Paper

Director-Oriented Shot Assessment and Evaluation in Virtual Cinematography

(仮想映像空間による映画製作のアセスメントシステム)

Shakil A. Hannan† , Daisuke Endou† and Masanobu Yamamoto (member)††

Abstract Traditional storyboards are considered the blueprints of live action movie shooting for narrative storytelling, but they have limitations. In addition, the conversion of storyboards to motion picture cinematography consumes time and money. We propose a more advanced tool than storyboards: the Shot Evaluation and Development System, which not only reduces the time and cost of live action shooting, but also helps a director to increase his or her artistry and creativity through the exploration of placements and movements of actors and cameras that best suit the storytelling. Because the system includes the motion of virtual cinematography, it is better than storyboards at communicating with cinematography departments in live action shooting. The pace of a moving shot along with the movements of actors, generated by motion data, influences the way a director orders shots to develop an appropriate rhythm in a sequence, and that helps a director make a proper judgment in developing a scene at the pre-production stage of filmmaking.

Key words: *virtual cinematography, director oriented, storytelling, shot evaluating, moving shot, live action shooting*

1. Introduction

Storyboards are transformed into motion picture at live action shooting. As the process of transformation requires expertise, precise communication between a director and experts is important for reduction of time and cost at shooting. Since a traditional storyboard lacks of motion of camera and actor, it is unable to show proper pace and direction of camera movement. That increases the role of a director and the works of cinematography department in finding out the exact pace and direction of camera movement. Therefore, the pace and directions required within the shots needed to be evaluated before live action shooting since evaluation is always essential to find out the best cinematic compositions and movements of camera and actor in a sequence of shots.

The existing automatic camera control[1),2)] in real time for virtual cinematography has a limited use and is good for works like sports event or sitcom. This kind of camera work is not good for artistic and creative works, because making system intelligent by automatic camera control follows conventional grammar of film language and continuity rule of movie making and is based on a general structure of editing. While artistic and creative filmmaking is related to subjectivity, a director should have the freedom in controlling the camera in developing the desired mood. Creating the desired mood is the main concern in narrative storytelling as it deals with human psychic and emotion. When someone develops a certain kind of mood by bringing variation within the existing grammar and rule, we would like to define it as "artistic". But "creativity" goes beyond predictible grammar and rules. The best creative images show subjects through the directors' eyes and perspective as art creation depends entirely on artists' perception and intuition, which has a natural tendency of overruling grammar.

Although as a complex medium of art, artistic and creative filmmaking encompasses many elements such as artistic and creative lighting, acting, set, sound and fashion designing, here we are focusing on artistic and creative camera work with relation to actors' placements and movements. It is the relation between camera and actors in narrative storytelling that has been a great deal of concern because the placements and movements of camera and actors develop the structure of a sequence, which is staging and compositing of shots in

Appeared in ICAT on Dec. 5, 2003
Received Sept. 2, 2004; Revised Dec. 6, 2004; Accepted Jan. 19, 2005
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motion picture cinematography. So, variation of rule or overruling the grammar concerns about the interactive relation between camera and the actor, which is greatly responsible in artistic and creative shot designing in staging of two or more actors.

In filmmaking, a director creates an ordinary mood with the use of a camera through a sequence of images in following the grammar of film language and continuity rule of movie making, by the same kind of camera, a talented director captures the images for a sequence of shots which reveals the subject in extraordinary ways and brings abstract psychic and emotion into a visual form. That's the reason we emphasize the creation of a virtual movie camera, which has the same kinds of characteristics as a camera of live action cinematography and is intelligent enough in communicating the direction of a director.

As we like to make live action shooting time and cost effective by reducing trial times of shooting, we propose Shot Evaluation and Development System (SEDS), an advanced tool than storyboard concept, which holds movement of camera and actor, and is used for perfect evaluation and development of shots.

2. Related Works

While available computer-aided storyboard softwares create storyboards, our proposed system develops virtual *shots* - *static* (when camera and actor are static) and *moving* (when camera or actor moves, or both move). Shot is the basic construction of film making and a shot lasts from the time the camera is turned on to the time the camera is turned off. Therefore, development of virtual shots gives a film director the sense of motion, movement and rhythm in a sequence, which a conventional storyboard lacks. The purpose of available computer-aided storyboard like StoryBoard Quick and StoryBoard Artist of Power Production Software[5] or Storyboard Lite[6] is same as traditional storyboarding. As these kinds of softwares do not have the capability to hold the movement of actor and camera, these are far from fulfilling our goal of reducing trial time of shooting and evaluating shots effeciently.

Although the final output of these digitally created storyboards are printed on paper, StoryBoard Artist has simple animatic type animation to run storyboard art works frame by frame - each storyboard corresponds to each frame. Storyboard Lite has also frame by frame playback system of its digitally created slides of storyboards. As these softwares are not intended to create virtual shots with motion, these do not have the features of combination of different types of camera movements, actor's movement or actor and camera movement simultaneously.

While Storyboard Quick does not have a camera, Storyboard Lite has camera controls related to actor's placement, but the perspective of shot is not changed when camera moves.

As for virtual cinematography, we analyze the paper of He *et al.*[1]. In this paper, the authors emphasize to the basic grammar of film language than to a director's talent. The authors have implemented a system of Virtual Cinematographer (a real time camera controller for automatic cinematography) and demonstrated its application in a virtual party setting. But the process of implementation is confined to the system 's rigidity because of its very conventional approach in compositing a sequence of shots. The authors also follow a certain basic formula to demonstrate an order of shots for the purpose of editing. But Pudovkin (one of the silent cinema's most noted directors) came to the conclusion that the process of editing - the selection, timing and arrangement of given shots into a film continuity - was the crucial creative act in the production of a film[9]. So, developing certain *camera modules* and *idioms* just limits a director 's artistic and creative concern. In that paper, a realization of strict continuity style has been followed in developing camera modules as well as organizing *2talk* (dialogue between two actors) or *3talk* (three-actor dialogue) idioms. But there ought to be a lot of unlimited variations in idioms in creating sequences of shots in different styles while following the grammar and continuity rule of movie making, as it comes to artistic development. Since narrative storytelling is a subjective matter, a director's style can not be developed by following certain formulas of order of shots.

When it comes to creativity, we see, the directors like Ozu, Bresson and Dreyer developed narrative techniques that frequently violate the conventions of continuity filmmaking to achieve their aims. So, we come to the conclusion that if anything is true of the arts, it is that there are no rules[10].

Miyazaki *et al.*[3] proposes a system to find out the popular camera movement from movies to express a certain expression of actor from a script. This kind of selection of camera work satisfies the conventional norms of expression rather than artistry and creativity of a director.

Tomlinson *et al.*[4] develop a behavior-based autonomous cinematography system, *Camera Creature*, where characters' interaction and emotion determines the motivated shot organization with conventional use of few camera angles. But the system limits itself with the authors' style of shots' organizations. The users do not have a chance to create their own shots.

The camera work simulation system developed by Makino *et al.*[7] is good for television program because of its simplicity. But the storytelling in movies deserves more complex interface where tracking movement of camera and the movement of actor in 3-D space are a necessity. We see the same kind of limitation in the camera switching simulation tool developed by Yamasato *et al.*[8] when the tool is used in a studio environment.

3. Limitation of Storyboard

There are two times in traditional film making, when a director has the opportunity to evaluate shots according to the story line. At first, it is at the time of storyboarding in the pre-production stage (before shooting) of film making, and then at the time of editing in the post-production stage of film making. But the crucial stage is at the time of storyboarding, because it's the time when a director makes decision of what kinds of shots needed to be shot to fulfill the editing order or line-up. Otherwise, the director has to make the decision at shooting, which is troublesome, time consuming and increases the production cost. This is the reason a complete shot evaluation is very important at pre-production stage of filmmaking. But the inability of storyboard to show motion, the movements of camera and actors, makes the evaluation procedure incomplete before shooting.

3.1 Communication

While the main goal of storboards is pre-visualizing the ideas of a director, storyboards also serve as the clearest language to communicate ideas to the entire production team[10].

As a traditional storyboard lacks motion, it allows only giving directions of camera movements of moving shots by arrows and descriptions (**Fig.15**).

3.2 Exploring Perfection

Motion has a major responsibility for artistic development of a story and to the development of a director's style. The various paces of camera and actor's movements change the meaning of sequences of shots and add new dimensions to the stories.

Besides, combination of different kinds of camera movements in different directions is a necessity for narrative storytelling. A director is able to explore more in structuring shots for a sequence when the director can move a camera in anywhere of 3-D virtual environment and can experiment with any kind of combined camera movements.

The sense of rhythm also helps to find out an appropriate expression for storytelling. Actually, when directors get a realistic feel for both static and moving shots, that provides them with more thought for artistic and creative perfection in designing a sequence of shots orderly. On the contrary, when a director follows traditional storyboard, the director has to wait for live action shooting to get the feel of movements and the sense of perspectives through view finder of camera or video monitor of video assist.

3.3 Order of Shots

The order of shots in a sequence gets changed when motion is added to a moving shot. As a result, new structures of shots developed matching the continuity of shots in the sequence. Besides, actual pre-visualizing the order of shots limits the necessity of taking extra shots at shooting and that reduces the task of editing as well in developing a sequence.

4. Virtual Cinematography

In traditional storyboarding, storyboard artists develop storyboards according to a director's satisfaction. As our proposed system is director oriented, a director has to be a film language literate and should have enough sense of aesthetics as well as cinematography. Therefore, the director can develop virtual shots and bring any change required for a shot as many times as it is necessary for the best possible selections of shots in a sequence.

In this research, although we concentrate on moving shots, there are rules and also breaking of rules in creating shots. As creating art is the main concern for an artist, we intend to keep our system free from any kind of grammatical constraint.

4.1 Variations within Rule

In this research, from a movie director's point of view, we have captured a specific *scene*, which is a sequence of shots. There are some basic rules to follow at the time of shooting shots. The most important one is the *continuity rule* of movie making, which is also called the *180-degree rule*. In this rule, camera should be placed according to the *line of action*, an imaginary partition running through the space in front of the camera to-

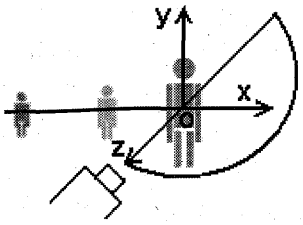

Fig. 1 Camera can be placed anywhere in half circle.

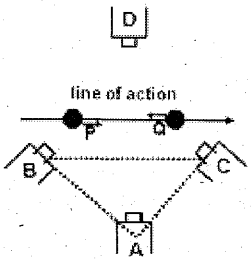

Fig. 2 Actors (P, Q) facing each other.

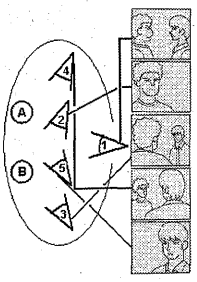

Fig. 3 An editing pattern.

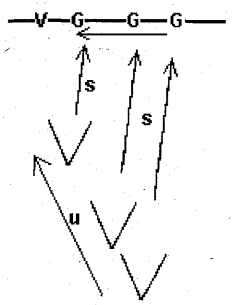

Fig. 4 s shows focus point, u for camera direction.

wards the motion or in the direction that an actor is facing. In x, y, z 3-D world coordinate of **Fig.1**, z-axis is the line of action because the three characters are facing forward.

Creating a sequence of shots generally follows the *triangle principle* when it is dialogue between two actors or more, or any general kind of composition. In triangle principle, camera is placed mainly at the three points (A, B, C) of a triangle like in **Fig.2**. There are few more variations of this triangle principle. Arijon[15] shows some basic variations in his book and possible editing patterns for a sequence. Combining two of these variations, we have developed an editing pattern in **Fig.3**. The order of the shots is 1-2-3-4-5 in a sequence. The order can be changed like 2-3-5-4-1 or 3-4-5-1-2 and so on, which depends on how the director wants to create a mood through editing.

This guideline is acceptable as long as camera and actors are static. But when the storytelling demands movement or motion of camera and the actor as well in creating the desired mood, the structure of shots get changed and so the editing pattern. The psychological and emotional ground of story building creates these variations of structuring and develops a director's style. So, art creation can not be confined in certain structures as variations are unlimited and yet to be explored.

4.2 Breaking the Rule

Consistency is always required in two consecutive shots in regards to the positions of actors. When we use any of the three cameras of A, B or C of Fig.2 actor P will always be at the left side of the frame and actor Q will always be at the right side of the frame.

In the same figure, if a shot is taken by camera A and then the subsequent shot is taken by camera D of the opposite side of the line of action, that is a breaking of rule, because the positions of actors, P and Q are transposed by the use of camera D. It is an error and abnormal in film grammar as viewers are confused and disturbed with this transposition. But there are certain rules in crossing the line, for which when camera crosses the line viewers are not confused of continuity with the positions of actors after transposition. So, if breaking of rule is occurred successfully to create a certain kind of mood, which does not distract the viewers, but creates a psychological impression on them, then it is cleared that there is no rule in creating art.

The powerful director, Andrei Tarkovosky breaks the continuity rule in his movie, *The Sacrifice*[12] to create a mood, which is something more than scary (that perceptible, but hard to express) in the sequence when the character Alexander (Erland Josephson) is looking for his immediate-disappeared son with fear in the wood. All on a sudden, the son appears into the screen by jumping on his father's shoulder first from the left side of frame and then from the right side of frame within couple of seconds. **Fig.5** and **Fig.6** are the two frames of the related shots edited side by side. Here, the son's jumping on his father's shoulder works very well when camera is static at the other side of the line of action. Besides, expression of father's face and the sound effect also plays an important role in breaking the rule. Instead of jumping, if the son walks slow or normal with the sound effect and father's expression, the director would not be successful in breaking the rule because that would not be able to create the desired mood, but confuse the viewers about continuity.

The other directors who break the rule have not created the same mood as Tarkovosky does and their ways of breaking rule are not the same as Tarkovosky. In breaking the rule, camera may have movement while the actor is static or both the camera and actor are static. Every time when a director breaks the rule in a completely different way than before to create a completely different mood, every time it is recognized as creative. Breaking the rule is something, which comes from a director's deepest sense of aesthetics.

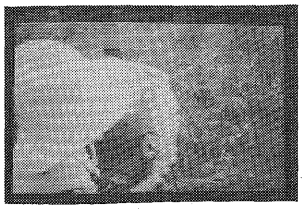

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Fig. 5 Taken from one side of line of action.

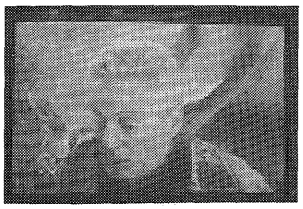

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Fig. 6 Taken from opposite side of line of action.

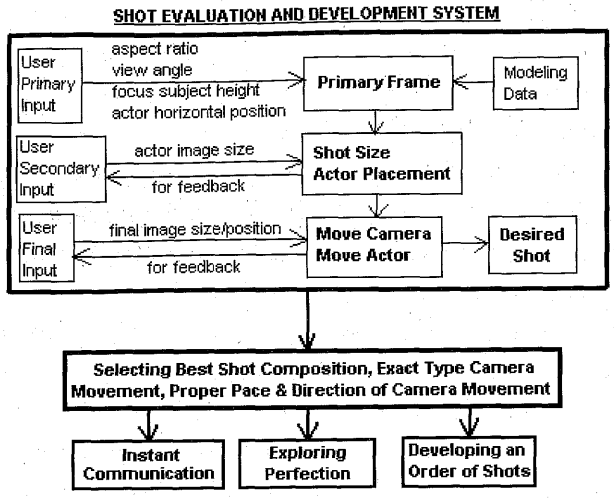


Fig. 7 System Overview.

Art is more than grammar, where aesthetics play a vital role in formation of storytelling. So, following grammar is not the answer to art, but the mixture of aesthetics and grammar, and sometimes going beyond of the grammar. While placing and moving camera with actor creates variations and breaks the rule for proper storytelling, camera angle and editorial treatment play an important role as well on psychological reaction of viewers. The principal psychological purpose of a motion picture is to sway the audience to react in a desired mood[11].

5. System Overview

Fig.7 is the organization of our full system.

Primarily a user of the proposed system places the camera and creates a frame which is called *primary frame* (**Fig.8(b)**), where the actors are supposed to be required to place in full sizes from the system to capture a shot subsequently.

In the secondary input, the actors are placed by the direction of the user for a *long shot*, which provides a distance perspective. But in the case of other kinds of *shot sizes*, - like a *medium full shot*, which cuts just over a person knee at the bottom of a frame, or a *close shot*, which cuts at the chest, or a *close up*, which cuts at the neck - a different approach is required for an appropriate camera placement. While these cutting heights are related to the actors' figures in these shot sizes, mainly camera focuses on the actor at origin of the primary frame and then the camera gets elevated up required to the related shot size along with zoom-in or front tracking. In case of a *full shot*, which shows a full view of a person, primary frame is used.

Creating proper shot size and placing actor fully depend on the user's satisfaction. So there is a two-way communication with the feed back of a user that is demonstrated in Fig.7 at 'User Secondary Input'.

When it is essential to complete a shot with the camera and actor's movement, the user finally inputs the required data for any kind of movement. There is also a two-way communication with the user feed back for the development of the desired shot, which is shown at 'User Final Input' stage.

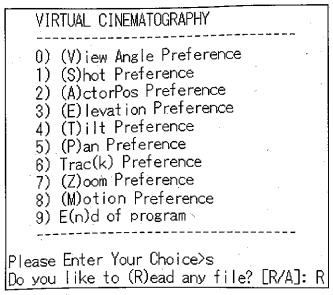
Therefore, by using the system, a user has the opportunity to evaluate the pace and direction of any kind of camera movement as well as the actors' placements and movements. As a result, the system helps a director in three different ways that are shown in the same figure.

6. Concept of Designing

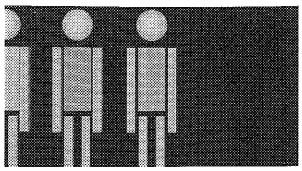
Unlike looking through a viewfinder of traditional movie camera, the focused actor's desired image size on the view plane defines a shot size whether it is a long shot, full shot, medium full shot, close shot or a close up. In opposition to moving camera while looking through the viewfinder in live action filming, a director requires to input the final image size or position of the focused actor into the system. Thus the system translates this information to the required camera movement and gets the information of pace of a camera as a director requires.

To choose a particular camera movement, we have developed a user interface shown in Fig.8 for virtual cinematography including the view angle, shot size, change of actor position and the camera movements with 6-degree of freedom. The system also saves the data of an image in a file after each type of camera work and reads the file for any further change of a shot. We have used 'View Angle Preference' from Fig.8 (a) to create the image in Fig.8 (b).

We retrieve the data of primary frame (Fig.8 (c)) when it requires any kind of actors' placements or camera works mentioned in the Virtual Cinematography Menu.



(a)Virtual Cinematography Menu.



(b)Image of a Primary Frame.

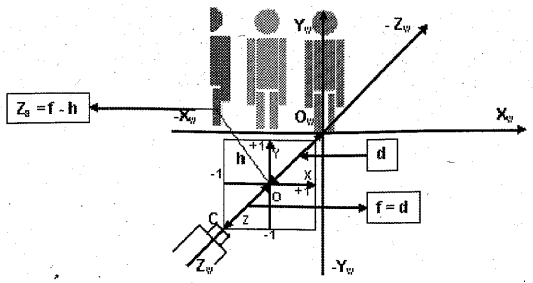


Fig. 9 Initial camera placement.

Enter the name of the readfile> viewAB3.txt

fovyDEG	fovyRAD	cam_Elev	focalLen	size_A [0]
8.000000	0.139626	6.916250	98.808076	13.832500
size_A [1]	size_A [2]	image_H [0]	image_H [1]	image_H [2]
13.832500	13.832500	7.469550	7.453942	7.407699
pos_X [0]	pos_X [1]	pos_X [2]	pos_Y [0]	pos_Y [1]
0.000000	-6.397532	-12.795063	0.000000	0.000000
pos_Y [2]	pos_Z [0]	pos_Z [1]	pos_Z [2]	focus_X
0.000000	0.000000	-0.206894	-0.824998	0.000000
focus_Y	focus_Z	halfWidth		
6.916250	0.000000	12.795062		

Do you like to change input? [Y/N]: y
Which actor size is to be changed?[C/G/Y/O] c
Enter the desired Y-size of Actor1> 4.6
Is the actor in (F)ocus? [F/N] f

(c)Retrieved primary frame file.

Fig. 8 User Interface.

We use Visual C^{++} programming system at development of our research.

6.1 Placing Camera Initially

In **Fig.9**, a camera of perspective projection is on the line of action on positive Z_w-axis of world coordinate and facing the Red character straightly as the actor is at the center of origin of the world coordinate while the other two characters are on the negative X_w-axis. OpenGL default camera placement is also the same on positive Z_w-axis of world coordinate and looks at negative Z_w-axis. When the actor at the center of origin of the world coordinate is in full size on the view plane, the focal length (f) is same as the distance (d). Therefore, we easily determine the initial placement of camera[13], where view angle, focus actor or object's vertical height and aspect ratio are given as user input. We also place the camera on the negative z-axis of world coordinate when it requires and find out the initial camera placement as the same way as we determine focal length when camera is on the positive z-axis of the world coordinate. Actually the initial placement of camera can be anywhere in the world coordinate upon the determination of focal length.

6.2 Creating Primary Frame

After choosing the proper camera lens, the user needs to create a primary frame, where the required actors' horizontal positions in the world coordinate are given by user and the actor's z-placement, Z_a, in Fig.9 is the subtraction of hypotenuse, h (that is determined by the *Pythagoras' Theorem*) from the focal length, f. To calculate the hypotenuse, the two sides of right angle are the actor's X_w-placement and the distance, d, which is same as the focal length, f. Finally to create a primary frame with the actors in almost full sizes, we have a camera elevation on the optical axis and the focus point is at the same level as the optical axis on the full sized actor of origin.

In planning a scene like Fig.9, live action cinematography procedure has been considered, which is setting the focal length first and then placing the camera. The required actors for a shot have to be ensured in a primary frame. Our system equips itself with a library of models, where a user has access to choose require models. As the visual extents in the image space are usually standardized into the minus one to plus one range in x and y axes[14], positioning the actors up to the width of half frame at the both sides on X_w-axis confirms their positions inside the frame with almost full sizes.

While in live action shooting, a director communicates with actors and cinematographer at the set or location, in this system, a primary frame helps a director primarily in positioning the virtual actors according to the need of a shot. When a user places the actor in a long shot, in this situation, the *formula of perspective projection* is simply used for actors' depths as in **Fig.10** from the primary frame (Fig.8 (b)), and the user can also change the actor's horizontal (H) placement like in **Fig.11** (green model's position changed) by using the reference of actors' horizontal placement from the same primary frame.

Besides, the primary frame is used to get reference of its focal length and the actors' full image sizes at the time of camera movements and the placements of camera for subsequent shots.

6.3 Movement of Virtual Camera & Actor

Although there are different kinds of camera movements in Virtual Cinematography Menu, we use mouse and keyboard programming for the combination of

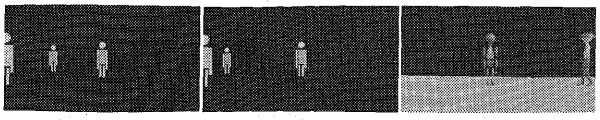


Fig. 10 Depths. **Fig. 11** H-change. **Fig. 12** Not desired.

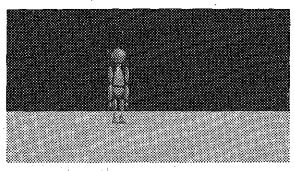


Fig. 13 Track left used to track-in of Fig.16.

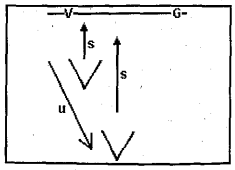


Fig. 14 s for focus point u for camera direction.

movements like tracking and tilting. We retrieve an intended file for evaluation by a desired set of combined camera movements.

We use 'Motion Preference' from cinematography menu to activate the movement of actor by motion data. The actors' motions have been captured by a video image-based motion capture system[16]. Piling up the motion data, we have a motion library including walking, sitting, and turning left or right. Picking up a motion data from the library, a virtual actor in SEDS can reproduce the movement as it has been. To keep the continuity of movements of the virtual actor over the different shots, a linear interpolation technique can connect successive movements smoothly. We have certain key strokes for the actor's movements, but for the combined movements with camera, various key strokes have been used.

Different shot sizes are created by using 'Shot Preference' from cinematography menu. These shot sizes are used for moving camera back or forth to the targeted distances when we need to move camera to a certain shot size at combined camera movements. But to move camera horizontally to place the actor at a certain position for certain combined movement, we have programmed our mouse left click for horizontal tracking. **Fig.13** is an example.

When the movement of actor and camera are combined, considering the preference of main actor's movement, camera moves. The paces of camera movements are stored in related files of shots.

7. Evaluating, Developing & Shooting Shots in Compare to Storyboard

We have chosen a story of "Vampire & Girl" by which we are able to demonstrate how the physical process of live action shooting has become time and cost effective by using SEDS. Besides, we see how the placements and movements of actors and camera are responsible for artistic and creative development.

The Story: Vampire & Girl

A vampire, in disguise of a man, is standing in a lonely place like a parking lot or street side or any other place at night in a low lighting condition. A young girl passes the area. As she sees a man standing alone, she walks slowly and wonders. She gets close to the man, the man blocks her way and his face changes to a vampire's face. That makes the girl surprised and frightened. She starts screaming as the vampire about to attack her.

Method of Experiment

At first, we have developed the hand-drawn traditional storyboard (TSB)-s for a sequence of shots on a story line (Fig.15). There should be notes or indication of place and lighting condition in hand-drawn TSB and actors' facial expression should also be shown. Since we focus on camera and the actor's placements and movements, we do not intend to draw or write in detail of other elements. Then we have evaluated TSBs by using SEDS before developing a sequence of shots (**Fig.16 to Fig.23**) virtually by the same system.

At live action shooting, we have mainly focused on trial times of moving TSB shots and shots developed by SEDS to prove the advantage of using our system. Subsection 7.1 explains the method in detail.

The number at the left top of each frame of hand-drawn storyboard indicates the shot number in a sequence. So, 'SBS1IP' indicates storyboard shot 1 initial position, 'SBS1FP' stands for storyboard shot 1 final position while 'SBS3' for storyboard shot 3. The arrows in SBS3 and SBS4 indicate high angle shots while the arrow of SBS6 indicates low angle shot. In **Fig.17** to **Fig.21**, the character at left of the frame denotes 'Vampire' (V) and the other character on walking pose denotes 'Girl' (G).

The traditional storyboards of Fig.15 are printed on a paper. But Fig.16 to Fig.23 are the samples of the moving shots created by SEDS. These shots contain the movement of Girl, which is generated by motion data, and have the motion of the camera movements as well. When Girl starts walking at shot 1 and finally stops walking in shot 3, it takes 433 frames in total, which are from the sequences of the animation.

7.1 Live Action Shooting

As we can assume that if someone has the opportunity to see the pace and direction of camera movement of a

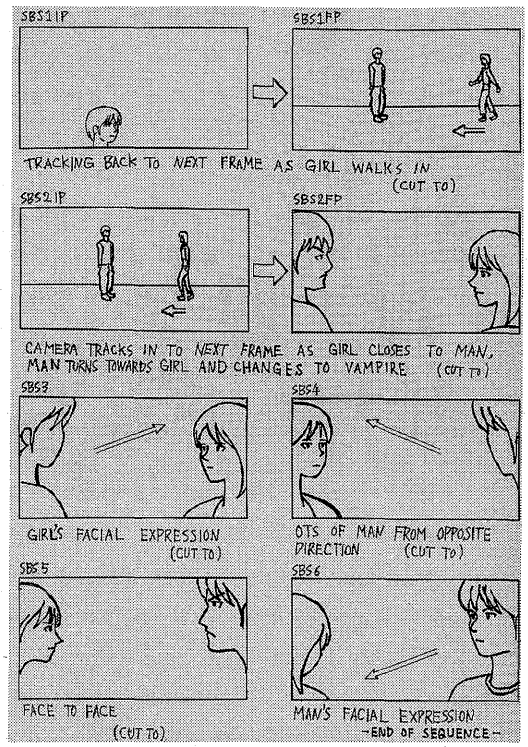


Fig. 15 Traditional storyboards based on camera and actors'placements and movements.

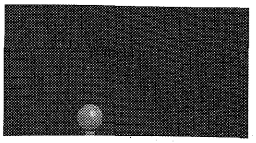


Fig. 16 Shot 1-initial position.

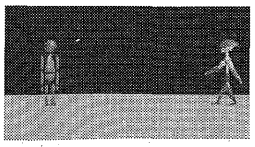


Fig. 17 Shot 1-final position.

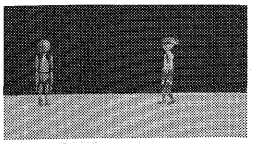


Fig. 18 Shot 2, G focused.

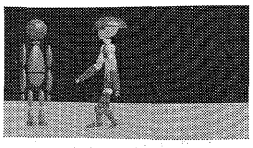


Fig. 19 Shot 3, angular track-in.

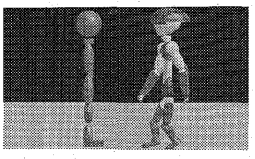


Fig. 20 Shot 4, track to left.

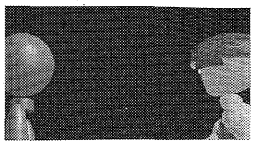


Fig. 21 Shot 5, track to close.

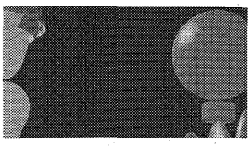


Fig. 22 Shot 6-low angle at V.

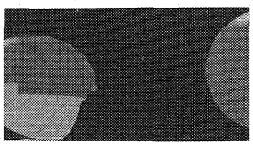


Fig. 23 Shot 6-high angle at G.

shot visually, it takes less time at shooting in achieving the same pace and finding out the direction of camera movement than seeing the same moving shot drawn on a paper. Moreover, our system helps a director to make a precise plan for shooting for the shots required in a sequence.

7.1.1 Comparing Trial Time

To prove it experimentally that SEDS-based shooting takes less time than TSB-based shooting for moving shots, we formed two groups of camera operators, A and B, from the students of our laboratory. Each group had five camera operators and five assistants. We used a DV camera, tripod, straight and half circular tracks, and a trolley as shooting equipments. While a camera operator needed to operate camera and to keep an eye in viewfinder or on monitor, an assistant drove the tracking trolley according to instructions of the camera operator. We trained them how to operate camera and move camera in different kinds of camera works. The groups had been given reasonable time to get used to camera operation and movements.

Let the operators be named as A1, A2, A3, A4 and A5 of group A and B1, B2, B3, B4 and B5 of group B. When an operator and assistant were shooting, no other operator or assistant was allowed to stay at the shooting spot at any time of shooting. Otherwise, it would hamper our experiment as other camera operators would find out the directions and paces of camera movements easily by watching others' shooting. All camera operators and two actors had been told the story and the female actor, who was acting as Girl, had been told to walk slowly after she entered into frame. She had also been explained about her positions in different shots.

Achieving the perfect pace of camera movement of each shot was the prime target of camera operators when we shot moving shots. As we evaluated TSBs of Fig.15 by SEDS, at the time, we determined the desired paces of camera movements for the two moving TSB shots (SBS1, SBS2) are were restored in our system. We also determined the desired pace of movement for each of the virtual shots separately by using SEDS, and the pace was the target pace for the related shot.

Process of Trial

We shot the two moving shots of TSB from two different forms - TSB and virtual - by both groups. We follow the same process for the six virtual shots developed by SEDS.

Before shooting any of the shots from TSB form, all camera operators had been explained the background of each shot. If any operator had any difficulty to understand any of these shots in TSB form, the operator had asked us for clarification and we tried to make it clear to them. As camera operators shot the shots from TSB form, we explained them the targeted paces, instead of

Table 1 Trial times for each camera operator of group A from TSB.

Shot	A1	A2	A3	A4	A5
1	4	3	3	4	3
2	3	3	4	3	2

Table 2 Trial times for each camera operator of group B seeing computer display of TSB.

Shot	B1	B2	B3	B4	B5
1	1	1	1	1	1
2	1	1	2	1	1

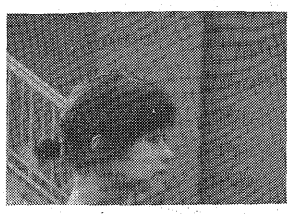


Fig. 24 E4-initial position.

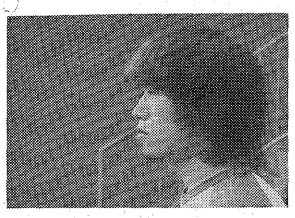


Fig. 25 E4-final position.

Table 3 Trial times for each camera operator of group A seeing computer display of shots by SEDS.

Shot	A1	A2	A3	A4	A5
1	2	2	2	3	2
2	1	1	1	1	1
3	1	2	1	1	1
4	1	1	1	1	1
5	2	1	1	2	1
6	2	2	1	2	1

Table 4 Trial times for each camera operator of group B from TSB of shots by SEDS.

Shot	B1	B2	B3	B4	B5
1	5	4	3	4	4
2	2	1	1	2	1
3	3	3	4	4	3
4	1	1	1	1	2
5	5	6	4	3	4
6	5	4	3	3	4

Table 5 Comparison of average trial times of moving shots from two different forms.

Sequence	Shooting	TSB-based	SEDS-based
TSB of Fig.15	Time(s)	3.2	1.1
Fig.16 to Fig.23	Time(s)	3.0	1.4

showing them the shots on computer display of SEDS.

On the other hand, computer display of the shots developed by SEDS helped to get the idea of directions and paces of camera movements of all virtual shots exactly without any description or arrow like in TSB or without any briefing from us. So, when camera operators shot the shots from the virtual forms, we showed them the shots on computer display of SEDS.

There were trial times to get the desired pace of camera movement for each moving shot before shooting the shot finally. Camera recorded every trial in digital video cassette as shot until the targeted pace and required direction of camera movement for each shot had been achieved.

At first, we showed shot 1 and shot 2 of Fig.15 in TSB form to each of the camera operators of group A. **Table 1** has the data of their trial times. Then group B watched these two moving TSB shots on computer display of SEDS. Their trial times are given in **Table 2**.

Later, group A watched the six shots developed by SEDS on computer display. **Table 3** is the data of their trial times. Then group B had been shown the TSB form of these six moving shots, which are similar to Fig.16 to Fig.23. The trial times of these shots are in **Table 4**.

The average trial times for two TSB shots of Fig.15 from TSB and virtual form are 3.2 from Table 1 and 1.1 from Table 2 respectively. The average trial times for six virtual shots developed by SEDS from virtual and TSB form are 1.4 from Table 3 and 3.03 from Table 4 respectively.

Table 5 explains the difference between the average trial times of moving shots.

To find out the appropriate camera directions in shot 1 and shot 3 of Table 4, trial times increase. But to achieve perfect paces of camera movements in shot 1 and shot 2 of Table 1, and shot 5 and shot 6 of Table 4, trial times increase.

7.1.2 Considering Extra Shots

While we were assessing TSB shots of Fig.15 by SEDS, at SBS1FP, we wanted to track camera to left in circular way to a certain degree while Girl walks toward Vampire to bring a variation in the order of shots. We had not been satisfied with the perspective as the movement takes the actors towards right of the frame (**Fig.12**). Later, this experience helped us developing virtual shot 3 of angular track-in.

We also developed a panning shot of variable speeds instead of shots 4, 5 and 6 of Fig.15. Panning starts at opposite side of line of action of SBS2FP from the profile of Girl to the profile of Vampire and goes back to the profile of Girl again. This way pan continues few times. If we had not had the opportunity to evaluate this moving shot by SEDS before shooting, we would shoot this shot at live action shooting like the shot of **Fig.24** and **Fig.25** as extra shot 4 (E4). Later on, E4 would be needed to decide at editing comparing with shots 4, 5 and 6 of Fig.15. But eventually, we explored the virtual shot 6 of half circular tracking, which starts with low angle *OTS* (Over the Shoulder) of Girl (**Fig.22**) and ends with high angle OTS of Vampire (Fig.23).

7.2 Artistic & Creative Development

The process of transformation of storyboard into celluloid at shooting is a complex process of cinematography. At this stage, a director especially needs to make a decision about the pace of camera movement. Besides, a director has a real opportunity to decide if the developed storyboards are satisfactory for the shots desired. When it is possible to get practical experience at

shooting with the movement of actor and camera while visualizing a sequence of shots from storyboards, it inspires a director to explore more to improving artistry and creativity. Therefore, before live action shooting, SEDS gives a user the same opportunity to explore more of shots and helps the user to set the proper paces and directions of camera movements that eventually saves the time and cost for live action shooting.

The sequence of sample shots from Fig.16 to Fig.23 developed by SEDS is different from the sequence of storyboards in Fig.15. As we have developed a rhythm by setting out the paces of camera movements from the sequence of storyboards, SEDS also helps us to explore the new compositions and directions of camera movements with the paces as well, when we have an accurate sense of perspective change in every single moment as female actor and camera move.

(a) Developing a Rhythm

All shots created by SEDS are moving shots. First, the sequence starts with a fastest tracking back like Fig.14 (shot 1), and then a short gentle pan from center of the frame to Girl (shot 2). Next is a medium pace of angular tracking like Fig.4 which follows Girl (shot 3). After that, camera tracks left slowly until the actors are at the center of the frame (shot 4). Then there is a faster tracking-in (shot 5), although the camera starts slowly at the beginning. Then, camera tracks at slower pace half circularly at other side of the line (shot 6), as it catches the expression of Vampire for few seconds at the beginning and ends up catching the expression of Girl for few more seconds. Since the beginning of this sequence, a kind of rhythm has been developed with the shots in different directions and it influences us to reach to perfection in breaking the rule by the use of slower pace half circular tracking shot at the end.

On the other hand, in TSB of Fig.15, we have developed an editing pattern, where at shot 1 a fastest tracking back is used. We keep the same pace of movement in shot 1 developed by SEDS although the direction of camera movement is different. In the next shot, camera tracks straight front in a medium pace until it reaches to the close *two-shot* (frames two characters) as Girl walks and stops close to center of the frame. There are four static shots afterwards that complete the sequence.

(b) Variations in Shots & Breaking the Rule

The placement of Vampire and the movement of camera have been changed when we have used SEDS. We have explored different kinds of compositions and directions of camera movements than the traditional storyboards that starts from shot 1 (**Fig.16**) and continues to shot 4 (**Fig.20**).

Instead of using three storyboards of SBS4, SBS5 and SBS6, which are from opposite side of line of action, we have developed only shot 6 (Fig.22 and Fig.23), which is taken from opposite direction.

8. Result

We edited two sequences of live action shooting in matching the female actor's movements - one followed the TSB of Fig.15 and another followed the shots developed by SEDS (Fig.16 to Fig.23). The two sequences have been placed side by side in two columns from **Fig.26** to **Fig.41**.

The participants - camera operators, assistants and two actors - had better understanding of our story. After editing the two sequences, we explained them about intended sound treatment for horror effect with the darkness of night. Then the participants had a proper grasp in imagining the whole sequence of our two edited versions. All of the participants had given their opinion in favor of the sequence created by SEDS that the sequence designing had greater potential in creating impact desired on viewers than the sequence developed in TSBs. 4 out of 22 participants had also said that the sequence based on TSBs had the potential of creating different kind of mood than another sequence. We have taken their opinion as viewers' reaction.

We are also satisfied with the output by our system.

9. Discussion

We see that our proposed system has the ability to communicate with cinematography department with moving shots and can reduce the time at live action shooting in exterior or interior.

In **7.1 Live Action Shooting**, for the shots of TSB, a camera operator needs briefing from a director. But our system removes that need. We see a reduction of trial time after watching the motion in computer display. For simple camera movements like in shot 2 (**Fig.18**)and shot 4 (**Fig.20**) developed by SEDS, the difference of trial time between Table 3 and Table 4 is very narrow. As camera movements get a bit complexes in shots 1, 5 and 6 developed by SEDS, the difference of trial time between same two tables gets increased as well. In Table 5, we see the reduction of shooting time when we use our virtual system for moving shots, which means reduction of shooting cost too. The cost of film stock is not included since trials happen before shots

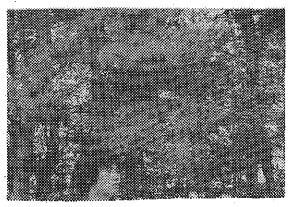


Fig. 26 SBS1IP, track back.

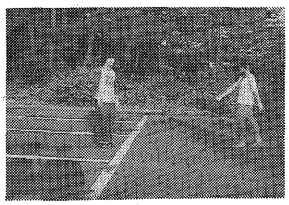


Fig. 27 SBS1FP, girl walks in.

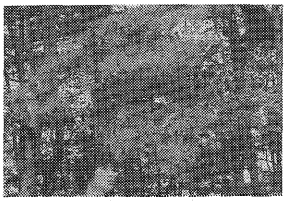


Fig. 34 Shot 1-initial position.

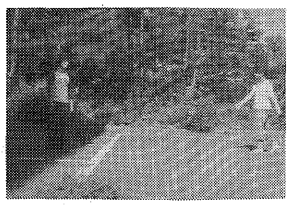


Fig. 35 Shot 1-final position.

Fig. 28 SBS2IP, track-in.

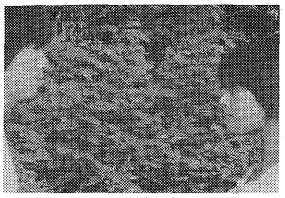


Fig. 29 SBS2FP, man turns.

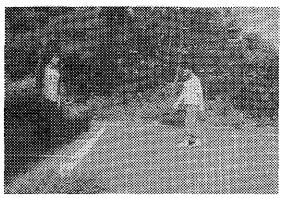


Fig. 36 Shot 2, G focused.

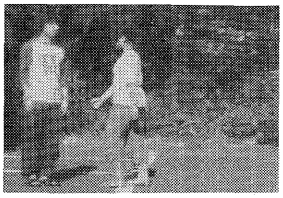


Fig. 37 Shot 3, angular track-in.

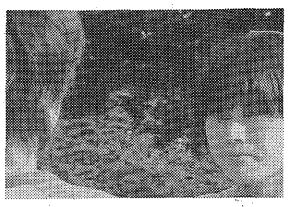


Fig. 30 SBS3, girl expression.

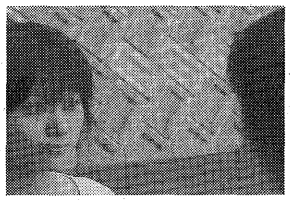


Fig. 31 SBS4, opposite direction.

Fig. 38 Shot 4, track to left.

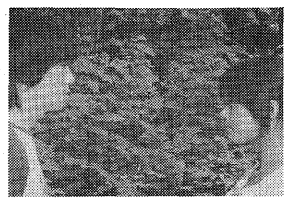


Fig. 39 Shot 5, track-in to close.

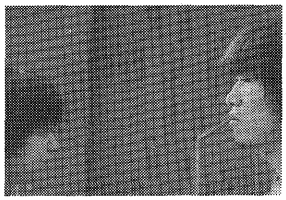


Fig. 32 SBS5, face to face.

Fig. 33 SBS6, man expression.

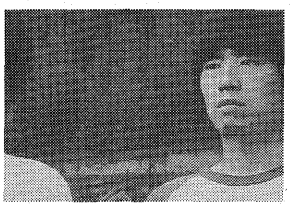


Fig. 40 Shot 6, low angle at V.

Fig. 41 Shot 6, high angle at G.

taken.

Traditional storyboard may not have the detail of the directions of camera movements, especially for combined movements like virtual shots 1 and 3. A camera operator has to spend time to figure out the directions of camera movements (**Fig.14** and **Fig.4**) for moving shots. Watching the computer display of a virtual shot, it's easier for a camera operator to figure out the exact camera direction.

It is also clear that proper planning before shooting reduces the need of taking extra shots like extra shot 4 and proper perspective sense is also a must for saving time and production cost as the shot of Fig.12 helps us with perspective sense.

From subsection **7.2 Artistic & Creative Development**, it is evident that the better evaluation is the more effective visualization is going to be. Perfect storyboards can not be assured without sense of perspective and proper feel of movement of camera and actor. Our system provides a film director with a tool to explore perfection for shots in a sequence, specially the new film directors who have less experience in film shooting.

It is also evident that how the order of shots has been changed and a new order of shots has emerged after feeling motion that influences to explore more for a more effective sequence. After virtual shot 1, we realize of having few more shots in matching the continuity of rhythm of the sequence. Then we develop shots 2, 3 and 4 by SEDS before getting a composition similar to final position of shot 2 of Fig.15. This is a great change in designing the shots and has improved the artistic value. Up to shot 5 developed by SEDS, we can tell it artistic development because the camera is still at same side of the line of action.

We have demonstrated creative development by breaking the rule at the last shot 6, developed by SEDS. The way we break the rule is not the same way as Andrei Tarkovosky has done and the mood we have created is different from Andrei Tarkovosky. Andrei Tarkovsky has created a mood which is more than fearful in a vast forest. It seems the director is trying to uncover our soul, which is the characteristic of the great director,

but we have just created a kind of horror mood. We have added a new dimension to this shot in accelarating the mood through exploration of half circular slower tracking that goes well with fear and distress.

Therefore, using our system, a director has more precision and control in shooting that is essential for better film creation.

As we are concerned about artistic and creative development, we are reluctant to make any compromise in creating art with time and cost. Our time and cost reduction is related to physical process of shooting.

10. Conclusions and Future Works

While a set designer can design any kind of set for interior shooting according to storyboard, it is a good idea to develop virtual shots accurately for shooting exterior after location scouting. Inspecting the location helps a director to get a proper idea about the scenery - environment, light, weather etc. As one of our future works, we have planned of developing facility for importing various locations to our system and then create virtual shots on it for accurate exterior shooting. This helps in minimizing adjustments with locations at live action shooting, otherwise, directors may need to adjust shots with locations in certain cases.

We would like to make our system portable in a note book computer at a shooting place. As it is important to get a proper feel of editing pattern on evaluating, our future plan is to play all shots of a sequence by a key stroke.

The creation of other virtual libraries - set, props, light, actors' fashion, facial expression - like the libraries for models and motion that we have already developed will help us to create an improved SEDS that is more than a virtual storyboard. The richer the libraries are the more effective virtual shots are.

The regular updates of these libraries through web will give a director more choices in creating shots. Moreover, development of a sophisticated user interface along with more intelligent camera works will definitely help a user to create shots promptly. The communication value of SEDS grows more than storyboards with the complexity of a production and saves a great deal of time and cost.

Acknowledgements

We would like to thank Dr. Toru Tamaki for his significant contribution during an earlier phase of this work. We also extend our thanks to Mr. Hidaka Uchida, Ms. Rie Ochiai and Mr. Wataru Yamaizumi.

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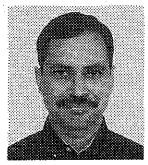

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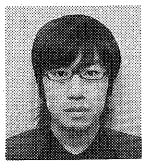

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