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An Effective Kinetic Art Generation Framework Utilizing Physics Engine Jbullet

Jihye An[1], Yunsang Jeong[2] and Jinho Park[3]

[1]Department of Information Communication, Materials, and Chemistry Convergence Technology,
[2,3]Global School of Media, Soongsil University, Seoul, Korea
3E-mail : c2alpha@ssu.ac.kr
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Abstract

We propose an effective kinetic art generation framework based on a 3D physics simulation. The framework focuses on the design process time required for an artist to express artistic ideas while reducing the time and cost of producing machine structures of kinetic art. We utilize JBullet, a well-known physics engine, to verify the physical accuracy of the kinetic art by providing rigid body simulation, collision resolution, and constraints. The experimental results show that the proposed animation framework can effetively handle the tedious and repetitive process of previous kinetic artwork.

***Keywords**: Jbullet, Kinetic Art, Physics Simulation, Rigid Body, Machine Structue, Constraint*

1. Introduction

Technology convergence changed direction toward the domain of creativity, art, and humanistic sensitivity beginning in the 2000s, and this brought about the development of communication media. As a result, kinetic art, which had focused on the movement of machines, has shifted its focus to the various effects or results of mechanical movements. In other words, meaning is given to feelings generated from looking at movements rather than to movements from interactions.

For example, artists want to formalize "beauty" in order to express an unspecific feeling or satisfy an aesthetic need of the audience for "beauty," which is formless. However, artists conduct multiple experiments to reduce gaps resulting from the formalization of formless things. This takes time and also produces financial burdens for the artists. However, if simulations that help save the time and costs of an experiment are provided, artists can understand the structure of machine movements through multiple simulations even if they do not initially know the structure. Artists can also have more time to satisfy the needs of their audience for formless beauty, because experiments in a virtual space save time and cost. In our previous work [1], we discussed the basic idea that the physics simulation of a rigid body can reasonably reduce the tremendous load on an artist with respect to kinetic art. In this paper, we focus on kinetic art and propose a physics-based animation using the JBullet framework, in which 3D models are moved by

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external sources of sustained mechanical power such as wind while reducing the time and financial burdens on creators of kinetic art.

2. Related Work

Thus far, research papers on kinetic art have mainly been related to education, techniques, and utilization, while research on the relationship between kinetic art and physics was limited to the movements related to kinetic art and to an analysis of the meanings of works according to the period. However, we can see that research papers on kinetic art often mention movements and link movements to work analysis and education. Because movements are such an important part of kinetic art [2], Jeong-Hwa Oh analyzed physical movements in traditional kinetic art and investigated the characteristics of kinetic art according to the period [3]. Movements in kinetic art can also enhance the scientific thinking ability of children [4-6]. The creative expressions of children are enhanced by expanding their two-dimensional expressions of aesthetic senses into the realm of mobility. The key to this expression is the scientific thinking ability, because when expressions through movements are predicted, the movements appear as expected. However, while it is easy to understand structural movements with simple forms, it is not easy to predict overall movements when a structure becomes complex. This difficulty applies not only to children but also to artists. Therefore, Yohsuk *et al*. [7] researched kinetic art design modules, including rigid body simulation for artists using CAD. The module that they proposed focused on kinetic art pieces based on weight and balance, such as mobiles. We produced our simulation program by focusing more on physical properties, because even though weight and balance are also important, kinetic art often uses complex mechanical structures.

3. Our Method

To allow artists to check complex machine structures in real time, we propose a physics simulation framework that provides models, constraints, a collision test, and a force for diverse movements as well as allowing easy adjustment.

Unreal or Unity3D, which provide physics simulation features, are game production engines and require high computing specifications, even though they offer various features. Background knowledge about dynamics is required to use detailed parameters, which are difficult for artists to use. Using a physics engine (JBullet), we produced physics simulations that only have physical properties and a graphics library (LWJG) instead of a game engine. The purpose was to use JAVA, which allows excellent portability of platforms for future expansion, so that artists could use the simulations in any environment.

We provided a basic model (Figure 1) for various forms of gears and provided a composition of works that produced various movements, based on an external force-receiving part, a delivery and conversion part, a moving part, and a fixing part [8]. Then we built the machine structure [9] using the Collision, Constraint, and Motor properties of JBullet [9].

Figure 1. 3D Models Provided in the Proposed Module

Figure 1 shows machine models that have physical properties, which allow artists to create structures and designs even though they do not understand the functions of the

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physical engine. For machine models, a toothed ratchet gear, a general gear, a pin bevel gear, a straight bevel gear, a worm gear, a helical gear, and a screw gear are provided. For general models, a hexahedron, a sphere, an elliptical ball, and a cylinder are provided. We focused on gear models, because most kinetic arts can perform various movements through combinations of these models [8-9].

The reason why only such limited models are used is to leave the formative realm as the exclusive area of the artists, because kinetic arts can create different feelings even with the same structure, depending on the formative sense of the artist. The 3D model authoring tool was not built inside the proposed simulation, because our physics simulation is a structure for aiding in the machine structure experiments of artists. However, data contained in the OBJ files (Figure 2) is checked to allow artists to call external 3D model files, and the relevant information is reshaped as mesh in JBullet, so that simulations, including the artist's designs, can be created.

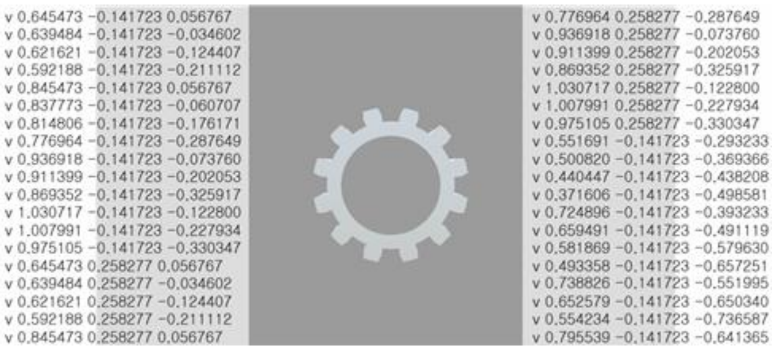

Figure 2. OBJ File (This Model Consists of Data at both Sides and Tooth Data at the Center)

In the four machine structures, 3D models are greatly affected by the aesthetic influence of artists, but Collision, Constraint, and Motor are more affected by physical properties. Collision refers to the collision between two objects, which is required to check and modify the actual operating range of the work, the collided part, *etc.* To detect collision, an outer area must be created to generate collision in the object expression, and this is called the Collider (Figure 3).

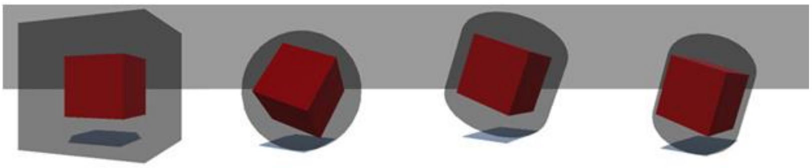

Figure 3. Collider Shapes Expressed in Black

The Collider must have the same information as the model to enable accurate collision. If the position, size, and other information of the Collider do not match the model, the collision is processed differently from what is actually seen, because the object is regarded as being at the location of the Collider (Figure 4). If each of two models has a Collider, and each Collider has the same information as its model, the objects can be piled up like blocks due to the collisions between two objects, as shown in the left-side image in Figure 4. However, if only one object has a Collider, the objects overlap, as shown in the right-side image in Figure 4, because collision does not occur. Therefore, the GImpect Mesh Collision function of JBullet was linked by using the peaks comprising the models, so that accurate collision areas could be created when 3D models were called from outside as well as when we provided the models.

Figure 4. Object Collision Forms Depending on the Existence of the Collider

While Collision detects collisions, the Constraint function applies constraints to the motions of models (movement, rotation), so that they appear to be bound. The Bullet engine developed with C++ supports a total of six constraints, but JBullet developed with JAVA supports five constraints. The types and characteristics of constraints are shown below (Figure 5).

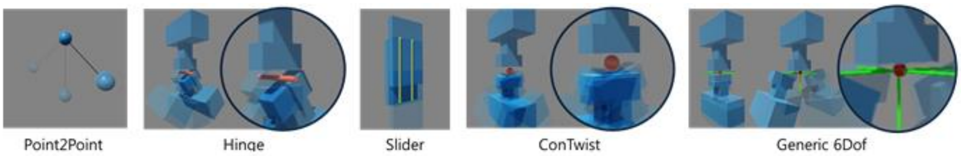

Figure 5. Constraint Types

In Figure 5, *the black axis* indicates the fixed distance between two objects, *the red axis* indicates that movement is impossible and the object can only rotate around that axis, and the *green axis* indicates that rotation is impossible and the object can only move along that axis. The *red sphere* indicates that there are constraints to movement, but rotation is possible around any axis. Among the constraints, *ConTwist*, which can apply constraints to every rotation axis, was not used in the proposed physics simulation, because the same effect can be generated through the combination or limitation of *Hinge* and *Generic6Dof*. The user must select the constraint required for each part based on the four constraints, but this presents artists with the difficulty of perceiving physical connections. Therefore, we designed the model in such a way that a preset constraint will automatically be applied when the artist sets a model to be connected to the center of the gear that we provide.

Motion State includes such physical properties as weight and gravity and forms a rigid body by being applied to the model for which a Collider has been generated along with Constraint. A model to which Motion State has been applied not only has physical properties but also has limited motions due to Constraint. Therefore, users can feel a model formed by a rigid body as being connected to machine parts. To continuously move rigid bodies that are interconnected and have limited motions, we need a motor that corresponds to the power device in a machine structure and which delivers external force. The user must apply Motor to the rigid bodies and check whether the rigid bodies are interconnected by constraints and whether they make continuous motions according to the machine structure in a virtual space. We designed this motor to be used as a mechanical power unit as well as a temporary force, for example, wind.

In JBullet, the user can randomly decide the calculation count when performing a simulation. Increasing the calculation count can improve accuracy, because the model calculates and interpolates the motions in the next frame based on the information (Transform) about the rigid bodies. We used this feature of JBullet and provided the user with the option to use Interpolation Transform, which performs interpolation calculation up to two frames in advance. Because the motions of rigid bodies are calculated to the next frame and the frame after that, the motions of the model are more natural between

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frames in the animation than they would have been if only one advance frame had been calculated. Therefore, users can see physics-based animation that is more natural. The reason that the calculation count is not increased to more than three frames is to prevent a slow animation speed due to the calculation, yet a two-frame calculation can obtain sufficiently natural motions of objects.

4. Result

The proposed physics-based animation framework was developed and tested on Windows 7 with Inter® Core™ i5-3470 CPU, 8 GB RAM, and a GeForce 970 graphic card. We observed the machine structures of kinetic art [10~14] and used only the models provided by default in our simulation program (Figure 6). It took from 10 minutes minimum to 40 minutes maximum from the initial model formation until the desired motions of the machine structure were finally obtained (Table 1).

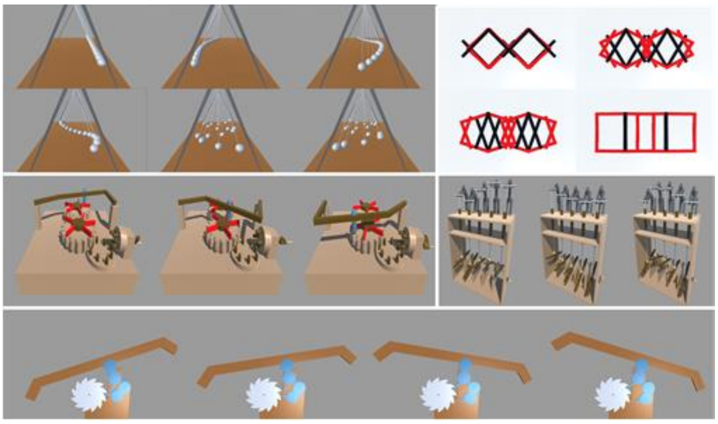

Figure 6. Experimental Results of the Proposed Animation Framework (See [10~14] Horizontally from Top Left)

Table 1. Lead Time and Constraints Used in the Project Design for Simulation

Project	Lead Time (min)	# of Objects	Constraints	Motor
[10]	15	42	Generic6Dof, Point2Point	X
[11]	10	24	Hinge	O
[12]	25	20	Hinge	X
[13]	42	67	Hinge, Slider	X
[14]	45	23	Hinge	O

In Table 1, no motor was used in [10,12-13]. In project [10], the animation was run by gravity that acted continuously instead of by a motor that was a mechanical power unit, because this project changed potential energy to kinetic energy due to the physical setting in which the potential energy was gravity. Motor was not set in projects [12] and [13], because power energy was delivered by the gear turned by external forces provided by people. These three projects show that the proposed method can simulate external elements, such as wind, as well as mechanical power units.

To demonstrate that the proposed method reduces the time burden of the artist during the production of work, the time from the initial model construction until the display of the desired mechanical motion was measured. As shown in Table 1, project [14] took considerable time for production compared to the number of models, because it was

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designed only with the given models, and the teeth adjustment took much time (Figure 1). However, this problem can be solved if the artist calls external OBJ files. The initial structure of machine movement can take a long time to create if the project structure is difficult, but this is not a big problem, either, because the time for machine structure experiments through simulation in a 3D environment is much shorter than the time required for an actual structure experiment, which involves repeated assemblies, tests, and the disassembling of parts. However, our experiment was conducted with finished projects, and the degree of help that was given to artists could not be expressed in quantitative numbers. Therefore, this data needs to be quantified in future research. Nevertheless, the motions were identical when the model was implemented in the same way as in the actual project, which shows that production experiments can be replaced with simulations.

5. Conclusion

The proposed physics-based animation will be easily portable to PC and to mobile and Web platforms for physical simulations in various environments by kinetic artists in the future, because it was developed on JAVA. Artists with no background knowledge about dynamics can also easily check the machine structure, because model assembly and constraint setting in the virtual space is simple. As a result, kinetic artists can reduce the burdens arising from the production of experiments involving assembly, disassembly, and reassembly. However, what is difficult about the proposed simulation is that artists must personally set the physical properties for models brought from outside, and an adapting stage for the proposed method is required. Artists could conduct virtual experiments more broadly if the physical properties setting could be simple for external 3D models as well.

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