

CREATIVE ANIMATION DESIGN FOR INVERSE KINEMATICS MOTIONS OF SHADOWGRAPHS SHADOW PUPPETS IN TAIWAN

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Abstract: Shadowgraph is the featured traditional folk culture and art in Taiwan. The operators play the roles of Shadow Puppets with the puppets' performance according to the stories and the plots. This study aims to develop creative animation design of shadowgraph, probes into the mastery of old shadowgraph craftsmen by design-based approach and explores the operation in actual performance, the skills to control Shadow Puppets' motions and presentation of Shadow Puppets' motions by IK (Inverse Kinematics). The story of the shadowgraph is based on the chinese classics: *Journey to the West*. The author renarrates the plot and the characters' dialogues include the idioms in the animation. The author tries to present the design of Shadow Puppets' motions by IK. The research findings will help the innovative development of shadowgraph, enhance the perception of Shadow Puppet operation and construct new cultural value in digital time.

Keywords: *shadowgraphs, shadow puppets, inverse kinematics, animation design*









1. Introduction

In recent years, with the development of national economy construction, Taiwan continuously invests the funds in many digital industries in order to enhance their positioning and characteristics. In Taiwan society of early times, there was one common activity of entertainment, art and culture: Shadowgraph (also called Shadow Theatre). It combined traditional drama style and presented the traditional folk art by lighting and shadow. Shadowgraph in Taiwan was introduced from China in Ching Dynasty and it was the shadowgraph system of Chaozhou. There were different stages of shadowgraph development in Taiwan. It is not only important in folk art, but also plays significant role in religious ceremonies, festivals, weddings and worship (Chiu, 2003).

The author considers the passing and new look of shadowgraph as well as the innovative development in response to the cultural impact of digital time. Shadow Puppet style of traditional shadowgraph technique is one of the main factors of the vivid performance of shadowgraph. In "Hand Puppet Theatre", another popular traditional art in Taiwan, Hand Puppets are the favourite collections of the fans. Design of the puppets not only attracts the audience, but also demonstrates the characters' personalities. "Mirror Man", the antagonist in the well-known Hand Puppet Theatre "the swordsman of YunZhou: Shih-Yen-Wen", always dress with leaf hat, mask and golden thread cloth. His mysterious and invincible image confronts the decent role of Shih-Yen-Wen. It enhances the tension of the theatre.

Motion technique of Shadow Puppets is shown by digital animation. By IK (Inverse Kinematics), the author simulates the interaction between motion structure and joints of bones of human bodies (Grochow et al., 2004) and thus Shadow Puppets close to two-dimensional curtain can show the motions similar to human beings'. Varied shadowgraph techniques have been presented by Digital Archives, such as the operation recorded and performance introduced by videos. Design of the Shadow Puppets not only attracts the audience, but also shows the characters' personalities. It is also significantly related to the culture of local society. Dressing and accessories of Shadow Puppets also reflect the fashion. Table 1 shows the modeling of the featured puppets in many countries. The delicate design of Shadow Puppets demonstrates the corresponding relation between the modeling of Shadow Puppets and local culture.

Table 1. Modeling of local Shadow Puppets in different countries (Source: Shadowgraph Digital Museum : <http://shadowlessona.kccc.gov.tw/a07-3.htm>)

Countries	Taiwan	Indonesia	Malaysia	India	China	Thailand	Cambodia	Myanmar
Shadow Puppets								

This study aims to develop creative animation design of shadowgraph and probes into the mastery of old craftsmen of shadowgraph by design-based approach. The author visits the historic Tunghua shadowgraph theatrical company in Dashe Township of Kaohsiung County, Taiwan to approach the characteristics of the skill and observe the operation in the real performance, the skill to control the motions of Shadow Puppets and the puppets' motions presented by IK. The plot of shadowgraph is based on the well-known Chinese classics Journey to the West. The author renarrates the story and the characters' dialogues are based on idioms in the animation. This study tries to show the design of Shadow Puppet motions by IK and the findings will help the innovative development of shadowgraph, enhance the perception of Shadow Puppet operation and construct new cultural value in digital time.

2. Inverse kinematics design concept of Shadow Puppets

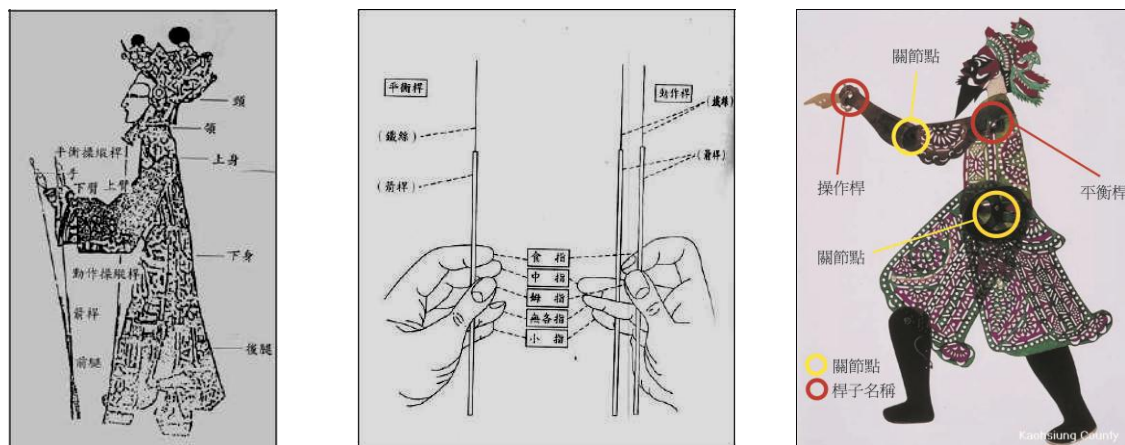


Figure 1. Design study is conducted on Tunghua shadowgraph theatrical company in Dashe Township, Kaohsiung, Taiwan to collect the images of research data (Source: compiled by this study)

The author visits Tunghua Shadowgraph Theatrical Company, probes into the types and characteristics of Shadow Puppets, performance and procedure, script planning and design, etc. Through design study, the author explores the old craftsmen' skills, discovers the questions on site, describes the questions, searches for the solution and validate the feasible research. According to old craftsmen' knowledge, the author sets and modifies the primary operation of Shadow Puppets and demonstrates circular and complete exploration. The study on old craftsmen focuses on the making of Shadow Puppets, oral description of performance, motions of Shadow Puppets and skills of operation, the practical situations as shown in Figure 1.

2.1. Action technique of shadow puppets

Three levers are used to control the motions of Shadow Puppets. One is called “balanced lever (middle lever)” which is set at the front of the necks of Shadow Puppets. It functions to balance the body and control singing and varied poses (Chin, Hong, 2001, Chiu, 2003). The other two levers are called “motion lever (hand lever)” which is set at two hands of Shadow Puppets. The purpose is to control Shadow Puppets’ hands for the necessary motions. For traditional Shadow Puppets, there are three to four levers. Nowadays, for the concern of performance, it is simplified as two or one lever. In orchestra scene, the characters are set with one lever at the front of the chest by iron wire (see Figure 2b). Thus, the shadow can be reversed. One lever is set on the hand for the motions of hands. As to the martial scene, the level is installed at the top of the back of chest (shoulder) for the martial art (see Figure 2a, 2c). There can be varied motions such as running, standing, sitting, lying and fighting.



(a) Positions of Shadow Puppets

(b) Operation techniques

(c) Shadow Puppets’ joints

Figure 2. Relative positions to control Shadow Puppets and technique of levers (Source: Shadowgraph Museum in Kaohsiung)

2.2. Inverse kinematics branch design of shadow puppets

The operational principle of Inverse Kinematics is “bones chained” to construct “branched armatures” structure and connect the objects with Parent-child relationships into animation. The bones are set in the shapes of different objects. By controlling the branches of Shadow Puppets, the motions of the objects are established by moving, rotating, stretching. When the bones move, the related bones of the objects will result in the motion. Simple interaction presents the animation of Shadow Puppets’ joints. Huang (2001) suggested that if Shadow Puppets’ joints are presented by animation, circular joints should be the necessity. Design of joints is based on the reasonable movement (centre of the circle among the joints). For instance, in the design of arms, the arms and shoulder joint can be 360 degree. However, the elbow and top arm can only set as 180 degree. It is different from the actual operation of Shadow Puppets with lines as the control component to restrict the motions (see Figure 3).

Animation design by IK characteristics only requires the setting of key motions in the frame and the setting from the start to the end of the motions; in interactive operation, operation of IK branches can simulate the motions of Shadow Puppets. Connection between the levers and Shadow Puppets’ joints is shown in Figure 3 and the setting is on Shadow Puppets’ shoulders and wrists. According to the setting of IK branch, it constructs the bones chained operation. The chains of Shadow Puppets’ joints can be established by IK. Poses on timeline can simulate hands, upper limbs, heads, bodies and lower limbs corresponding to levers of Shadow Puppets. Thus, Shadow Puppets can move freely. In this stage, the author integrates Shadow Puppets’ IK motion setting by Flash and accomplishes branch setting of digital Shadow Puppets. There are two functions of Flash IK branch tool. By bones, branches can added to the objects or shapes and the connection tool can adjust and control the joints of the branches in the objects.

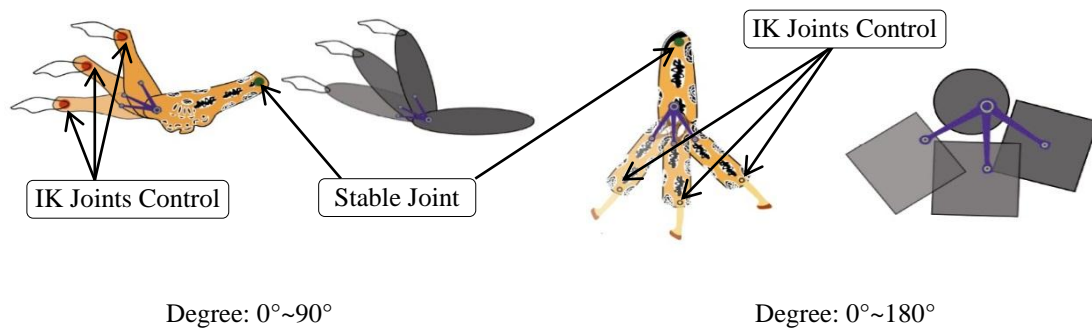


Figure 3. IK branch connection of Shadow Puppets (Source: compiled by this study)

3. Creative animation design of shadow puppets with inverse kinematics

Journey to the West is the classic of Chinese mythology written by Wu Chen-en (1504-1582) in Ming Dynasty of ancient China (1368-1644). It is one of Chinese “four great classics”. It describes Tang-monk’s pilgrimage to the west to acquire the doctrines of Buddhism and classics. It shows the ancient themes to punish the vice and reward the virtue. Since the publication, *Journey to the West* has been spread in China and around the world. It becomes well-known and translated into different kinds of language. It is adopted as local dramas, movies, TV operas, animation and cartoons. The main characters include Sun Wukong, Tang-monk, Zhu Bajie and Sha Wujing and “Havoc in Heaven”, “Sun Wukong Hit Lady White Bone” and “Flame Mountain” are the well-known plots.

3.1. Character design of Shadow Puppets of Journey to the West



Figure 4. Roles of Shadow Puppets in Journey to the West (Source: compiled by this study)

According to the structure of *Journey to the West*, this study re-designs and develops shadowgraph animation. In the animation, the plots and characters’ dialogues are based on idiom descriptions. The reseracher tries to enhance joyful learning value of shadowgraph animation by watching the animation and learning the idiom descriptions of the dialogues and asides. As to the technique of Shadow Puppets, the author re-designs the characters of Shadow Puppets of *Journey to the West* according to the principle and characteristics of Shadow Puppets technique, as shown in Figure 4, including Tang-monk, Sun Wukong, Zhu Bajie, Sha Wujing, white horse, Jade emperor, heavenly generals, goblins,

Golden Toad, Mental Devil. As to Motions technique, the author simulates the joint design of real Shadow Puppets and designs the motions of Shadow Puppets by IK.

3.2. Scenes and action scenario design

Journey to the West is based on the process of Tang-monk's pilgrimage to the west. The story is interesting with the education of "idioms". Besides, the character's vivid personalities are significantly related to the ending of the story. Sha Wujing is set as coward, Zhu Bajie is greedy and selfish and Sun Wukong is crude and impetuous. Tang-monk tries to reform and teach them according to their characteristics. It is the ending of the story. As to the technique of the theatre, the author treats the self-designed scenario, such as six scenes (desert, mental evil cave, heaven, flame mountain, corpse heart swamp, window) in Table 2, as the scenes which is related to the relationship between the characters and plots.

Table 2. IK motions descriptions of shadowgraph *Journey to the West*

Background: After Tang-monk and his apprentices acquired the classics of Buddhism in Tien Chu, they started returning to Tang. On the way home, Tang-monk decided to introduce Buddhism in the country and told the apprentices to return to Heaven first and he would wait for the end of his life.	
Scenes	IK Motions Descriptions
Scene 1: Desert	IK setion #1: <i>In the sunshine with intense heat, Tang-monk and his apprentices walk in the desert (walking). Tang-monk sits on the white horse suddenly stops. Sha Wujing behind stops with his master. Sun Wukong at the front turns around (turning) and wonders why the master stops. Zhu Bajie carelessly bumps into Sun Wukong.</i>
	IK section #2: <i>Tang-monk sits on the horse watches the three brothers who also look at the master.</i>
	IK section #3: <i>Sha Wujing watches the master leave by riding the white horse. Tang-monk returns and reminds Sha Wujing with the last words.</i>
	IK section #4: <i>Three brothers stand still and watch Tang-monk leave on the white horse.</i>
Scene 2: Mental Evil Cave	IK setion #1: <i>Out of the mental evil cave, Mental Devil catches Tang-monk back to the cave.</i>
	IK setion #2: <i>A goblin jumps from the back of the stone, raises the yaksha and talks to Mental Devil excitedly.</i>
Scene 3: Heaven	IK setion #1: <i>In Ling Hsiao Palace of Heaven, Sun Wukong, Zhu Bajie and Sha Wujing knees down in front of Jade emperor (kneeing down). Jade emperor sits on dragon chair and points to Sun Wukong and his brothers.</i>
	IK setion #2: <i>Suddenly, a heavenly general rushes in from the gate. Three brothers look at the heavenly general who reports to Jade emperor.</i>
	IK setion #3: <i>Sun Wukong immediately rushes out of Heaven on Quicksilver Cloud. (Jumping and leaving on the cloud) Sha Wujing raises the head and talks to Jade emperor. Sha Wujing leaves and Zhu Bajie follows.</i>
Scene 4: Mental Evil Cave	IK setion #1: <i>Mental Devi grabs Tang-monk with left hand and sees three brothers rush in the cave. Sun Wukong yells at Mental Devil.</i>
	IK setion #2: <i>Sun Wukong jumps (jumping) and immediately rushes to Mental Devil. ALPHA value of Mental Devil suddenly becomes zero (the screen moves to the left or right) and disappears. Only the sound of Mental Devil leaves. Sun Wukong catches nothing and yells at Mental Devil.</i>
	IK setion #3: <i>However, only the arrogant laughter of Mental Devil leaves in the cave. Sun Wukong turns (turning) and talks to Zhu Bajie and Sha Wujing. Thus, three brothers leave for the two treasures.</i>
Scene 5: Flame Mountain	IK setion #1: <i>They walk on the mountain (up toward the hill), sweat and breathe deeply.</i>
	IK setion #2: <i>The middle scene shows three people's fatigue because of heat (they bent the body with hands put on the chest) and the close-up of palm-leaf fan. The sun and the moon alternate in turns. Sun Wukong walks and searches for the bodhi tree on the top of the mountain (raising his head) and Zhu Bajie sometimes pushes Sha Wujing.</i>
	IK setion #3: <i>At night, Zhu Bajie and Sha Wujing felt asleep on the hill. Close-up of Sun Wukong with hands picking red glossy ganoderma at the root of bodhi tree. Sun Wukong scratches the</i>

	<i>head and is confused (raising the right hand to screen the head).</i>
Scene 6: Indoor Window	<i>IK setion #1: Sun Wukong suddenly comes out with the reminders of the master. Sun Wukong sits by the window and is thinking.</i>
Scene 7: Corpse Heart Swamp	<i>IK setion #1: Three brothers search for the toad eggs by corpse heart swamp (walking). Sun Wukong holds red glossy ganoderma in his hand (holding something in the hand) and suddenly stops by the swamp.</i>
	<i>IK setion #2: When walking, Wukong finds a little toad besides the stone at the front and ignores it. Wujing finds that there can be toad eggs and tells his Big Brother.</i>
	<i>IK setion #3: Impatient Zhu Bajie pokes it with hands (Zhu Bajie behind Sun Wukong stops Wukong with one hand). Sun Wukong rushesto the front. (passing Sun Wukong and rushing to toad eggs)</i>
	<i>IK setion #4: Little Golden Toad comes out from the other side of the stone and becomes bigger. (little toad disappears behind the stone and big toad appears)</i>
	<i>IK setion #5: Zhu Bajie greedily catches the eggs after finishing talking (bending and catching the things) and finds himself sinking in the swamp (the character moves down the scene).</i>
	<i>IK setion #6: Sha Wujing was ready to rush to Zhu Bajie. Golden Toa tried to catch Sha Wujing with one hand (catching forward). Sun Wukong went forward to push Sha Wujing away (Wukong pushing Wujing). Golden Toadarms caught Wukong and Sha Wujing fell on the ground (sitting on the ground).</i>
	<i>IK setion #7: Sun Wukong tries to get out from Golden Toad's arms. However, the steel wool on Golden Toad's arms was entangled with Wukong. Golden Toad entangles Sun Wukong and asks Sha Wujing. Zhu Bajie finds himself keeping sinking and Wukong is caught. He is agitated.</i>
	<i>IK setion #8: Sha Wujing thinks for a while, takes a deep breath and talks. After talking, he rushed with his crescent moon shovel. (rushing to Golden Toad with the weapon and trying to fight)</i>
	<i>IK setion #9: Sha Wujing saves Sun Wukong with crescent moon shovel (rushing to Golden Toad with weapon and trying to fight). He defeats Golden Toad with Sun Wukong (fighting). They pull out Zhu Bajie who almost sinks in the swamp. When they are all safe, Tang-monk appears at the back.</i>

(Source: compiled by this study)

3.3. Shadow puppet IK animation of *Journey to the West*

Different types of Shadow Puppets show varied characteristics of motions (Chiu, 2003). Civil and military officers are different. Military commanders and military officers come on the stage from the right of the curtain. The civil officers come on the stage from the left curtain. There are generally several kinds of technique as following:

1. Military Shadow Puppets shows the flexible motions of the feet and fists. The examples are the roles of Sun Wukong, Zhu Bajie and Sha Wujing in the story.
2. Shadow Puppets of jester (servants): servants and subordinates; when the servants come on the stage, the operator controls the main lever to quickly move forward and the side lever follows immediately and wiggly. Thus, images and motions show the hurry. The example is the role of Goblins in the story.
3. Shadow Puppets of soldiers: they are mostly operated by one lever and they usually appear in the great fighting. The operator usually holds three to four levers with one hand. The wooden lever is grabbed by one hand and controlled by thumb, forefinger and middle finger which move up and down. Shadow Puppets' arms demonstrate fighting and waving. The example is the role of Heavenly Generals in the story.
4. Shadow Puppets of dragon (animals): the operator controls the main lever at the head with one hand and side lever at the tail with the other hand. Thus, the body of dragon can move up and down. There are varied animals, such as tortoise, cow, tiger, and the operation is similar. Main lever is at the head and side lever is at the tail. The examples are the roles of Golden Toad and White Horse in the story

In addition, according to the basic operation skill of Shadow Puppets, when walking, Shadow Puppets' hands will move forward and backward and the lower part will shake. Thus, according to primary observation, the operations of Shadow Puppets are below:

1. Touchdown: although the motions of Shadow Puppets are controlled by the operator, the Shadow Puppets' roles should match the scenario. Shadow Puppets' feet should be on the ground and the feet should sway quickly and touch the ground to meet the reality.
2. Flying action: when Shadow Puppets fly, the operation of the side shows the vibration of the wings. The operator controls the head with operation lever and vibration of wings or physical turning by motion lever.
3. Turning action: the operator treats the lever at the head as the center of the circle and stays and turns the puppets on the curtain. Another lever is thus turned with 180 degree. Shadow Puppets will overturn from the left to the right.
4. Leg splitting, somersault and speaking action: besides the basic motions, there are also somersault and fighting. When one role is speaking, other Shadow Puppets should not move. Thus, the audience will recognize the speaking puppet.

Table 3. Screenshots of Shadow Puppets IK animation of shadowgraph *Journey to the West*



For the complete animation, please see <http://www.youtube.com/watch?v=sR9sArmBbJk>. (Source: compiled by this study)

According to idiom story script of shadowgraph *Journey to the West*, the author draws six scenes, designs Shadow Puppet roles with IK joints and integrates the IK animation of Shadow Puppets. The storyboard is shown in Table 3. Each scene implies the change of space/time by fade in/fade out. IK is applied to design of Shadow Puppet motion technique. In scene 7 “Corpse Heart Swamp”, it can particularly simulates real operation of Shadow Puppets. For instance, Zhu Bajie flied across the swamp to steal the eggs of Golden Toad and he was caught by Golden Toad and showed the struggling motion. In the scene when Sun Wukong and Sha Wujing fought with Golden Toad to save Zhu Bajie, the author sets the motions such as jumping and flying of Golden Toad and weapon holding, turning and jumping of Sun Wukong and Sha Wujing by IK joints and it can properly demonstrate the effect in real operation of Shadow Puppets. (See the screenshots of Table 3)

4. Future study

At present, we have finished Shadow Puppets' IK motion design. In the future study, we will integrate digital environment of interactive narration of shadowgraph. This study proposes the interactive operation environment of digital narration of shadowgraph and tries to simulate real shadowgraph

theatre by Multi-Touch and Shadow Puppets with vivid motions and IK branches. Operational concept of interactive operation environment of digital narration means to divide the narration into several *episodes*. In the same scene, there can be several episodes with different lengths. However, the lengths of episodes will not be over the scenes so that the users will not be confused. Complete narration can be the sequential episodes. The episode includes Shadow Puppets' cell animation, dialogue, Shadow Puppets' interaction and scenes. An episode should be clearly set with narrative purpose: beginning, narrative process and ending to regulate the structure of episode. It will be easily applied and develop interactive narration model.

However, interactive narration digital environment of shadowgraph can be treated as the cooperation of digital theatre. By Multi-Touch, digital Shadow Puppets are operated. After recognizing the narrative purpose of the episodes, it starts with narration, operates Shadow Puppets, experiences proper narrative process and finally reaches the ending. Using the above scene "Heaven" in *Journey to the West* as an example, Sun Wukong and his brothers kneed down in front of the Jade Emperor and it is considered one episode. The narrative purpose is to make Sun Wukong to walk to the right position and finishing the kneeling (including bowing, knees on the ground and kowtowing). At the beginning of the narration, three people go to the Heaven. Sun Wukong walks to the right position and knees down (narrative process). After Jade emperor allows them to stand up, it means they finish the task in the episode (Ending). If the users can finish the episode by touch, the narrative process will move to the next stage.

After finishing the rules of cooperative operation of Shadow Puppet's motions, in overall narration of Shadow Puppet, according to narrative purposes of the episodes, the performers work together to control the Shadow Puppet. After accomplishing the purpose, they will move to the next stage until finishing all narrative process. Cooperative cooperation of Shadow Puppets not only challenges the work division of the performers, but also guides the understanding of the behaviour of the roles of Shadow Puppets and the plots. Thus, the performance will be more challenging and the users will further recognize the touch operation of the motions of Shadow Puppets.

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