A Pen and Paper Interface for Animation Creation

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Abstract: We present a Sketch Based Interface that allows non-expert users to create an animation with sound from a drawing on paper. Current animation programs may be daunting for novice users due to the complexity of their interfaces. In our work, users first draw a sketch on paper. Such a sketch is then processed by our tool and converted to an animation that includes sound. We do this process by means of a predefined set of 2D symbols and words that represent 3D characters, animations, and associated sounds. We present three studies of the proposed system, one related to the accuracy of the recognition process, another on the convenience of our system, and a third on the effect of sound on the final animation.

1 INTRODUCTION

Computer generated 3D animations are usually created by experts because current animation tools require a lengthy training process. Although some approaches show promising results for novice users (Jeon et al., 2010), they still require access to a computer or a tablet, or expert assistance. Moreover, the scene composition and animation processes are time consuming tasks that require artistic skills in order to produce a visually appealing result. The main objective of this work is to enable a larger group of people to enjoy the excitement and fun of creating animations, even without proper access to a computer during animation editing. This is particularly suitable for classrooms where not all students have a computer, or moments when the use of a computer may be inconvenient.

This paper presents a technique to ease the creation of 3D animations. Users create a sketch with a pencil and paper that follows some basic rules. Such a composition is scanned and processed in order to identify characters, animations, and sounds. Once these elements are identified, a movie with such an animation is produced and sent by email to users. Due to the minimalistic nature of this interface, simple drawings can be converted into simple animations without passing through the complex and tedious learning process required for specialized software such as Blender (Blender Foundation, 2011) or Maya (Autodesk, 2011). An example of this approach is shown in Figure 1. A simple drawing (Figure 1a) can be processed to produce a 3D scene (Figure 1b). Users need only draw predefined symbols, action words (e.g. WALK, RUN, JUMP), and animation trajectories in order to create appealing animations. Expert animators are required only for the initial creation of the models and their animations, while non-expert users can compose these models and mini-animations into animated 3D scenes.

Previously, in (Wilches et al., 2012), we presented an initial prototype of this approach with a small set of symbols and a different system for animation generation. In this work, we have included sound in the final animation and have greatly improved the symbol recognition rate (from about 40% to 84%). We have also included animated characters from the open movie Big Buck Bunny (Blender Foundation, 2008), so the resulting animations are more interesting. We have improved our user interface, and we have done more tests and user studies on our approach.

Sound is an important element in animations. We take into account three main elements for sound treatment (Ulano, 2012): classification, authenticity, and synchronization. In terms of classification, we follow the most simple system that classifies sounds in an animation into three categories: environment sound, voices, and sound effects (commonly known as Foley effects). As we will describe in Section 4.3, our system incorporates these three types of sound into a generated animation. In terms of authenticity, we reuse algorithms for sound generation from Blender

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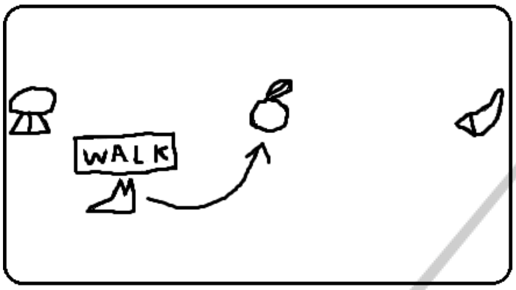
(Blender Foundation, 2011) that localize a particular sound in a 3D scene and modify its characteristics according to its distance to the camera. We also describe in Section 4.3 how we add information to a final composition in order to synchronize special sound effects with animations.



(a)

(b)

Figure 1: (a) Sample of a 2D sketch that represents our proposed interface. The arrow extending from the squirrel represents movement towards the apple. The word enclosed in the box indicates the action that the squirrel performs while moving. (b) Initial frame of the 3D-animation resulting from processing the image shown in (a).

This paper is divided as follows: In Section 2 we present present the works most related to our own approach. In Section 3 we describe the components and intended uses of our interface, and provide examples of its use. In Section 4 we describe the pipeline developed to implement this interface. In Section 5 we present the results of both a performance test and a user study of our tool. Finally, in Section 6 we present conclusions and areas for future improvements.

2 RELATED WORK

Our work is related to previous results in the areas of sketch-based interfaces for modeling (SBIM), sketch-based interfaces for animation (SBIA), and sound for animation and interaction. Results in field of SBIM include techniques to capture sketches and recognize a user's intent in his or her drawings. SBIA has found ways to describe movement by means of a sketch of still images. Sound is an important element in any animated film or interactive application, but is sometimes forgotten or ignored. We discuss here a classification of sound in film and animation, ways to categorize sound, and some previous results that incorporate sound for animation or interaction.

2.1 Sketch Based Animation

There are many offline systems that can turn a sketch into an animation. Davis et. al. (Davis et al., 2003) developed a system where a 3D animation of an articulated human is generated from a sequence of sketches representing different keyframes in the animation. Although this represents a powerful system for the creation of animations, we decided to use an even simpler approach for novice users, in which symbols in a drawing depict characters and words depict prerecorded animations/actions. This saves users from the burden of describing an animation in detail.

The system in Jaewoong Jeon et. al. (Jeon et al., 2010) allows novice users to specify the camera position and orientation, a character's path, and a character's posture by means of an input sketch that identifies possible 3D poses from a database.

Masaki Oshita et. al. (Oshita and Ogiwara, 2009) propose an interface for controlling crowds. The system estimates a crowd's path from a user defined sketch. In this way, users can control a crowd's path, moving speed, and distance between characters. Our approach does not consider crowds yet: every single character and its trajectory is individually defined.

Other important approaches can be found in real time animation systems. In Motion Doodles (Thorne et al., 2007), users define a route for a character by drawing a continuous sequence of lines. Arcs and loops represent the location, timing, and types of movement that such a character can perform.

Igarashi et. al. (Igarashi et al., 2005) show how users can deform a 2D shape represented as a triangle mesh. Inside such a mesh, users define and transform control points, while the system repositions the other vertices and minimizes distortion. All these systems focus on manipulation of a character.

We want to allow users to create an entire scene. Due to the focus of our research - in which we emphasize ease of use in the creation of an animated scene over the expressiveness of individuals characters - the control given over a particular animation is more limited in our system than in these works.

2.2 Sketch Based Modeling

A variety of real time constructive systems have been developed that enable the creation of 3D models given 2D sketches. Igarashi et. al. (Igarashi et al., 2007) describe a system to create 3D models from 2D contours. Since a 2D sketch is naturally ambiguous in 3D, such systems have complex heuristics for transforming 2D into 3D.

Karpenko et. al. (Karpenko and Hughes, 2006) propose a system that is able to reconstruct a 3D model from 2D drawings. In their method, a user draws some lines that correspond to a model's outline and their system infers hidden contours and creates a smooth, solid 3D shape from them. In (Nealen et al., 2007; Rivers et al., 2010; Lipson and Shpitalni, 1995; Lipson and Shpitalni, 2007), user-drawn strokes are applied to a 3D model surface and serve as handles for controlling geometry deformations. Users can easily add, remove or deform these control curves as if working with a 2D drawing directly. While those systems reconstruct 3D models from detailed strokes, our system uses shapes to retrieve 3D models from a database; i.e. 3D models and 2D strokes do not need to have similar shapes.

In methods proposed by Lee and Funkhouser (Lee and Funkhouser, 2008) and Yoon and Kuijper (Yoon and Kuijper, 2011) users draw sketches to retrieve 3D models from a database. Our work uses a similar concept to retrieve objects from a database, although we retrieve complete models and animations, instead of just model parts. In addition, the symbols in our system are very simple and abstract representations of the 3D characters and their actions.

2.3 Sound for Animation and Interaction

There have been several works that incorporate sound into sketch based interfaces. Chiang et. al. (Chiang et al., 2012) create an interface that reproduces musical notes from user defined strokes. Lee et. al. (Lee et al., 2008) present a pen that recognizes strokes and reproduces prerecorded sounds. Although the question of how users can control sound in an animation is an interesting one, we decided to implicitly incorporate sound into the animations and the overall generated scene, with no particular control from the user's point of view. This approach keeps our interface as simple as possible, while at the same time enabling the creation of interesting animations complete with sound. Future work will study ways to explicitly describe sound elements in a scene.

3 INTERFACE DESCRIPTION

Figure 2 shows the interface of our system (Rodriguez et al., 2013). First, we ask users to either upload a new scanned sketch into our system or select a previously uploaded sketch. Our system then shows a still preview in which a user can see the overall composition from the position of the camera, complete with predefined scenery and the characters identified by the system. If a user is satisfied with such a composition, he or she can ask our system to generate the entire animation. In that case our system asks for an email address in order to send a link to the final animation file.

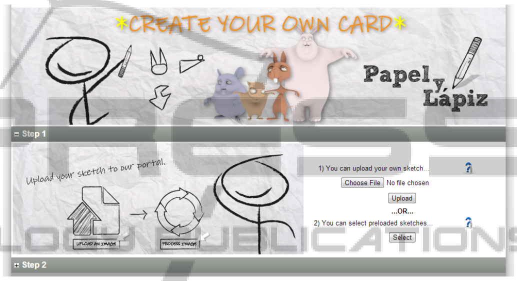


Figure 2: Web Interface of our Tool for Animation.

Three types of elements can be drawn in a sketch: object symbols, actions, and arrows. Object symbols represent 3D characters in a scene, actions are words that identify a particular animation for a 3D character, and arrows describe paths that characters should follow in the animation. Predefined sounds are associated with the scene, 3D characters, and their animations - as we will describe in Section 4.3 - and are automatically added to the animation without any particular input at the sketch level.

Some restrictions should be taken into account while drawing:

1. None of the symbols may overlap with others.
2. An object symbol must have at most one arrow.
3. An object symbol must have at most one handwritten word.
4. Handwritten words must be spelled in uppercase, and surrounded by a rectangle.
5. The composition must be drawn on plain white paper without grid lines or other designs.

3.1 Object Symbols

Object symbols are abstract representations of 3D characters in the scene. They are simple shapes that convey some resemblance to the 3D character they represent. Their main purpose is to identify a particular 3D character in a scene in a desired position.

Current object symbols and their corresponding 3D objects can be seen in Figure 3. These symbols were chosen with the following guidelines in mind:

- Symbols should be as simple as possible for ease of drawing;
- Symbols should be meaningful for users to reduce the time spent looking up symbol associations;
- Symbols must be sufficiently different from one another to facilitate the symbol recognition process, and
- We consider a box to be a reserved symbol for the purpose of enclosing text for actions (see WALK in Figure 1a). Such a symbol can not be used for other purposes.

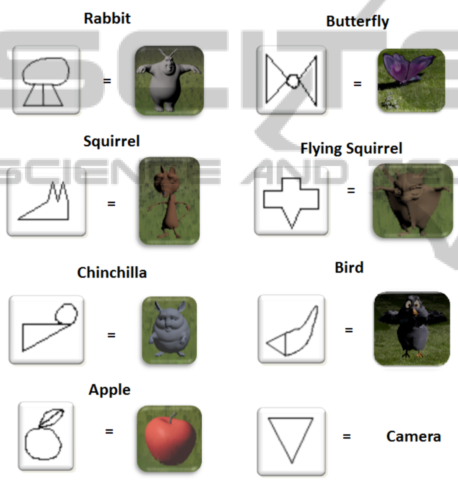


Figure 3: Object Symbols and their corresponding 3D objects.

Object symbols can be drawn anywhere in a sketch, and they can be used as frequently as desired. Consequently, the amount of object symbols in a sketch is only limited by practical considerations such as the size of the paper and computer memory.

3.2 Actions

Describing an action in a simple sketch can be a challenging task (e.g. drawing a sketch for jumping). In order to support novice users we decided to prerecord several animations for each 3D character, and use simple words such as "RUN", "JUMP", or "WALK" to execute such animations. In order to associate an action with an object within a scene, the name of the action must be enclosed within a box next to the object (see Figure 1(a)). Proximity is used to associate action with object symbols in the scene.

There is also a default action defined for each object symbol. In this way, if there are no specific actions in a scene, a default animation will be selected for each 3D character.

3.3 Arrows

An arrow represents a movement path for a 3D character. The 3D character closest to an arrow's tail is associated with the described movement, and it will follow such a path in an orientation tangent to the arrow. Since sketches are drawn from above, an arrow specifies the XZ movement of a 3D character, while the Y component is determined by the ground, currently a plane.

4 SYSTEM IMPLEMENTATION DETAILS

Our system performs the following four tasks in order to generate a new animation from an input sketch: input denoising, segmentation and interpretation, sound generation, and animation generation. Input denoising cleans as many artifacts from the scanned sketch as possible. Those artifacts come from the scanning process or from the original sketch. In the segmentation and interpretation task, our system separates elements in a sketch so they can be matched against predefined symbols. Once elements are separated, our system identifies them as object symbols, actions, or arrows. Sound generation enriches the interpretation of a scene with all the sound elements that such a scene might have. Finally, animation generation deals with the creation of both an initial screenshot and the entire final animation.

The details of each task are described in the following subsections.

4.1 Input Denoising

Once a drawing is made on paper, it must be transformed into a digital image and passed into our system. This transformation can be made, for instance, by scanning the paper sheet or capturing it through a camera. However, these capturing processes could create noise that could affect the segmentation of elements in a sketch, such as paper imperfections or problems with color balance. To deal with common noise issues our system applies a filter to remove small objects (15x15 pixels or less). Our system then scales the image's histogram, in order to better handle too dark or too light images. Then it applies a mean filter on the processed image, thus removing some of the noise. Finally it applies a threshold filter using

Otsu's method (Otsu, 1979). We have found that although there are still some noise artifacts in the images after applying these filters, the remaining noise artifacts are filtered out as unrecognized objects by the pattern recognition algorithm thus the generated animation is not affected.

4.2 Segmentation and Interpretation

After constructing a gray-scale, nearly noise-free image, our system proceeds to extract connected components and assign a unique label to each one. We first separate all boxes and the components we find inside them, which we assume to be words. Our system then attempts to match each component against the predefined symbols in Figure 3 using the Angle Quantization Algorithm (Olsen et al., 2007). If a component does not match any object symbol, our system determines whether or not it is an arrow. These techniques are described in further detail within the following subsections.

4.2.1 Box and Object Recognition

In order to recognize object symbols from the set of all components, the angle quantization technique proposed by Olsen et. al. (Olsen et al., 2007) was implemented using k = 16 bins. As per the work's suggestion, one-pixel thinning and point tracker filters are applied before using Angle Quantization. Boxes are treated similarly to any other symbol, but they are recognized first so that the text inside them may be filtered from the composition. Such text is handled differently from other symbols.

The segmentation of a drawing into different elements makes the angle quantization algorithm more accurate. As a result, the comparison metric (Euclidean distance) between two features becomes more precise, allowing the use of an experimental metric as low as 0.02 in order to identify two features as similar. We compute such a comparison metric between a feature in a drawing against all symbols in our system. The symbol with the smallest metric value is chosen as the feature's corresponding symbol. Elements that do not fit this criteria fall in the set of possible arrows.

4.2.2 Words Recognition

We apply a standard OCR system to all words enclosed in boxes, identified in the previous step. In this implementation, Tesseract OCR (Tesseract OCR, 2011) was used. Having recognized an action's name, the system checks if the 3D character closest to the surrounding rectangle has an action with that name and then executes it in the final composition.

4.2.3 Arrows Recognition

Every object recognized as neither a word nor a 3D character is considered a possible arrow. To determine if the object is indeed an arrow, our system applies a thinning filter and then determines if the thinned-object is composed of three segments, three end-points and one intersection point as seen in Figure 1(a). Any thinned-object meeting these criteria is recognized as an arrow and the longest segment is followed to determine the trajectory such an arrow represents.

4.2.4 Scene Composition

Once all the symbols in an image have been identified, all that remains is to generate an animation from those symbols. For this, our system places the 3D characters in their initial position according to the objects' position in the sketch. Information regarding the path (arrow) and animation (action) the 3D character must perform are now processed.

If the camera symbol is present in the composition, our system determines the initial camera's position and orientation from the one present in the sketch. If the camera symbol is not present in the sketch, we compute the bounding box of all 3D characters in the scene and then we position the camera according to the following heuristics:

- The camera's X coordinate position is located in the middle of the bounding box.
- The camera's Y coordinate position is located at 4 units, which corresponds to the tallest character in our scene, and with an inclination of 15 degrees below horizontal.
- The camera's Z coordinate position is located in the middle of the bounding box, minus a fixed and experimental offset value (12.0) to move the camera away from the actors. In this way, the camera captures a good portion of the scene.

It has to be noted that the coordinate system in considers the Y axis to point up and the Z axis to point towards the screen, in a left handed system. We also define the entire scene to be 16 units wide (in X) and 8 units deep (in Z). Our system generates an XML file describing the identified elements within the scene, for readability and loose coupling to our animation system. This file contains all the symbols that were recognized by the system, the paths they follow and the actions they should perform. This constructed file acts as the input for subsequent phases in the system's pipeline.

4.3 Sound Generation

Sound generation in our system is achieved by a combination of predefined elements, algorithms that enrich a scene, and the use of existing tools. Besides a basic scene, 3D characters, and their animations, our system takes as input a set of prerecorded sounds classified as one of the following three types: environment sounds, voices, and Foley effects. We associate these elements to other elements in our system: the environment sounds to our scene, voices to particular animations of our 3D characters, and Foley effects to the scene and particular animations. Particular care is taken in the timing for voices and Foley effects so they emphasize the action in their corresponding animations.

After all 3D characters and their animations are identified in the scene interpretation and composition stage, we execute a basic algorithm that creates a score of all corresponding sounds in the scene by traversing the scene elements and identifying sounds and timing constraints. We use FFMpeg (Bellard, 2012) and Sound Exchange (SoX) (Bagwell and Klauer, 2013) in order to prepare sounds for the final composition, i.e. creating a long version from a loop sound in the background. The result is an enriched XML file that instantiates sounds for particular animations, including play times for such sounds.

4.4 Animation Generation

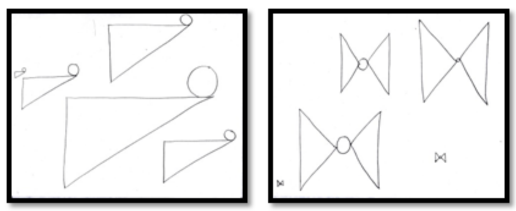
We developed a Python script in Blender (Blender Foundation, 2011; Python Software Foundation, 2013) that reads an XML script file and generates a 3D animation. Blender uses information contained in the XML file to appropriately configure the camera, load the characters' 3D models in their specified positions, and associate animations and sounds. Since a composition is drawn from a top-down perspective and our scene's ground is currently flat, all the elements are placed in the XZ plane, leaving the Y component at 0 (Y representing the height). All 3D characters are initially oriented towards the camera, except for those characters that have trajectories, which are oriented towards their direction of movement. This is accomplished by calculating the angle between the current position and the next point in a path, and updating a character's direction. This calculation is performed along the trajectory of movement, and is embedded within the XML file. Finally, a Python script in Blender reads the score produced in the previous stage and incorporates sound effects into the final animation.

5 RESULTS

We performed a performance test and two user studies on our system. Our performance test measures the rate of errors in our pattern recognition system. Our first user study compares the ease of use between our system and traditional methods for animation creation. Our second user study examines the effect of sound on the users' acceptance of the animation.

5.1 Pattern Recognition Accuracy

To test the accuracy of our current implementation, we recruited 15 students in our University to perform a stress test. The average age of these users was 29.6, ranging from 18 to 37 (three undergraduate students and twelve graduate students). They were asked to draw three of the nine symbols, five times each, with differences in size but not in orientation. Examples of such drawings are shown in Figure 4. We balanced the number of sample sheets drawn for each symbol such that we received 5 different sample sheets per symbol. We then proceeded to scan the papers in order to test our recognition software with a consolidated database of 225 repetitions in total. None of the students claimed to have difficulties while drawing these symbols. To assess the accuracy of our system we took each one of the 225 symbols and asked our system to identify it. The average image size used as input was 2700 x 2200 pixels. Figure 5 shows the number of successfully and unsuccessfully identified symbols, categorized by symbol. 50% of the unsuccessfully identified symbols were recognized as another symbol whereas the other 50% went totally unrecognized. The main sources of errors in this process were gaps between lines in a symbol, but further studies have to be developed in order to fully characterize these errors. We can observe that the most problematic symbol is the bird, but with a success rate of 76% we consider it good enough. Overall, we have a success rate of 84% in the identification of symbols.



(a) (b)

Figure 4: Test drawings made by a graduate student on (Only two sheets are shown) different sheets of paper. Our proposed symbol of a Chinchilla (a) and Butterfly (b) was drawn 5 times at different scales of size throughout the whole space using only a pen.

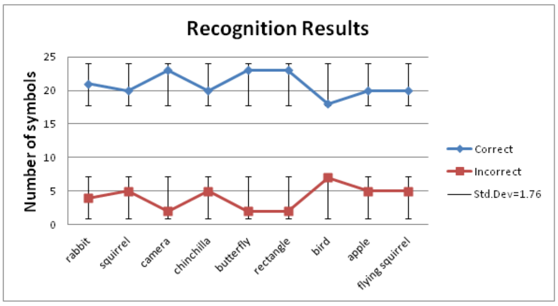


Figure 5: Recognition results for all symbols. Approximately 21 out of 25 symbols are recognized correctly with our system.

5.2 User Study: Blender vs Sketch-based Interfaces (SBI)

In order to test how convenient and straightforward our system is, we performed a user study that compares it versus a guided creation process in a conventional animation tool. We recruited 8 students from our University, seven undergraduate and one graduate student. The average age of these users was 21.1, ranging from 18 to 32. Six out eight had never heard of our SBI system. Subjects were asked if they happen to know Blender, and only one of them answered affirmatively. Only three people had made an animation using a computer with Flash, and they claimed to have spent at least 4 months in order to learn how to use it. We asked our participants to create a 3D animation, both with our system and with Blender. Before each trial subjects received a short tutorial on how to use the tool. In the particular case of Blender, we developed a step by step video that showed subjects how to perform the task. The Blender test consisted of exploring the files in the Big Buck Bunny movie, then creating a snapshot of the Bunny on top of a ground as seen in Figure 6 (a). In the SBI test we encouraged the students to draw our Bunny symbol and upload it to our web-based tool, in order to create a similar snapshot (Figure 6(b)). After each trial we asked subjects to answer some questions regarding the creation process in that tool. We counter balanced the use of our system and Blender in order to minimize possible bias due to order of exposition.

We asked subjects to evaluate the difficulty (on a scale from 1 to 7: 1 being difficult, 7 being easy) in producing an animation (question 1), using the software as a whole (q.2), and loading characters (q.3). Figure 7 shows the results for both our tool (SBI) and Blender. In general our system was considered easier than the Blender based process.

At the end we asked subjects what was the most difficult part of creating an animation with Blender.

(a) (b)

Figure 6: (a) Snapshot of an image produced following the tutorial for Blender. (b) Snapshot of an image produced following the tutorial for our SBI system.

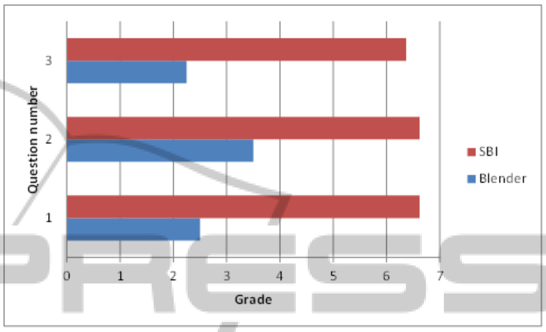


Figure 7: Results from questionnaires.

Most of them said that there were too many steps and they were not easy to follow. Finally, all eight subjects agreed that the rabbit symbol was quite easy to draw.

5.3 User Study: Sound

The sound generation evaluation was performed by presenting two different videos to a group of 18 people that were asked to answer 3 questions related to the characteristics of sound. The first video was generated with the SBI tool without any sound and the second one was composed with the sound generation system. We asked participants if (1) the sounds matched the scene, if (2) sound helped them better understand the scene, and if (3) they prefer the scene with or without sound. After results were gathered, there was some evidence that people prefer to watch these animations with sound, because it helps them focus on the story and the scene.

6 CONCLUSIONS AND FUTURE WORK

We have presented a tool that allows non expert users to create animations by drawing a simple scene on a sheet of paper. Users create a composition on paper, scan the composition, and our system creates a corresponding animation with basic sound effects. We leverage 3D characters from the Big Buck Bunny open movie in Blender, so our compositions look professional despite the basic information given by users. Tests we have performed in our system evidence an 84% success rate in symbol recognition, and a good level of acceptance from our users.

Future work will focus on enriching the input vocabulary in order to express timing constraints, different background scenarios, and special sound effects. We would also like to facilitate the creation of more complex stories, and integrate this tool into the production lines of other types of digital media.

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