Papimation: A Symbol System for Children to Animate Their Drawing

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Abstract. Drawing for children is an intuitive way to express themselves. But the static property of paper drawing and children's shortage of expressive words limit them. Animating children's drawings could break the static state into a dynamic one and help them to convey ideas. However, the complex animation process is difficult for children to understand and correctly use.

So, in this paper, we present Papimation, an animation symbol command system for children to achieve animation effect on their drawing by themselves. We conducted three user studies to design and evaluated it. Progressively we investigated the possible motion that children intent to achieve, generated understandable and accessible animation symbol command vocabularies for children, and evaluated the feasibility and enjoyment of our system. Results show that children achieve high agreement in our system and could learn and use them with ease. Our system gave more play to children compared with only drawing.

Keywords: Drawing · Animation · Symbol command

1 Introduction

Drawing on paper is the most intuitive way for children to express themselves. No matter how messy children's drawings are, there are stories or ideas conveyed. What matters is not the final artwork they draw but the idea or story they express through drawing. The act of drawing is a dynamic process however the end product is static in paper or digital interface, making it hard to convey their idea fully. Animating children's drawings as they wish could largely diminish the static state of drawing, at the same time express children's ideas more clearly and visually dynamic. We think this would help them greatly in imagination, self-expressing, and fun play.

However, there are few opportunities for children to make animation by themselves because of the complexity of animation making. So, we introduce the neo smartpen

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technology and augmented paper to our system to achieve drawing on paper while synchronizing the draw in the digital platform to break the traditional static paper drawings while preserve the affordance of paper drawing for children.

In this paper, we conducted three user survey studies to analyze and design the animation symbol command system to help children animate their drawing for better expression and fun play.

The main contributions of our work are:

1. exploring the possible symbol command that is understandable for children to achieve basic animation movement.
2. contributing the Papimation system which was valued by participants for its feasibility and attractive property.

2 Related Work

2.1 Drawing

In this paper, we refer to children's drawings because it is the most intuitive way for children to express their ideas and stories. Einarsdottir J, Dockett S and Perry B [1] stated that children's drawing is a way for them to express their idea and experiences. Malchiodi and Cathy A [2] conclude the children's drawing development, children's drawing become more and more concrete and start development of visual Schemata in their 6–9 years old. In this scope of age, children were stated to have the most willingness and capability to draw to express themselves. That's also why we choose children in this age group as our participants.

One drawback of paper drawing is that the image is static, but the children's expression has its limitation both in words and drawings. Many researches are dedicated to introducing multiple dimensions of expression for children's drawing. Jabberstamp helps evoke children's ability in talking by introducing voice and sound recording in children's drawings [3]. But voice still has its limitation in display children's dynamic idea since not all children are good at vocalizing their imagination out. Jacoby and Buechley [4] use conducted ink for children to draw and enable voice record once conducted ink linked with slots attached on paper. Conducted ink is an intriguing way in children's the drawing. But again, voice is not dynamic enough for children since some children are not expressive enough.

So in this paper, we integrate animation into children's drawing, hoping that the dynamic of animation could help set off drawing's static and thereby help children in learning and better expressing their story.

2.2 Animation

Animation is a broad subject. For children, as we researched in the last section, hand drawing is the most intuitive and ubiquitous way for children to express themselves, so here we mainly focus on animation that drives hand-draw object moving.

Momeni A and Rispoli Z [5] introduce a real-time animation control on drawing or pictures by hand gesture which required a lot more equipment setting and lacked access

to the non-expert and younger users. So, they developed a new version that only required a smart tablet [6]. Their method to animate drawing is by hand gesture while ours is by symbol command in the paper interface, the advantage of ours is this may realize multiple objects animate in the same time to form a harmonious animated picture.

Besides the animation achieved by hand gestures, some achieve the animation effects by strokes as well. Motion doodles [8] are the motion sketch that works as a trajectory to direct characters' motion which was quite similar to our intention to use symbol stroke to animate the sketch. While the difference is that their motion trajectories were delicate in differences which are way too difficult for children to control their stroke that precisely. Davis J, Agrawala M, Chuang E, et al. [7] created a rapid 3D figure animation by drawing 2D keyframe poses. which is different from our 2D drawing oriented animation for children. Among all the stroke-driven animation, Yonemoto S's [9] work is the most similar one to ours however. Their work mainly aims for novice animators and it's controlled in a computer which is not fit with children's intuitive preference to drawing on paper and the operation are not very explicit for children.

Besides passive driven animation, Lingens L, Sumner R W, Magnenat S [10] described a system that could automatically animate the drawing however its animation process performs deformation a lot which might frighten children as they mention in their paper. Besides, it is automatic animation so it is not controllable like ours.

There are also many commercial products to help novice users make animation such as stykz [11] pencil 2D [12] and FlipaClip [13]. But these are difficult and time consuming for children in general.

Based on previous research and inspiration, animating children's drawings is a promising field to help children express their idea. So, we present the animation symbol command system which enables children to transform their paper drawing into digital animation themselves.

3 Symbol Command

Inspired by the finding in the research stating that children tend to draw arrows or lines to indicate the direction of their drawing subject's motion [14], we thought about using such indicative symbol in children's drawing and let children's drawing moving like they imagining by themselves.

To accomplish children's usage of the animation symbol system, we need to take children's drawing habits, their ability of learning and understanding, and their anticipation into account. We summarized the following design goals for the system design:

- Easy to understand and use: the system needs to be simple enough to present in front of children so that it costs children little to learning, understanding, and memorizing
- Combine with children's drawing habits: children's drawings are creative and nothing should limit their freestyle in drawing.
- High agreement: the symbols need to obtain children's high agreement while being used by them.

Following these principles listed, we need to solve the following three key questions:

- what kind of animation/motion effect that children want to express in their drawings?
- what type of symbol can children understand and recognize with ease?
- how to achieve the corresponding animations accurately, when children draw the symbols?

To solve the questions above, we carried out three survey studies accordingly through which we extracted the motion that children want to express, explored what kind of symbol children will achieve high agreement, and finally analyzed system accessibility (see Fig. 1).

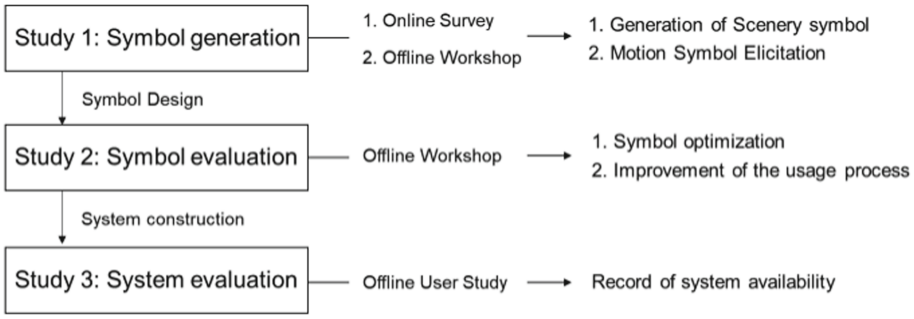


Fig. 1. The workflow of three studies

4 Study1: Symbol Generation

The goal of this study is to solve the first question. We first started online research to analyze drawings of children age 6 to 9. Then we conducted an offline workshop to test which animation operation children would understand and likely to use. Comparing the online and offline analysis, we analyze the most commonly used element in children's drawing, extracted the scenery symbol stroke, and understood what type of animation effect children can understand and have willing to do.

4.1 Generation of Scenery Symbol

To understand what kind of motion children want to express. We collect 435 drawings of children (aged 6 to 9) from the internet. Two researchers analyzed the drawing by looking into what type of motion children has expressed in their drawing and what kind of element they use to express it. Table 1 shows the result.

Table 1. Motion and the element used to express the motion

Motion	Element to express
Fly	Bird, butterfly, balloon, kite, airplane, spaceship
Fall/drop	Snowflake, raindrop, cloud, the trajectory of fallen leaves
Float	Boat, bubble, curvy stroke, cloud
Swim	Fish and bubble
Flow	The wavy line for water/river flow, dot, and lines
Run	Athletic track, running people, multiple lines, curvy line
Drive	Car, multiple lines, the spiral line for gas
Wave	Figure hands up, wavy line
Wiggle	An object that leans to the other side like flowers and tree
Speak	Dialog box
Smile	Smiley faces
Blink	Star, moon, wink eyes, sun

From Table 1 we found that besides different types of lines that children use to express emotion, the property of certain objects is another way to show motion such as sun and star in the sky, raindrop, snowflake, smoke from a chimney, etc. Therefore, we list the most frequently drawn item that can indicate motion (see Fig. 2). We categorized them as scenery symbol which defined as a set of sketch item that has its own motion property and acts as decoration in children's drawings.

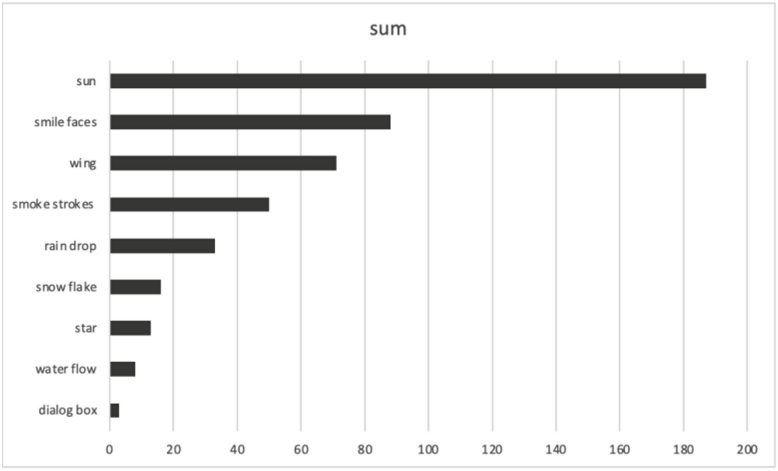
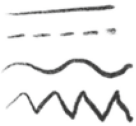


Fig. 2. The top 9 items drawn in children's drawings.

We further conclude the basic stroke that children used in the drawing set we gathered (see Table 2). Besides that, we could not summarize more symbol information because children's stroke is so random and not all of their drawings have motion stroke.

Table 2. Basic element stroke children used in their drawings.

DOT	
LINE	
SHAPE	

4.2 Offline Workshop: Motion Symbol Elicitation

As children at a young age have limited words to express and their drawings are too different to summary the common symbol. We tried to identify what kind of motion children could understand and like to use.

To obtain the possible motion, we refer to 18 animation operations that K-sketch system [15] concluded. Among which, we ruled out 6 that are too difficult for children like set timing, interpolate and move relative, etc.

We recruited 12 children (8F/4M) from the local neighborhood and school with an average age of 8.2, two participants a group. All of them have drawing experiences in school but none of them experienced making animation. We demonstrated the left 12 animation operations effect with 12 short video clips showing the animation effects of the operations. The animation effects were demonstrated by the element we summarized in study 1 (see Table 1). We showed each video clip to participants and encourage them to describe the motion. After that, children were asked to rank their degree of understanding of the motion and the possibility of using it in their drawing again. We provided the emoji to help them valuation. There are three levels smile face (stands for positive answer) none expression (stands for average answer) and a sad face (stands for negative answer).

4.3 Result

We calculated the 3 emoji faces from children's feedback for the degree of understanding and possibility of using the motion again. Figure 3 shows the result. Base on the children's rate and feedback we choose the following animation operations (see Table 3) that are more understandable and likely to be used in children's drawings according to their feedback.

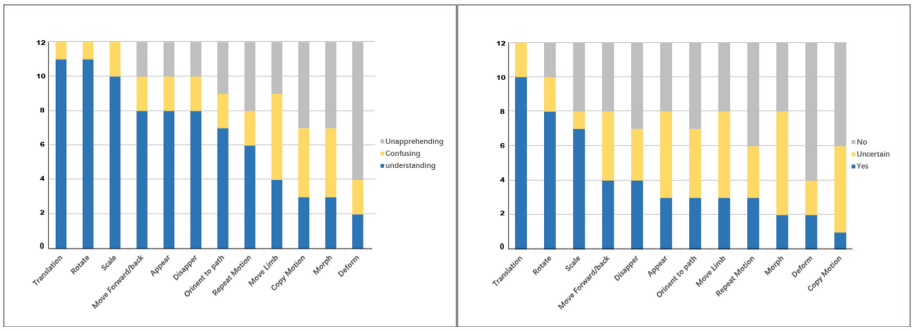


Fig. 3. Understanding of motion feedback (left) and likability of using the motion (right)

Table 3. Motion and the element used to express the motion

Animation operation
Translate, rotate, scale
Appear, disappear
Repeat motion
Move back and forth
Orient to path

4.4 Symbol Design

After the online and offline study, we tried to design the motion symbol by integrating the basic element (see Table 2) to express the motion effect that was proof understandable and possible to be used by children. The design of the motion symbol must be simple and easy to understand by children. Figure 4 shows the design process. All symbols will be listed in the next session after symbol evaluation.

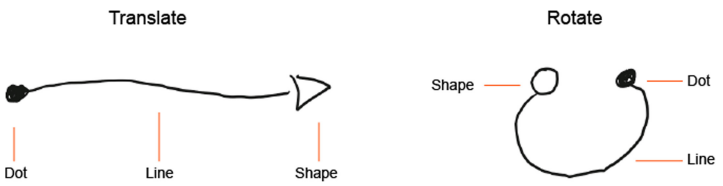


Fig. 4. The design of symbols command.

5 Study 2: Symbol Evaluation

5.1 Symbol Evaluation Workshop

In this study, we aimed to evaluate the motion symbols whether it is understandable for children to use.

We recruited 10 children (5F/5M) with an average age of 7.6 from local families and neighbors. They participated with their parent's consent. Participants were surveyed in pairs and each session were recorded. Each pair were firstly given an introduction of the motion symbols. Then they would be asked to try to use the symbols to draw in pictures we gave them and describe the motion they drew.

In the introduction part, to explicitly explain the function of a symbol without technical involvement yet (we use PowerPoint here to demonstrated). Each motion symbol was shown with an example object. After the symbol applied to the objects, the object would move as the symbol defined (on next slides). To help participants identify drawing stroke and symbol stroke, we use different colors to indicate them, black color for drawing stroke and red color for symbol stroke. The Combination of different drawing objects in the same pictures is also demonstrated in two comparing slides, one was before adding the static symbol, the other was after adding the symbols in which the picture is animated. These example usage of the symbols at the end were working as a guideline and visually extend to show how this symbol would work.

After the introduction of the motion symbols, participants were given several already drew sketches which are all sketches accessible in children's recognition like animals and scenery sketches. They need to use the red pen we provided and draw the symbol stroke on to these semi-construction sketches according to what motion they want to achieve. When participants were drawing, all the symbols drew in square cards were shown in front of them. The intention to do so is what we want to explore is whether children could use the symbol as they wish, while not require them to remember all the symbols. When they finish drawing motion symbols, researchers encouraged them to describe what kind of motion they want to express by using the symbols. We measured whether the symbol is understood by participants by two standards. First, if participants could draw the motion symbols correctly, and Second If they express it with the right motion effect.

Finally, we asked children to comment on the experience to use the symbol strokes. We encourage them to comment by using the semi-constructed phrases, if only, the experience will be perfect. Figure 5 shows a peek of study 2. Participants were welcome to drawing new pictures themselves (in black pen) and use the symbol command (in red pen) to express the dynamic of the drawing.

5.2 Result

In general, the feedback of most group was positive, many children expressed their interests and curiosity in the introduction part and convey a willingness to animate their drawings after the semi-construction session. However, we also found some problems:

Fig. 5. A pair of participants listening to researches introduction of the symbols (left), and drawn symbols by themselves (right) (Color figure online)

- there are some preferences on certain motion symbols, compared with other symbols, translate is the most used symbol. We assume that is because the symbol is most intuitive and convenient for every drawn object.
- two participants had a confused understanding of "Orient to Path" and translation for its precise differences.
- symbols with more strokes more inclined to evoke error drawing. 3 younger participants misusing the motion symbols with less stroke in.

According to the feedback from the participants, we adjusted and redesigned motion symbols as Fig. 6 shows.

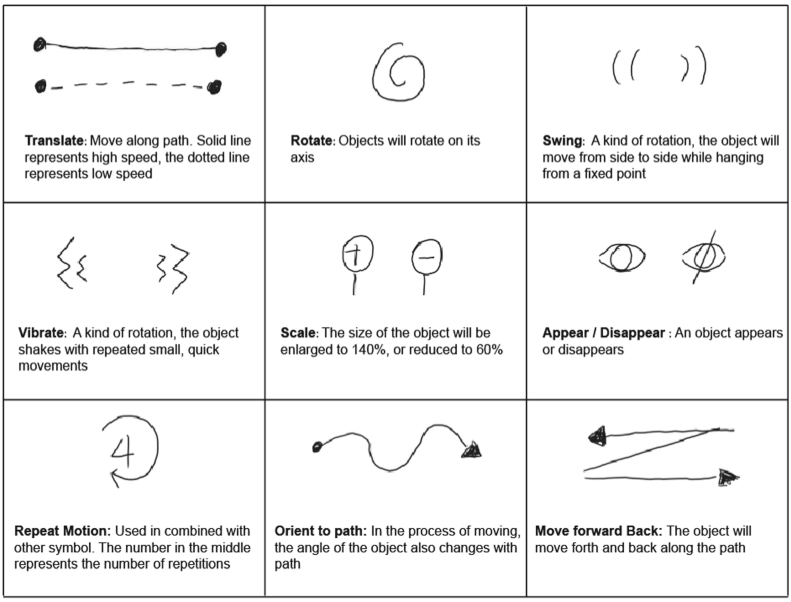


Fig. 6. The motion symbol command we iterated after study 2.

Other Advice. Participants also give us very precious feedback about their experience.

Children's Worries. 4 participants express their unwillingness to add symbol to assign any motions because they afraid it would ruin the drawings

Colors in Drawings. More than 5 kids ask for a more colorful pen to drawing since we only provide a black pen for them to free sketch at the end of the study.

Unexpected Mistakes. Most participants encounter mistake stroke. They unexpectedly star the wrong sketch and ask researchers for help stating that the stroke wasn't their intention. In the other situation, some younger participants forgot to use different color pens to draw the symbols which also drew our attentions.

6 Study 3: System Evaluation

6.1 System Introduction

Hardware. We use Neo Smartpen [16] and augmented paper with special dots pattern (Ncode [17]) as our input devices. With the help of the IR cameral embedded inside the smartpen to trace the sketch in dot patterned paper, users' sketch in the paper could be synchronized to digital display in real-time. Through this way we could preserve the quality and enjoyment of paper drawing for children while accomplishing dynamic animation effects which would fulfill children with a sense of satisfying and accomplishment for drawing and animating all on their own.

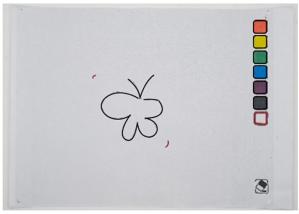
Base on the participants' feedback from study 2, we redesign the paper interface with the help of Ncode [17] to assist children to obtain multiple colors and other additional and necessary functions we found in study 2. We add 5 more color selections on the paper interface and one extra square outline with red color to indicate the symbol command used only. We also add an eraser icon on the paper interface for the sake of error symbol input. In terms of pen fill, we prepared them colorful pen fills according to colors on the paper interface. Because the smartpen could not recognize the pen color other than black. Users need to dot the color-coded area on the paper interface with a pen tip.

Software. We developed our own digital interface and link it with Neo Smartpen using their SDK. What the digital interface function was to display the dynamic state of the drawings after the animation symbol marked. The application could recognize two kinds of input (drawing and symbol commanding) base on the input from the Smartpen side (whether the user selects the symbol input square or not). Scenery motions were defined as both drawing sketch and symbol command so it could be drawn under drawing stroke. We adapt the google quick draw dataset [18] to spot the scenery motions and they will be animated automatically according to the Python script we defined. We trained our motion symbol drawing classifier ourselves. And the recognition procedure of the motion symbol would only be triggered once the input devices changed to symbol command mode (pen dot the specific area on paper before drawing). To encounter the multiple objects' animation problem, we introduced the quote stroke which is the corner mark on the diagonal of the target objects. It is also recognized under symbol drawing mode,

without which the algorithm would regard the full paper's object as the target to animate by default.

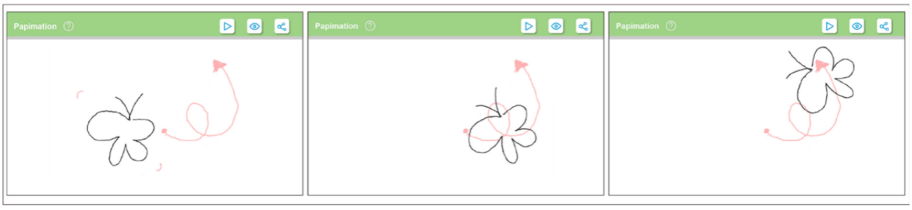
The digital interface could be seen in Fig. 7 which were also explained the procedure of the system.

(a) Draw a butterfly



(b) Select the target object

(c) Draw the motion symbol



(d) Animation result on the digital interface

Fig. 7. The process of the system functions.

6.2 System Evaluation Workshop

In the study, we recruited 14 participants (10F/4M) from local neighborhoods and schools with an average age of 8.2. Six of them participated in our second study. At the beginning of this study, we introduced them to the symbol commands and showed participants how to animate the drawing strokes with a few examples. Then participants could draw themselves with one researcher besides to guide them. After they finished their drawing, Researchers will ask them the following 3 questions, and participants were asked to answer with emoji faces we introduced in First study.

- Q1. I feel interested in animating my drawings?
- Q2. I find it easy to use the system?
- Q3. With this system, I will have more ideas when I draw

6.3 Result

In general, participants showed great interest in our systems. Most of them required to do more drawing after they experience it once. Figure 8 shows the children's answers to the question we designed which indicated that the system is promising and interesting

for children to use. Over 86% of participants felt over average interesting in the form of animating their own drawings. They express their interests in it not only by the answers but also expressing it during the study. In terms of the accessibility of the system, half of the participants gave positive answers while the other half gave the average or below. We found that those negative answers were given by younger participants whose strokes sometimes are unrecognized by our system. When asking whether they could generate more new ideas when using the system to draw, we didn't get many positive answers as we expected. We analyzed it may be because of the limited time of our study goes, children were too fascinating into trying drawing and animating with our system. So, they didn't even come to the idea of whether they have a new idea or not.

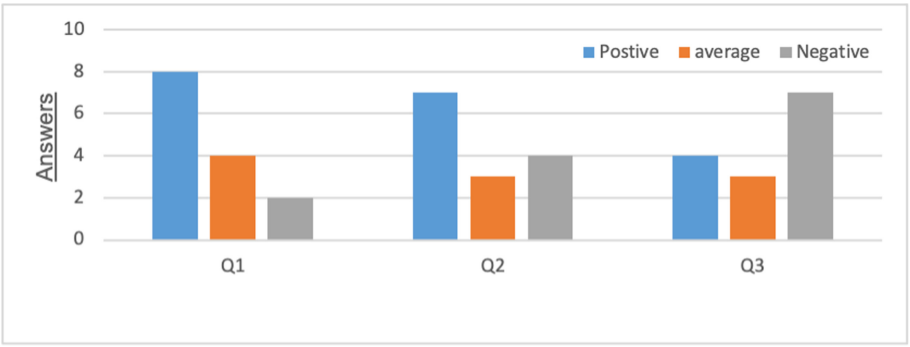


Fig. 8. The answer children gave after they experienced the motion system.

Besides the data we collect, we also found some problems during the process of the study.

- Younger participants whose strokes were broke times during symbol drawing, causing mistake recognition of symbol and no response sometimes. This largely frustrated them while using our system. One of the participants became cranky seeing other counterparts' drawing works while his not.
- Some participants forget the step to quote the targeted objects and failed to animate the drawing. We found that children prefer to draw one object with one symbol command followed instead of finishing the drawing and animated them at last. This causes way more steps to go between drawing and animation commanding.
- The objects in participants' drawings sometimes were too close causing the selection of objects were overlaying. some of our participants are tent to fulfill the whole pictures or draw two objects really close which cause the selection problems and bug the animation process.

7 Discussion

Through three studies, we completed the end-to-end exploration of the animation symbol command design for children, from children's dynamic drawing potential, their

preferences in animation effect, symbol command generation, symbol evaluation to the usability study. Base on the result of three studies, we discuss the dynamic intention in children's drawing, understandable and accessible symbol command for children to use and the usability of the Papimation system.

The fundamental design goal of Papimation system was to design the intuitive command that children can use with ease to animate their drawing to better express their ideas. In study 1 we invest what kind of motion children intended to express in their drawing in online research and concluded that other than using line or dots to express speed or trajectory of the objects, there are several common scenery items to express motion appeared in children's drawings which we categorized it as scenery symbol and could animate themselves. However, we also concluded that children's drawings have too many uncontrollable factors we could not distill more drawing symbols from it. Instead, we put our eyes on what kind of animation effect that children could understand and design it with the basic element children use in their drawings.

To evaluated the design of animation symbol we conducted Study 2, the feedback of the participants was shown that some most intuitive commands are commonly used like translating and rotation while some similar command were confused used in the drawing. And comparing with the symbols that have more strokes, less stroke symbols have high accuracy among children. So, we iterated the symbol commands and developed the Papimation system.

The usability of the Papimation system was tested in study 3, participants were taught and encourage to use the system by themselves afterwards. Through the workshop and feedback of participants, the system was understandable and accessible for children which was in line with what we hope in the beginning. However, the current symbol system has several limitations, the tolerate for children's stroke is still low and the multiple-steps like quoting were burdening children's drawing process, and the feedback of the system was not very clear for children when their commands weren't recognized.

Looking into the future, we will iterate the system and hope to bring this system into a broad field. We believe it is promising in children's habiting nurturing and learning for example children's storytelling and expression.

8 Conclusion

Papimation is a system that enables children to use symbol stroke on paper and animated their drawings on the digital screen. Children's drawing is a static way to express their ideas, this paper was dedicated to let children animated their drawings by simple symbol command stroke which could turn the static expression into a dynamic one. We conducted 3 survey studies. From the first study, we concluded scenery symbols from children's drawings on the internet and filter the animation operations effects that could be understood and described by children. Base on that, we design motion symbols and evaluated them among children in study 2. We filter again with children's better understanding of motion symbols and iterated the motion symbols after study 2. Papimation system were developed and applied to study 3. We evaluated the system's usability among participants. As results shows, most participants were like to use the system except for some problems they encounter in the process which we will solve and

upgraded the system. We are hoping to use the system in children's education, fun play, and storytelling in the future.

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