

# Art animation control based on Maya embedded language

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**Abstract**—More and more industries tend to integrate with the computer industry for its rapid development; as a result, the digital media industry is born. This study adopted Maya embedded language (MEL) to control art animation, which overcame the problem of manual control and also accelerated the generation of three-dimensional animation. At first, the operation mode, modeling and technological content of Maya embedded language were introduced; then a three-dimensional tree animation generation experiment was carried out based on inverse kinematics (IK). The results demonstrated that, the method could skillfully manifest the actions of tree branches such as defoliation, fracture and swinging. Therefore, the technology is proved to be feasible, and it can be applied in the animation for trees and other aspects, thus to provide more technological supports for art animation control and offer assistance for people who begin to learn the production of three-dimensional art animation.

**Keywords**—art animation control, control technology, digital media, Maya embedded language

## I. INTRODUCTION

COMPUTER based art animation is a new digital media technology integrating computer technology and animation art, whose key technology is reflected on software and hardware [1, 2]. Benefiting from the high-speed development of computer technology, computer based animation production has gained a great progress. Currently, the extensively used excellent three-dimensional animation software include Maya produced by Alias Company, 3D Studio Max produced by Discreet Company, Softimage |XSI produced by Avid Company, Houdini produced by Side Effects Software Company, etc [3-6]. Among them, Maya has the most excellent performance because it not only has ordinary function of three-dimensional and visual effect production, but also is equipped with advanced technologies such as modeling, digitalized simulation, fur rendering and motion matching.

Guo [7] designed a user control interface of animation characters using Maya script language programming; after the setting of keyframe in the interface, task skeleton moved and thus formed animation. Bei et al. [8] constructed a three-dimensional skeleton model using Maya embedded language (MEL) and motivated it to make the skeleton move and thus form animation. Besides, they adopted particle swarm

to realize group motion. Niemann et al. [9] designed particle collision effect which was frequently used in three-dimensional animation using MEL script to avoid the waste of production time and cost.

This study described and analyzed the establishment of three-dimensional animation for trees in detail after the introduction of relevant technologies and concluded that MEL based art animation control was feasible.

## II. DISTRIBUTED WEB CRAWLERS

### A. Brief introduction of traditional modeling tools

Animation production based on computer graphics has started from the 1980s. At that time, 3D animation was produced in large workstations. With the advancement of science and technology, computer operation system has changed, and the functions and models of 3D animation production software have become more and more. The current software in the market is shown in Table 1.

Table 1. 3D animation software in the market

Dimension function	Software type	Function and use
With	AutoCAD	Industry, product and architectural design
	Rhinoceros	Industrial design and style design
	3D MAX	Industrial design, multi-media and space design
Without	light wave	Multi-media
	Softimage XSI	
	Maya	

3D animation production software is selected according to different demands. For example, production software with dimension unit function is usually selected for spatial design or architectural design because dimension is crucial in spatial or architectural design. In the design fields which put little emphasis on dimension such as advertisement and animation movie, production software without dimension function but with strong texture rendering is usually selected. For example, in this paper, the modeling of trees only considered the stress and movement of branches instead of dimension.

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The traditional 3D modeling software often cannot produce smooth models in animation production due to different application purposes and professional fields. [16]. For example, Rhinoceros modeling which is developed for industrial design has mass precise attribute data. But most of the data are static. Hence the operation is complicated and low-efficient if it is used for animation production. Maya software put forward in this paper is different from the traditional modeling software. It is featured by simple operation, smooth modeling and little dependence on mass precise dimension data. Therefore it is the best option for tree modeling.

### B. Technology operation mode

Overall, Maya can be divided into two parts, i.e., node and MEL command. Generally, node is used to demonstrate results, while MEL is used to control the whole process. Every operation of Maya is realized by MEL. Usually, Maya will not call MEL command directly. As every MEL command is able to complete multiple simple tasks and the modifier of MEL command determines the appointed task to be completed, integrating multiple MEL commands can help select out the best modifier for the current task and the MEL command combination is called script. Script document is generated after script is stored into document. Developer will use a specified word as the call command for script document, and the command is called script command [10].

MEL, as a custom programming language, is the most convenient and flexible programming interface used in Maya software, because it has more extensive application for its simpler syntax structure than C++ programming language [17]. C++ language needs compiling and source code link before execution, but MEL can run directly as it is an interpretative language. Moreover MEL can be written, debugged and tested in Maya software, without the need for program setting using an additional programmer in advance. Interpretative language programming has drawbacks, and MEL as one kind of interpretative language is no exception. Compared with C++ language, its running speed is lower, but considering the complexity and complexity of animation, MEL still has more advantages.

### C. Module building

Curve modeling, polygon modeling and subdivision modeling are several modeling methods in Maya software; models can be divided into low model and high model according to different requirements as well as scene model and role model based on various attributes of the model; besides, industrial model, mechanical model and cartoon model are also included [11]. When multiple models need to be constructed repeatedly, the application of MEL is easy to operate and moreover MEL is suitable for the building and modification of models with high requirement.

### D. Art animation control technology

#### (1) Keyframe animation

Early-stage Keyframe animation technology originates from the production of traditional animated cartoons. At that time,

skilled animators drew out keyframes and middle frames were completed by ordinary animators. In art animation, i.e., three-dimensional animation described in this paper, middle frames are generated by computer interpolation.

Parameters of keyframe are those which can influence pictures, such as location, rotation angle and texture [12]. When interpolation method is used, if there is no enough data points, animation with smooth picture is nearly impossible to generate. Therefore, a large amount of keyframes are necessary for the production of exquisite animation effect using interpolation method, which requires skilled animators to spend plenty of time on producing keyframes. Though the method consumes time and energy, the eventual animation effect is the best. Therefore, the method has been extensively used currently.

Figure 1 is a three-dimensional animation made using keyframe method. Frame A and E are the beginning frame and ending frame completed by animator; frame B to D are generated by interpolation calculation.

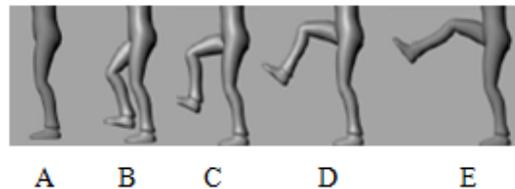


Fig. 1 Keyframe animation

#### (2) Skin morph technology

To make three-dimensional animation more delicate and precise, a key technology called skin morph is extensively used. Skin morph includes two models. The first one is hierarchical model which is made referring to the structure of human body. It is composed of skeleton layer, muscle layer and skin layer. The skeleton layer is responsible for controlling movement and the muscle layer aims at controlling the contraction and extension of muscle. The muscle layer aims at controlling the contraction and extension of muscle and thus changing the appearance of the skin layer. Skin wrap modeling defines curved surface via point set of equipotential field values. In this way, model can simulate the movement of human body. Once layered structure is determined, vivid animation can be produced by operating skeleton [18]. The other one is surface model which is composed of skeleton and outer skin. However, the model has two disadvantages. One is the difficulty in controlling curved surface at joint and the other is the input of a large amount of point sets.

Maya software also provides user with different types of morphers, including Cluster, Lattice and Bend [13]. These morphers can make created tasks more vivid.

#### (3) Motion capture technology

Motion capture technology is an extensively used animation production tool. Data are sent to computer through sensors equipped in every joint of the body of actor and then applied into three-dimensional model to generate real human motion [14]. However, the application of motion capture technology usually consumes huge capital investment; besides, the wires

tioned on the body of actor limits movement, which can result in some errors. The emergence of motion editor technology improves the utilization rate of motion capture because it effectively connects motion capture and animation production. On one hand, it can reuse motion data; on the other hand, it can realize some actions that cannot be completed by actors. Using motion editing technology, actions can be more realistic and vivid and moreover the intention which is expressed by capture motion originally can be modified. The conversion process of movement editing data is shown in Fig. 2.

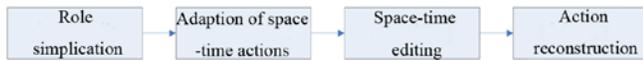


Fig. 2 The conversion process of movement editing data

But the collected movement data of actors is actually difficult to describe the real movement of skeleton structure, let alone the muscle movement between skin and skeleton. To solve the problem of difficult treatment of simulated movement and reduce computational burden, loosely connecting data set with control point is considered [19].

#### (4) Skeleton assembling

Skeleton assembling means establishing action control system for three-dimensional model [15]. Skeleton assembling can be divided into the assembling of realistic role and the assembling of cartoon character.

What the assembling of realistic character pursues is the expression of real posture and action of creature. The basis of skeleton assembling of such kind of character is deep understanding of the overall structure of role. Only in this way can qualified skeleton be constructed. Usually, multi-layer model is used to construct the skeleton of role and motion data of role is obtained by motion capture. Fig. 3 shows a dinosaur in the movie Jurassic World. In the figure, the motion and the muscle changes of the dinosaur demonstrated are realistic and vivid.

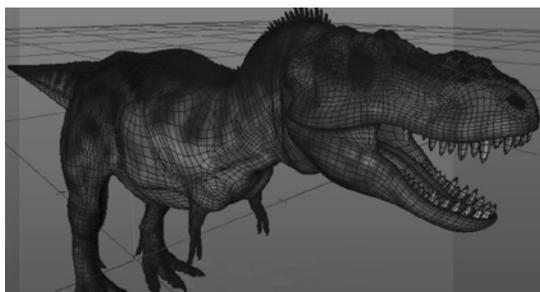


Fig. 3 A dinosaur model in the movie Jurassic World

The assembling of cartoon character focuses on diverse limb deformation effects according to the setting of script rather than realistic effects of action and muscle. Usually, cartoon character is constructed by using single-trip model; animation can be generated based on motion capture and keyframe technology. Fig. 4 shows a character in the movie Inside Out. To express the anger of the character, red fire and exaggerated mouth are used.



Fig. 4 A character in the movie Inside Out

### III. IK AND FK TECHNOLOGIES

Three-dimensional animation manufacture software in the current market all has programming function. MEL controls animation based on language or other programming interfaces. Taking the control of the arm action as an example, for people who just begin to learn the production of three-dimensional animation, the largest difficulty is the irregular shaking of role model when their limbs are adjusted, which can result in a huge difference in the final result from the expected one. The major reason for the phenomenon is the incoherent transition between IK and FK.

IK, short for inverse kinematics, can be explained as the motion which child joint motivates parent joint. In common words, when a coach helps an athlete to exercise joints, the arms of the athlete will do actions under the effect of power generation of the coach, though the athlete generates no power. FK, short for forward kinematics, can be understood as parent joint motivating child joint, for example, throwing something out of hand (Fig. 5).

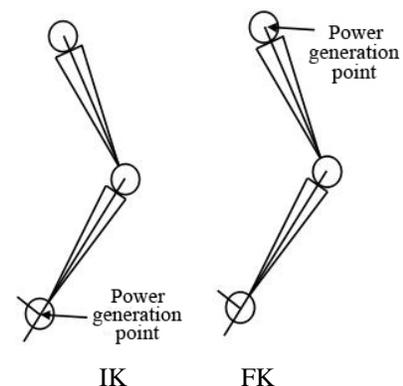


Fig. 5 IK and FK in Maya software which simulates arm skeleton

In actual animation design, different roles will demonstrate different actions because of different characters. Mutual conversion between IK and FK which is a key of animation design is needed at that moment. Table 2 shows several common methods of conversion between IK and FK.

Table 2 The common methods of conversion between IK and FK

No.	Detailed description	Advantages	Disadvantages
1	Directly converting according to the attributes of IK carrier	Simple, original	High risks of skeleton dislocation, not beneficial to subsequent works
2	Converting using set IK/FK key tool in Maya software	An improved version of method 1; it can effectively avoid skeleton dislocation; operation is simple	Unable to realize time identity of key frames, increasing workload
3	Applying three sets of skeleton control, IK control, FK control and skin according to actual requirements	Little difference with method 1 and 2, with the some advantages	Problems will be complicated if there are too many roles
4	Realizing conversion using MEL language	It can effectively realize seamless conversion; operation is simple	Programming is needed before conversion, incapable of real-time operation

#### IV. THREE-DIMENSIONAL ANIMATION EXPERIMENT BASED ON MEL

##### A. Three-dimensional animation – tree modeling

Modeling in Maya software can be divided into three categories according to the application and requirements of models.

(1) Curve modeling [21]: It is for production of curved surface objects whose model is always composed of curves and surfaces. It can be used to make models containing complex curved surfaces and special effects such as human skin and odd sports cars.

(2) Polygon modeling [22]: It is used for building models composed of polygon surfaces. As the shape of a polygon model

is determined by the distribution of its vertices in space, the way to build the model is to adjust the position of vertexes. The technical requirements of the modeling are lower. Now it has at the same position with curved modeling in computer graphics industry. It has more advantages than curved modeling in the construction of complicated models with insertion structure, but is weaker in mapping.

(3) Subdivision modeling [23]: It is a relatively new technology which combines the advantages of curved and polygon modeling; hence it can build more detailed models. It is easy to operate and is capable of building smooth curved surface and complicated polygonal body with insertion structure. Its advantage lies in its subdivision. The computational speed is limited in subsequent work though it can improve the level of detail of local model.

Considering the structure characteristics of trees and comparing the three modeling methods, polygonal modeling was selected because it is easy for polygonal modeling to build irregularly distributed branches.

##### 1. Modeling of tree branches

Generally, one end of a tree branch grows on the main trunk and the other end grows in the opposite direction, and there are a lot of small branches between the two ends. Firstly, a basic cylinder was established and then more lines were added. As shown in Fig. 6, the basic shape of branches was adjusted by extruding polygons, the shape of branches was extruded, and then the thickness of branches was adjusted. In the figure, the green arrow stands for the main growth direction and the blue and red arrows were used to adjust the thickness of branches. The extruded branches are shown in Fig. 7. The last step was the manufacture of small branches. The model and position of leaves and the natural growth rules of tree branches were considered to maximize sense of reality. The whole model is shown in Fig. 8.

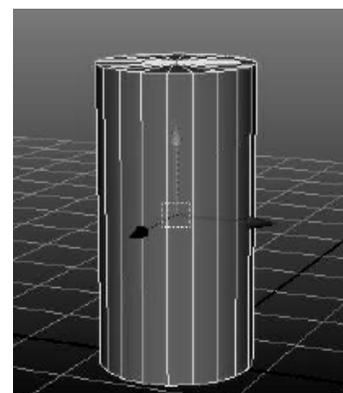


Fig. 6 Cylinder

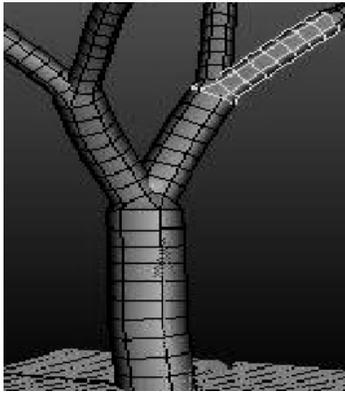


Fig. 7 Extruding tree branches

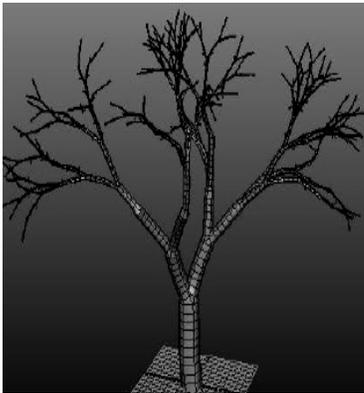


Fig. 8 The final design sketch of tree branches

## 2. Modeling of leaves

As leaves were in a large quantity, they were manufactured using transparency mapping method. Firstly, a model of leaf facet was made using polygon modeling. Then the model was copied and put in a proper position according to natural growth relationship of leaves. Thus the skin of branch skeleton should be paid attention to. The final design sketch is shown in Fig. 9.

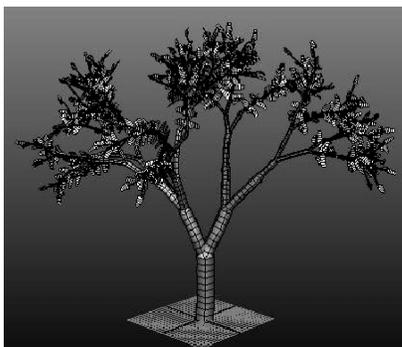


Fig. 9 The design sketch of a tree

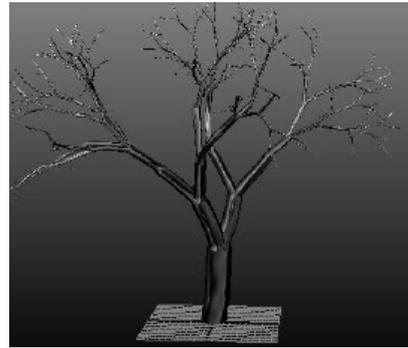


Fig. 10 The tree model

According to the attributes of tree branch surface in the natural world, proper material spheres were established to improve sense of reality. A figure of tree branch texture was attached to the model. Then the material and texture were added reasonably on the tree branches. The final design sketch is shown in Fig. 10.

## B. The implementation of skeleton modeling and smooth skin

### 1. The establishment of skeleton

The skeleton of the trunk was established firstly. Six segments of skeleton were set for the main trunk. Considering the fracture of the branches, the skeleton was set according to the branches. The relationship between skeletons was established according to father-child relationship. There was only one root joint in each skeleton. Root joint was at the highest level; parent joint could be any joint as long as there were affected joints. The seventh joint above the main trunk was the first branch of skeleton establishment, which played a huge role in the motion of the branches. The other five skeletons were established as well according to the above idea. Eventually, there were 80 segments of skeleton and 160 joints, as shown in Fig. 11 and 12.



Fig. 11 The seventh joint

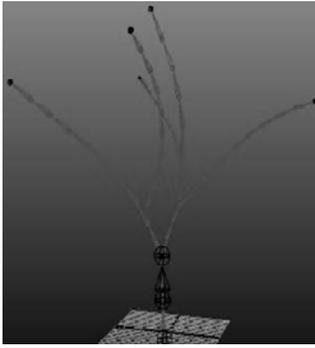


Fig. 12 The skeleton

## 2. Skeleton skin

The basic model of skeleton has formed; however, the model cannot move. Smooth skin was adopted. The weight value of each vertex was set as 1. Weight values affected the allocation of joints based on different ratios. Higher percentage indicated stronger and more natural controlling. Then the influence scope was determined based on skeleton distribution and the weight was drawn.

### C. Controlling and stress analysis of the tree

The stress analysis of the tree involved tree branches, defoliation and branch fracture.

#### 1. Stress analysis of tree branches

When a tree branch swung under the effect of wind, the wind force was supposed as even, the free end of the tree branch generated a return force. The wind force born by the first branch was set as  $F_a$  and the return force was as  $F_b$ . Without considering air resistance, the calculation formula for the return force was  $F_b = -kF_0$  ( $k$ : restoring force constant;  $F_0$ : force generated under the effect of wind). To make the tree branches swing more natural, noise effect was added. The formula for noise bearing capacity was  $F_n = k_1 f_1 V_1 + k_2 f_2 V_2$  ( $V_2 = V_1 \times V_0$ ,  $k_1 = 0.5 - cr_a^1 - (1-t)r_{\alpha\sigma}^1$ ,  $k_2 = 0.5 - (1-t)r_{\alpha\sigma}^2$ ). In the formula,  $V_1$  stands for the vector of the wind direction,  $V_0$  stands for the unit vector in the direction of tree branch,  $f_1$  and  $f_2$  stand for the maximum value of  $V_1$  and  $V_2$ ,  $t$  stands for a constant which is used for adjusting density and hardness.  $r_{\alpha\sigma}^1$  and  $r_{\alpha\sigma}^2$  stands for the noise of tree branch  $\sigma$  on the direction of  $V_1$  and  $V_2$ . Therefore, the force acting on the tree branches was  $F = F_1 + F_2 + F_n$ .

#### 2. Stress analysis of defoliation

An attribute  $F_\lambda$  was added for leaves to represent the maximum force born by the  $\lambda$ -th leaf its formula was  $F_\lambda = F_v + Q \times F_n$  ( $F_v$ : a constant which could be adjusted according to simulation or could be 0;  $F_n$ : noise bearing capacity;  $Q$ : adjustment coefficient). Finally, the force bearing condition of  $F$  of the leaves at the time point was calculated and compared with  $F_\lambda$ . If  $F > F_\lambda$ , then the leaves fell; otherwise, the leaves moved according to the original track.

$F_z = 0.5a \times e \times v^2 \times s$ ,  $F_y = 0.5b \times e \times v^2 \times s$ , and  $F = F_m + F_z + F_n + f$  ( $F_z$ : resistance acting on the leaves;  $F_y$ : the buoyancy force of the leaves;  $a$ : resistance coefficient;  $b$ : buoyancy force coefficient;  $e$ : air density;  $v$ : wind speed;  $s$ : the area of the leaves;  $F_m$ : the gravity of the leaves;  $f$ : air resistance;  $F_n$ : noise bearing capacity).

#### 3. Stress analysis of branch fracture

Tree branches will fracture under the effect of strong wind. The following experiment investigated the animation manufacture of tree branch fracture. Based on the effect of Maya midfield and according to the thickness of the tree branches and elastic coefficient, the tree branch was assigned with a critical value. When the critical value was smaller than the bearing capacity in the direction of a tree branch, the tree branch will fracture.

$P = g + F_j + Q \times F_n$ ,  $f = a \times s \times v_\epsilon$ ,  $v_\epsilon = v_l - v$ , and  $F = F_m + F_z + F_y + F_n + f$  ( $P$ : critical value;  $g$ : constant determined according to the simulation effect and its value could be 0;  $F_j$ : average elastic analog quantity;  $Q$ : adjustment coefficient;  $F_n$ : noise bearing capacity;  $s$ : the area of the leaves;  $f$ : air resistance).

#### 4. The control of leaves swing

The tree branches moved under the control of skeleton controller on the main trunk. To make the main trunk and the branches move at the same time, a parent-child relationship was set up between the controllers. When the main trunk controller generated animation curves, the tree branches would produce animation curves under the leadership of the main trunk. Therefore, the key is to control the motion of the main trunk. To control the main trunk better, the force bearing point at the position of the main trunk controller should be analyzed. Animation curves could be calculated by the controller according to the force bearing condition, thus to motivate the motion of the whole tree. Computer data were sent to the skeleton controller of the main trunk through MEL. The attribute of the key frame was rotated according to the swing angle of the tree branch. Moreover, under the effect of wind speed, the swing angle of the tree branches would change as time went on. Longer time and higher wind speed resulted in defoliation and much higher wind speed led to fractured branches.

#### 5. The control of branch fracture

Branch fracture usually occurs at the crotch. The position of the fracture point had been determined during early binding. The fracture of the tree branches could be achieved after the critical value of the controller on the critical value and the key frame were calculated. After fracture, the falling process should be processed; the procedures were as follows. Firstly, the tree branch was regarded as a material point and its motion track was obtained according to Newton's second law. Then the branch was randomly disturbed to make the motion track more natural and real; the branches were affected by wind power and gravity

in the process of falling, leading to the swing of the branches.

#### 6. The setting of skeleton controller

Considering the motion effect of tree branches in the natural world and the properties of IK curve editor, the IK curve editor was adopted in this experiment. Each tree branch was added with an IK curve editor. The seventh node at the first skeleton fork node and the end node at the last skeleton were selected to set up the IK single-chain resolver. An IK rotation plane resolver was established on the skeleton of the main trunk. The circular ring and skeleton were controlled. All controllers were set according to the above method. The final figure is shown below.

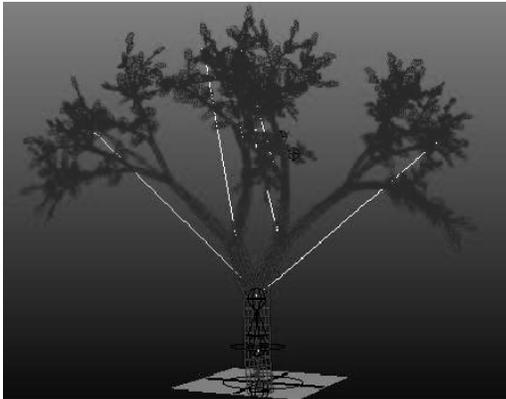


Fig. 13 The model after skeleton setting

#### V. THE DETERMINATION OF ANIMATION UNIT

MEL will release many orders while creating and editing animation and moreover can create, edit and delete key frames. The application of MEL technology reduces the time spent on ordinary tasks and improves working efficiency. The standard film animation time unit Film was adopted in the design of this test.

Table 3. Time unit table

Item	Frames per second	Unit
Animation speed	15	Game
Presentation format (frame)	48	Show
Standard animation film	24	Film
PAL format (frame)	25	Pal
NTSC format (frame)	30	Ntsc

#### VI. EXPERIMENTAL SIMULATION RESULTS

Figure A ~ F are the figures captured at the 1st, 75th, 130th, 188th, 195th and 235th frame. Fig. A is a static effect picture; Fig. B shows the swing of branches and the falling of leaves when the wind speed was low; Fig. C shows the branch fracture

at the moment the force bore by the tree branches exceeded the critical value; Fig. D shows the moment when the tree branches fell onto the ground; Fig. E shows the fracture of the second branch under the effect of increased wind power; Fig. F shows the falling of the second branch onto the ground after fracture. The swinging, defoliation, fracture and falling of the tree branches could be clearly seen in the figures, suggesting the application of MEL could effectively control the presentation of animation.



A



B



C



D



E



F

Fig. 14 Simulation effect figures

## VII. CONCLUSION

This study made a fundamental description on the operation mode of MEL and its model construction. By reading this paper, beginners can understand the principles of art animation production faster. Besides, a theoretical statement was made on some key technologies involved in the process of animation production such as keyframe animation, skin morph technology, motion capture technology and skeleton assembling technology. Based on that, a simulation experiment was carried out on the tree branches. The swinging, defoliation, fracture and falling of the tree branches were simulated by applying the operation mode of MEL. The experimental results suggested that, MEL could achieve vivid simulation effects based on attributes such as quality elastic resistance in real world. Moreover, the method could control animation better, reduce time spent on ordinary tasks, improve working efficiency, and avoid the defects of traditional artificial animation technology. Besides the control of trees, MEL could also be applied in other animations. Due to the limitations in aspects of time and technologies, there are many problems. Problems that may be encountered during the application of MEL in other animations remain to be further investigated in the future. This work is expected to be useful to the beginners.

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