



## Animating for a Digital Manipulative: how to create restricted action libraries without restricting the players' creativity

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### Abstract

Animating for an interactive device requires a thorough planning and task division from the creative team, regarding character design and behaviors. This paper outlines the development of a set of characters and its animations for an interactive game with a digital manipulative (DM) that intends to foster children's creativity and storytelling competences while promoting multiculturalism. The DM consists of a set of physical blocks that represent characters, sceneries and objects from different cultures, and an electronic platform that connects to a computer or tablet, which displays animated responses triggered by the combination of blocks on the platform. We look into the process of creating the behavioral rules for the animated elements and the difficulties in aligning the volume of work with the available human resources and available time, reflecting on how this affects the creative process and how this process can be improved.

### 1. Introduction

This work reports on the development of 2D animations for a digital manipulative (DM). Digital manipulatives are devices composed of physical objects that mediate the user's interaction with digital content (e.g. graphics and audio content)<sup>5</sup> [1]. The DM presented here, aims at fostering children's creativity and storytelling competences while promoting multicultural awareness, offering the children a variety of characters, landscapes and objects from different cultures<sup>6</sup>. Those elements are divided in kits, consisting of a set of physical blocks that work together with an electronic board connected via USB to a computer or a tablet [2]. The platform has six slots for placing blocks. The placement of the blocks triggers animations that are displayed on the screen. The combination of different blocks results on different animations. Up until now, we have developed three kits, each of them representing a country - namely In-

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<sup>5</sup> Although commonly the digital devices (such as computers, video games consoles etc.) require a physical object (e.g. mouse, keyboard, joystick) to interact with the digital content, the role those have in representing the user interface excludes them from the notion of a DM, Ulmer and Ishii say that their physical form has little 'representative' significance [1].

<sup>6</sup> This study is part of a Masters final project and it is being developed in the context of a national research project that investigates the learning and socializing potential of digital manipulatives among young children [mobeybou.com]

dia, China and Brazil – all fully animated and implemented on the game for carrying out trials with various focus groups.

It is important to say that, so far, the use of the electronic board imposes a limitation on the number of active elements in the gameplay, as the player can only use six blocks simultaneously. This system is based on a previous device developed on the TOK project [3], and it has been used to test the interaction between the characters and the animations implemented in the game. Presently, we are exploring new hardware possibilities, by developing blocks that will connect to each other and to the computer via Bluetooth, giving the users the possibility of combining more elements simultaneously. The game elements are identified by an illustrated sticker on top of each physical block with the representation of its content (see Fig. 1). We are also studying the use of certain visual cues to make the placement of the blocks more intuitive.

The development of the DM aims at giving the children freedom to play with the blocks using them as the foundation for building creative narratives. Regarding the animation, this means creating a range of virtual interactions as wide-ranging and simple as possible, given that the interactions between the characters are triggered by the combination of the physical pieces. In the following, we will explain how the kits were created, and describe the development process of the animations of the first cultural kits, as well as the challenges of building a restricted yet functional “action library” for animating the characters.

**Fig. 1.** Example of physical blocks used in the DM.



## 2. Animating for a Digital Manipulative

### 2.1. Cultural Kits – Creating the Basic Materials

The DM is composed of various kits, each representing one culture/country. Each cultural kit is composed of seven elements: a scenery<sup>7</sup>; two characters (a boy and a girl), one animal, one mythical creature, one magical object and one musical instrument. There is a range of secondary blocks which affect the whole environment when they are used, such as weather phenomena: a ‘rain-block’, that floods the set, when it is placed on the board; a ‘snow-block’ that makes the characters shiver and “freezes” the screen; a ‘thunderstorm-block’, randomly hits the characters with lightning. There are also blocks that represent time phenomena: a ‘night-block’ changes the color and the light of the scene when it is placed on the board, and makes the characters fall asleep as long as there is no musical instrument active, or a conflict taking place.

In order to be able to define the interactions between the different game elements and to create a great number of animations as required, as well as to optimize the development process of the animations, we decided

<sup>7</sup> The sceneries do not have any effect on the other elements but can be affected by some of the blocks (such as rain and snow).

**Fig. 2 and 3.** China kit: conflict between protagonist and antagonist, with the help of the kits' magical object.



to group the elements into classes and to set a limited number of actions and reactions that would be generated by their possible combinations<sup>8</sup>. Each class acts in a certain way and every action will trigger a reaction accordingly. The behaviors of the elements are affected by the combination of blocks and by the number of blocks from each class present in the gameplay.

The major classes are: Protagonists, Antagonists, Animals, Magical

Objects and Musical Instruments. This division is based on the structure of classical narratives, which by tradition relays in a dual opposition: good versus bad, protagonists versus antagonists, heroes versus enemies [3]. This structure grants the emergence of a conflict and its resolution. To achieve this, we have created following rules: a) a protagonist by itself is always weaker than an antagonist, so when an antagonist attacks a protagonist, the latter will always be defeated by the former; b) the protagonist will always require help of other elements to escape or win a conflict; c) the animals and the antagonists are equally strong, so in case of conflict, if they are equal in number, the system randomly decides who wins the conflict; d) the musical instruments can only be used by the protagonists and when they enter the game, they stop all conflicts (all characters in the game will look happy and start to dance<sup>9</sup>); e) similarly, the magical objects can be used only by the protagonists and

will grant them special powers over the antagonists, either to escape (the magical shoes will make the protagonist float in the air) or to defeat them (a fan will create a typhoon and blow the opponent away) (see Fig. 2 and 3).

## 2.2. Characters: Designing and Animating

In the following we will focus on the description of the human characters' process of animation and the development of what we will call a shared restricted action library. Regarding the animation and the design of the game elements, all the human characters have a similar silhouette and behaviors: they all share the same skeletal structure and have the same range of animations, being all equally affected by the other elements.

This limitation was chosen in order to optimize the art team's work. Trying to convey our goal to have a large number of unique blocks with the limitations of time and human resources<sup>10</sup>, we decided to compromise on the variety of the characters to achieve an optimal development pipeline. To accomplish this, we designed the protagonists, which are the larger

<sup>8</sup> We will call this set of actions for each character a limited "action library".

<sup>9</sup> This reaction was inspired in the children's use of the Musical Instrument cards during the first interaction with the game, although some children would use the instrument as a weapon, most said the music would calm down the enemy, thus ending the conflict.

<sup>10</sup> The project art team is composed by an illustrator and an animator.

group of characters and who share the same nature – all protagonists are based on human children of similar age – with a similar basic shape, and similar height and features, however they differentiate from each other through hair styles, clothes and color. These characters also share the use of objects, such as the musical instruments and their animations. This process is commonly found in mainstream animation, and is subject to controversies, if on one hand we have more production in less time, on the other hand it can be argued that this creates a deprived repertoire of characters. [4] On a more positive note, this simplicity generates characters that are easily recognizable, that have a neutral personality, this way, being easily transformable according to the player desire and creativity.

In contrast with the human characters, the animals and the antagonists have exclusive designs and, their uniqueness grants us more freedom to create their animations even while respecting the behavioral tree delimitations. For instance, all animals and antagonists have an attack animation, but every attack is exclusive of each antagonist, e.g. the panda bear (China kit) turns into a ball and ‘rolls’ over its opponent, while the elephant (India kit) blows flowers from its trunk (see Fig. 4). The process of animating these characters, which are unique and therefore pose a higher level of difficulty, is a lot more exciting. It is challenging to convey their personalities and the unusual behaviors that we design for them into the animation, but this is also the highlight of working on them.

Analyzing the creation of these elements from the perspective of character design, the non-human characters “travel well across national boundaries. These characters avoid activating ethnicity, and they are forgiven for behaving in odd ways because they are so clearly not part of the usual human social structure” [5:60].



**Fig. 4.** Both characters have the same design with different patterns and details unique to each.

### 2.3. Creating Restricted Action Libraries

The need to simplify the creation process required a careful planning of the game elements’ behaviors. For that we designed a complex table of interactions, specifying how the combination of blocks would interfere with each other, according to the order of placement and the number of blocks in action. Table 1, presents a simplified overview of the interactions between the elements according to the number present in the gameplay:

*P	*A	*N	*MO	*MI	Conflict Result
1	1	0	0	0	Antagonist attacks and wins
1	1	1	0	0	Animal attacks and Antagonist loses
1	1	0	1	0	Protagonist uses Magical Object to win
1	1	0	0	1	Protagonist plays Musical Instrument and everyone dances
1	1	1	0	1	Protagonist plays Musical Instrument and everyone dances
1	1	1	1	0	Protagonist uses Magical Object to win

**Table 1.** Simplified Table of Interactions

\*P: Protagonist,  
 \*A: Antagonist;  
 \*N: Animal;  
 MO: Magical Object;  
 \*MI: Musical Instrument.

In interactive animations, the animator has to bear in mind that the player will hold control over the characters' actions. In the work presented here, the player has not only control over the characters but also over the narrative, through the combination of the blocks during the gameplay. In a linear animation, like an animated movie, the animator is responsible for modeling the characters' behavior, and s/he is the one that decides when and how it happens. However, in a video game, this decision has to be made instantaneously by the computer, as it 'reads' the players' actions, turning control inputs into animated responses that are displayed on the screen. Tomlinson refers to that as "taking an intuitive process (the way an animator or animation director decides to have a character act) and making it explicit (so that a computer program can make the same decisions on-the-fly)" [6:6]. To make this intuitive-to-explicit process possible, the animation team and the character designers will create a suit of actions and behaviors for the characters – the action library – and specify the rules for the actions and reactions, these will later be coded in the game system by the programmers or engineers.

As mentioned in the introduction, the main goal of this work is to offer the players a wide range of materials to create their narratives. This implies creating the largest possible number of cultural kits<sup>11</sup>, so it is critical to consider the progressive amount of required animations and the restrictions that we face when creating them.

To find the best way to address the challenge of working with limited time and limited human resources, and to optimize not only the process but also the product (DM), the present work follows a Design-Based Approach, wherein practice and theoretical studies are intertwined, the theory instructs the design and the design itself improves the theory. Sylla stresses that "Design Based Research is practice driven, pragmatic, flexible and iterative", being a cyclical process of design, test and redesign from the users' responses after each iteration. [3:96] Every time a new kit is created, animated and implemented in the DM, it requires testing to verify if it is working properly (debugging) and usability tests, which provide feedback on how and where to improve the digital manipulative, e.g. during the first trials, while observing the groups experimenting with the DM, we noticed the users looked for an immediate response from the active blocks, rapidly swapping the blocks on the board.

When we started working on the animations, the team was still deciding on the composition of the cultural kits. The classes and the interaction between them were not yet defined. At first, we animated one single character mainly as a way to test which range of expressions and customization a character could have. This first character has not yet been integrated into the game and will probably require to be completely remade in order to be incorporated into the game universe.

The first cultural kit that was fully developed was the Indian kit. The first animated set comprised only one human character, a young girl named Meera, as the protagonist. While testing the interactions between

<sup>11</sup> In a first moment we are trying to represent the most common cultures present in Europe, but future work will extend the number of available kits in the game.

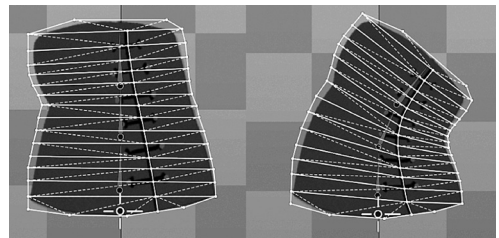
the characters we were confronted with the issue of gender representation and decided to create both a boy and a girl for each cultural kit. However, adding characters to each kit increased the volume of work necessary to animate them. Fortunately, we found a way to significantly reduce the amount of time required for the extra character animations: by using the same base for both character (see Fig. 5), we could duplicate the skeleton and its animations, therefore having to do only minor adjustments to each animation e.g. to animate individually the movement of hair, clothes, etc.



**Fig. 5.** Both characters have the same design with different patterns and details unique to each.

Another issue we were confronted with was the use of interchangeable elements: in order to give the players more freedom for constructing narratives and to promote multiculturalism, it was established that they should be able to mix the elements from the different kits. This meant that every human character should share elements and animations. The new character would inherit the magical objects, the musical instruments and its animations from previous characters, and the previous characters would inherit the additional objects, musical instruments and animations. For every new character added, the number of bones and animations in each skeleton would increase by at least two. This presented us with the challenge of how to speed up this process and avoid redundant work. The ideal process would involve not having to add all the new bones and images manually, as the development of new kits would affect and be affected by all previous work. On our first approach, sharing skeletons and animations between the human characters of each kit was done by duplicating the original file, renaming it and replacing its images. This allowed us to produce two animated characters in almost half the time. Designing the characters with the same basic shape, as shown in figure 2, also allowed us to share meshes between them.

The meshes are constructed on top of the 2D image, by attributing a series of triangles that will allow the image to simulate a 3D movement otherwise impossible to achieve in this type of animation. By manipulating the mesh, we can bend the image simulating a malleable surface, adding a fluid feel to the movement (see Fig. 6).



**Fig. 6.** Mesh created over the character body sprite and its deformation.

Although this was a valid and helpful shortcut, we still had to deal with the animations for all the other elements. During the first months of work, the software used to animate allowed us to import animations from one skeleton to another, but crashed when we tried to copy bones and images between two skeletons, forcing us to add new elements and bones one by one. When preparing the third



**Fig. 7.** The Bones and the attachments can be copied from one skeleton to the other.

project (See Fig. 7) This software improvement significantly reduced the amount of work, improving its quality and quantity.

Every animation is individually adjusted to better fit the characters this way giving them a sense of individuality, but the structural basis on which it is created is shared between all. This allows us to give the characters some personality and to consequently increase interest from the players, while optimizing our production capacity.

### 2.3. Does a limited action repertoire affects the player experience?

So far, we have only tested the digital manipulative in a Portuguese school with a class of 2nd graders. The first trial was made with sets of paper cards representing the initial illustrations for each kit, in a simulation of the DM, and the second trial was made with the digital manipulative. Even so, during the first field trials, it was possible to infer some important aspects regarding the players' experience when comparing the use of an analogic version of the game and the DM itself. In the analogic version trials, we presented the children with seven complete kits and seven secondary cards to play with, and asked them to use the cards to tell a story. The children tried to use all the available cards, often creating stories that consisted of a series of "and then" events. In the second trial test, with the digital device, we offered them only two Cultural Kits (namely India and China) and four secondary blocks to play with (rain, wind, snow and night time). After exploring the blocks and learning their interactions, the children produced more creative stories, sometimes embodying the main characters. In the next section we highlight some excerpts of the informal interviews done with the children during the second field trial.

### 2.4. Field trial with 2<sup>nd</sup> graders and informal interview

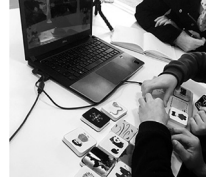
The first series of field trials resulted in some interesting feedback from the users. In the trials with the digital manipulative we started by letting the children interact with the interface without giving them any guidelines, just asking them to play with it and observing how they would manipulate the blocks and behave (see Fig. 7 and 8). They would intuitively place the blocks and wait for the animations to appear on the computer screen<sup>13</sup>.

<sup>12</sup> We started with eight animations per protagonist in the first version of the game. In the last version, which comprises three kits each human character had 19 animations and 28 bones.

<sup>13</sup> This first interaction showed the importance of immediate response from the blocks, if the animation took more than a couple of seconds to be triggered by the use of a block, they would remove it and place a different block on the board.

kit, given the increasing level of complexity<sup>12</sup>, we started researching for a way to simplify this process. Fortunately, thanks to improvements made in the software during that period, we could now also copy the bones and images from one skeleton to another as long as they were in the same

After a few minutes getting used to the interface, they were invited by the researcher to tell a story using the DM, which was followed by an informal interview as mentioned previously. We compiled below some highlights from the interviews:



[group 1, boy and girl]

They started slowly placing the blocks on the platform and experimenting, talking in a very low tone, shyly. There were some difficulties with the fitting of the blocks on the platform [this observation leads us to work on visual signals to make the placement more intuitive as previously mentioned.] After the children get used to the interface, the researcher asks them what do they think the platform is.

Both: "It's for theatre with the pieces", "it's also a game"

Researcher: "why do think that this is a theatre?"

Boy: "we invent sceneries, stories, and happenings, I think"

R: and do you think this helps creating stories?"

B: nodding vigorously with head: "it helps, it helps a lot"

R: "can you explain why?"

B: "we have these pieces and when we place scenarios it helps us in the stories"

[group 4, two girls]

They start the interaction by saying the platform is for creating stories (they remember tok from the year before) Researcher asks: "how does it work?"

Girl 1: we place a block here (platform) and we have to talk about that piece

Girl 1 to Girl 2: "do you want me to start?"

[When it started snowing both girls said "AH!", delighted by the reaction of the block, they also laughed about the interactions.]

Researcher: do you prefer telling stories with this or with the paper cards [researcher referring to the first field trial]?

Girl 1: "with this, we get more ideas"

R: how would you describe what you have done at home?

G 1: "we did stories with pieces that give us a lot of ideas"

R: do you think that this is a game?

Girl 2: "it's more than that, it helps us create a story, when we want to create a story, when the teacher tells us to create a story, we have more things in our head (gives ideas)"

[group 6, two boys]

Researcher: How would you call this [the tool]?

Boy 1: "puppet projector interesting the idea of projecting the figures that they have on the hand"

R. Do you like it?

**Fig. 8 and 9.** Field trial - Children interacting with the digital manipulative.



B 1: “yes, if we place them here, they appear there [on screen]. They like to see the images on the screen.”

R: do you remember using the paper cards?

Children answer yes, but they prefer this version “because they appear on the screen, and always appear the scenarios.”

Note: This pair was the first to give their own names to the characters on screen and use direct speech and dialogues on their storytelling. They were also the first to verbalize relationships that weren't of equal statute instead they using the protagonists to express mother/son relationships.

### 3. Conclusion and Future Work

Animating interactive characters is always a challenging task. This work forces us to reflect on the process of designing and animating the characters and on what is more important to offer: a wider range of characters or characters that are more unique. During the initial tests, the restricted action libraries did not seem to constrain the players.

Presently, we are planning new trial sessions that will allow us to test with a larger focus group and gather feedback from the players. This will allow us to keep on refining our work method and final product. This paper presents a work in progress, which will be improved on. We'll continue the research on animating for digital manipulatives in the context of this project, allowing the possibility of applying this research's methods to similar projects in the future.

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