
[4] http://mi-lab.org/projects/penwar

The sketching device has implications on system design and user experience. Stroke properties that affect the interpretation process include the tip diameter/thickness, colour, and luminosity. Real world objects of different materials (e.g., organic, granular) can also be used to annotate a sketch and add content to it. This allows creating mixed media and collages of reality.

Display

Viewing the augmented sketch can be done using any *display device* used in AR, such as projection-based displays, monitors, handheld displays, and HMDs. Different displays provide different advantages for In-Place Sketching applications. For example, an HMD frees the user's hands for sketching, while a mobile phone provides mobility and ubiquity at the cost of limiting the scope of possible interactions.

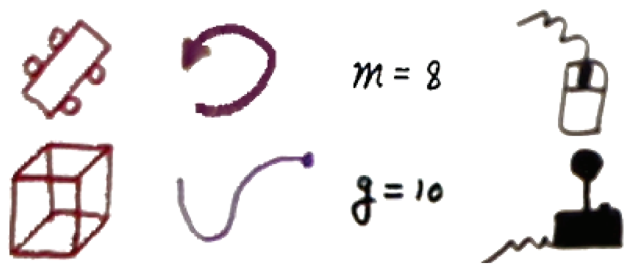
4.2 Sketch Interpretation

The sketch interpreter component of an In-Place Sketching system breaks the sketch content into basic elements, referred as *sketch elements*, or *sketchels*. It then infers their meaning according to the predefined set of visual language rules.

For different practical reasons, such as sampling and lighting conditions, image enhancement usually forms one of the first steps in the interpretation process. The next step will usually be rectifying the incoming frame in order to proceed with interpretation independently of the camera viewpoint relative to the sketch. This is done using the pose information provided by the registration solution.

4.3 Visual Language

The visual language of an In-Place AR application is defined as a set of symbols and rules that can be used to trigger different content creation and manipulation operations. The scope of the general concept of a visual language is beyond the scope of this paper. Here we focus on classification according to applicative rules that are useful for interactive AR applications, i.e., examining the nature of the virtual content it gives rise to.



(a) (b) (c) (d)

Figure 3. Different types of sketched content: (a) visual content (b) animation content (c) behavior content (d) interaction content.

The basic class of content that can be sketched is *(audio-)visual content*, whose main function is introducing virtual entities into the augmented scene. The creation methods of visual content span a *vocabulary-grammar* continuum ranging from the recognition of symbolic sketch elements to the generation of virtual objects according to geometric reconstruction rules. For example, Figure 3(a) depicts a sketched car that may cause the insertion of a predesigned 3D mesh into the virtual scene. On the other extreme, the box sketchel may be geometrically reconstructed into a 3D box, as proposed in [2]. Both discreet and continuous properties of sketchels can be used through scene construction. For example, the size and orientation of a recognized symbol can define the size and orientation of the corresponding rendered virtual model.

Common visual game assets that can be authored in In-Place Sketching games are environments (e.g., terrain and vegetation), urban content (e.g., buildings and roads), controllable objects (e.g., vehicles and cannons), game play content (e.g., collectables and health kits), characters (e.g., humans, monsters, and animals), and ambient elements (e.g., weather and lighting).

Another class of content is *animation content,* which causes visual content to change with time. For example, sketching a circular arrow, as depicted in Figure 3(b), may cause a virtual object to rotate around itself. A line emerging from a sketchel may define a path for its virtual object to follow.

Visual assets can be given different dynamic properties to be used according to the applicative context, e.g., physical properties for simulation and artificial intelligence rules. We refer to content of this class as *behaviour content.* Such content can define properties for specific virtual objects or for the entire scene. For example, the mass of a virtual object and the gravitation coefficient may be defined using the alphanumeric annotations in Figure 3(c), triggering simlation in runtime.

Sketched *interaction content* causes virtual objects to be controllable by user actions. For example, sketching the annotations in Figure 3(d) next to an object may wire the object or its properties to a mouse or a joystick, allowing the user to manipulate the object through the game.

4.4 Other Human Factors

Sketching and video games both generally require good eye-hand coordination skills. This requirement holds for In-Place Sketching games in a unique way. The separation between the sketching surface and the display surface, e.g., in the case of a monitor-based setup, has implications on user experience. The user's gaze may need to be switched back and forth between the two surfaces and increased coordination is required.

While sketching, the user inevitably occludes the sketching surface from the camera, which causes a visual conflict if the content is rendered over the sketching hand. We address this issue by rendering the content semi-transparently or in wireframe style.

An important design decision is the choice of AR device, which has impact on the *occupancy of the user's hands* while sketching. For instance, an HMD frees both hands for sketching and manipulating the sketching surface. On the other hand, a handheld display, such as a mobile phone, increases the mobility and ubiquity at the cost of limiting the scope of interactions.

4.5 Game Play

As in any other game, the game play itself defines the final factor of the user experience. An In-Place Sketching game can define a new game concept, or be based on existing game concepts, such as Capture the Flag or The Sims. Similarly to other video games, an In-Place Sketching game can be *synchronous or asynchronous*, as well as *collocated or remote*. In this paper, we focused on synchronous collocated games, where the two players sketch on a shared surface. In a different game, each user may be able to sketch on a separate surface, where only the generated shared virtual content is augmented.

In-Place Sketching offers different *game flows.* Specifically, the temporal interrelation between the sketching task and traditional manipulative tasks (e.g. using a joystick) participates in defining the final experience. Although various options are possible, several main ones can be identified:

Sketching then Playing: Players first sketch the game content and then play by manipulating it. For example, in the Sketchaser game described above, players sketch the arena at the beginning of each round and then manipulate it using the keyboard and joystick.

Sketching while Playing: Through the game, players alternate between sketching game content and manipulating it. Such games can involve, for instance, sketching and virtual manipulation that are limited in time. Another example can involve two competing or collaborating players, each performing one of the two tasks.

Sketching is Playing: The game play consists mainly of sketching activities. For instance, in a farming game the main task may be to design a farm solely by sketching.

The game flow can be examined with respect to Milgram's Mixed Reality Continuum [29], i.e., considering the tasks the users perform in the AR environment against the tasks performed in a purely virtual environment. For example, players can author game content in AR mode and play the game in VR mode, or the system can switch between these modes at different stages of the game, as in Sony's Eye of Judgment[5].

4.6 Tracking

3D pose estimation and tracking of the sketching surface allows registering the virtual content to it in every frame. Heavy-duty tracking solutions are highly accurate and insensitive to different environmental conditions. Vision-based methods are cheaper, less cumbersome, and ubiquitous. The most commonly used vision-based tracking solutions are based on fiducials. This comes at the cost of adding visuals unrelated to the sketched content. Natural Feature Tracking (NFT) methods, on the other hand, generally require training and heavily textured surfaces to operate robustly.

It is also possible to use a tracking solution that relies on the sketch itself. For this purpose, we developed *Nestor* [27], which is a shape recognition and pose estimation system for mobile AR.

5 Conclusion and Future Work

In this paper we presented our design space for developing In-Place Sketching applications, with attention to AR games. We described an In-Place Sketching game we developed to explore the In-Place Sketching design space.

In the future we will conduct a formal user study including different types of In-Place Sketching games, with special emphasis on the social aspects of collaborative experiences. In addition, we intend to introduce more prototype games and extend our exploration on the design space.

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