Simulation on Influence of Physics on Figure Skating Action

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Abstract

This Figure skating is one of the most popular sport, having practicing and learning figure skating for several years, the author is fascinating in perform some action such as spin and jumps and wanted to perform better each time, in the training the author figured out that the right body movement and position can optimize the successfulness of the performing action in figure skating. During the training by understanding that with actually practices on ice-rink about how some world class skater can perform such a perfect spinning actions, the author would like to produce a simulation of the figure skating to investigate some idea of techniques in simulation environment and use them in practices when on the ice rink. The purpose of this simulation model is to investigate the how influence of physics on figure skating actions can affect the effectiveness of action such as spinning and vertical jump performance. In this model the physic considered are the speed, force, momentum, body mass and friction, i.e. the general equation of involve spinning (momentum proportion to radius against the ice-surface can create speed of rotation).This idea can also be apply in the jumping action, there are many kinds type of jumping, some kind of jumping involve spinning in the air after the launch, such as Axel, which the spinning speed can also be demonstrate in the model and also with the time to landing, that will require calculation gravity and body mass.

1. Introduction

The Empirical Modelling is an approach to computer-based modelling. It can assist sense-making by allowing the exploratory experimenter to construct artefacts.

In terms of experiencing the environment in science, carrying experiment is pivotal to explore in this area, the motivation of Empirical Modelling (EM) can help to observe the potential support in some experimental are in some advanced computing environment. Since in the current existing computing technology and calculations are based on the work which done by the previous researchers in scientific theories. (Beynon & Russ 2008)stated that in exploring the EM behaviour in experimenting in computing, it can classified in two kinds of experiment, the first one is post-theory experiment[1]which can describe the situation of theories from the previous researchers, the state-changes behaviour within the experiment can be learnt and observes within the framework of the classical theory of computation. The second one is the exploratory experiment which explains the situation that the computing technology that sometimes which is difficult to accommodate to accepted the existing theoretical framework in computing. (Beynon & Russ 2008) described that EM is as alternative conceptual framework for computing which can better in adapting to the demands of exploratory experiment and it can be find in wide range of activities in exploiting the computer-related technology.

1.1 Motivation of EM

In the theme of this report which based on simulating the speed of momentum of on the spinning movement of the skater with the basic idea of physical calculations and applying the law of inertia and the theory on the speed of movement can be classified as post theory in the view of experiment and this idea of interpretation of human involvement in the physical experiment can be described in the motivation in EM which considering the situation of sense-making activity. Although this is the case,

(Beynon & Russ 2008) explain that base on the fact that come logical empiricism from the previous knowledge and experience cannot be exactly predicted in some situation.

It is necessary to view the experimental activity in exploratory aspects and combine with the required computing support on the pervious scientific theory and computer calculation, by the above explanation, it can be illustrated that EM is consist of correlation between these two post-theory experiment and exploratory experiment.

EM is centrally concerned with the much softer, and more personal,
For example the game of noughts-and- crosses [1] in the area of AI is an the an example of EM which consist of post-theory experiment and exploratory experiment, in this game it implement a human-player vs. computer-player, It involves human interaction between the computer intelligent artefact with the based rules in the game.

1.2 Implementation of EM

In the implementation of EM, it is based on functional programming principles, about the one of the principle that practices with EM. In a Functional Programming (FP) approach, it can be also describe as post-theory perspective as in the principle idea of FP approach is that it can represent the interaction between the player and the computer using functions and produce output. In EM, the definitive programming also considered as the major component. The deriving program-like behaviour can be describe as modelling with definitive script, in which (M Beynon 2008) describe in a definitive script it is important that variable in a script is not to be construed as a mathematical variable in referring to the variables.
In the Modelling with Definitive Script(MWDS) reference to direct experience of an external situation that is conceptually distinct from manipulation of the script the example would be a cell in the spread sheet which hold one particular value and may subject to change as update of other attributes or cells, such as the cell that contain the student number and also the idea is that there are *dependencies* [1]within the situation, so that when the value of one observable is changed, the values of other observables also change according to some predictable pattern. As a result these dependencies are expressed in the definitions of observables within the script, if an observable is redefined, and another variable is implicitly defined in terms of it hence the MWDS aim to achieve state-changes by redefinitions in the overall framework idea of EM.

In nowadays scientific research environment, there is an increase in the awareness of the idea of sense-making activities EM provides conceptual framework approach to software development subject. [2] In the traditional life cycle, making of UML which demonstrate the modelling process in the software, waiting to be construct and implement in the programme is one of the example of sense-making activity in EM by the fact that the Modelling activity can be classified according to different states of knowledge about the domain in which the software system is being developed.

In the paper of (N.Pope ,M Beynon 2010) desrible the situation of current existing type of modelling as three types [3] Those three type of modelling can be considered as "*Type A, Type B and Type C which Type A modeling is the most related to the computer, and to the formal abstract perspective on computation. Type B modelling invokes experiential and physical ingredients that demand empirical investigation and finally Type C modeling is the furthest from formalisation, and on the face of it is not well suited to the application of computers*." The paper idea is that developing Type C to type A in the software development in the aim of EM, because it is a general conceptual framework for studying how computing technology can support type C modeling. A prototype tool of EM, DOSTE environment is developed to supplies the basis for a radically new kind of software development that can be seen as extending the range of EM, where the principal focus to date has been on modelling *environments* and *agents*, to encompass modelling *processes* and *objects*.[2]

In simulation model of the report, EDEN is used in developing the physical changing environment. As describe in [4] EDEN is the Engine for Definitive Notations. It is the primary software tool of the Empirical Modelling research group. We build models with it, using a variety of definitive notations that it implements.
Science [Computer with experience] EM aim to provide a direct experience for the user rather than using abstraction from conventional programming. The EM also embodies the modeller's personal construal of a phenomenon and consist of collections of observables, dependencies and agents.[5]
The ant navigation model [ANT] illustrated another kind application of EM. This model contains several kinds of agents of the developer, scientist and an ant. And different roles are assigning to each of them. The model-builder develops cognitive perspectives on this agency through the close integration of different agent perspectives that EM affords. In thinking of developing this EM model one of the agent in this simulation would be the users, the users can change the properties for example would be by

sliding through a bar and press the start button to observe the change in behaviour of the model in the simulation, and the users can always apply some changes during the running of the model.

2. Introduction: The Background of Simulation Model

Spinning is one of the basic movements in figure skating; usually skater will start to learn spin when they are in level 2 or level 3 in one foot spin. During the spin progress the skater put her arms on each left and right hand side parallel with the shoulders in between and a leg in and speeds up very strongly. This situation occur as a result of the conservation of **angular momentum,** when the skater reduces her rotational inertia by pulling her arms and leg in, his rotation speed will increase in order to maintain constant angular momentum. This Angular momentum conservation plays a significant important role in all figure skating spinning actions and in this report will discuss about the implementation of simulation model into the EM perspective by using the tool of Eden.

Firstly, the physical momentum law of angular momentum conservation should be explained. The Angular momentum is specially calculated in the change in rotation. The idea that it works similar to the linear momentum $\rho = mv$, in which in the linear momentum, when something is keep moving with a momentum, in order to change the motion of it we have to apply a force on it. Fig 1.1 below illustrated the similarity of linear momentum and angular momentum. If there is no force present, then momentum will not change [6] so when explain in context in rotation, there is conservation when there is rotation and force is applied to it. In this case the force is called *torque*, so for example when a man pulls the string on a top, he is applying a torque to make it speed up. It can be described as increases in angular momentum. The movement will finally slow down after being released due to frictional force of torque. When this situation apply on the spinning figure skater, due to the fact that there are a very low friction in contact with the ice, and also there is little net torque on his body. His angular momentum is nearly conserved.

There is also Inertia of rotational need to apply in the equation when calculating the speed of spinning with angular momentum. In straight-line motion, inertia is describe as mass while in rotational motion, the inertia involve more than in the straight- line motion, In explaining the behaviour of rotational inertia, the example of the moon move around the earth and assume that the distance are always constant. In this case the moment of inertia, *I*, for inertia and single mass as *m*, then the rotating distance is *r*. The equation of rotational inertia can be shown as ($I = mr^2$)
After defending the usage of rotational inertia, the rotational speed needs to be considered. As in the model simulation, it aim to achieve the simulation of spinning movement which the speed of the rotation is a important part to be calculated. The parameter of rotational speed can be also call angular velocity, is in this symbolω.The revolution/minute (RPM) or radian/sec are usually used as describe rate of rotation. A complete rotation is 2π radians in a full circle, so one revolution per second is an angular velocity of 2π rad/s.

2.1 The Angular Momentum & Linear momentum

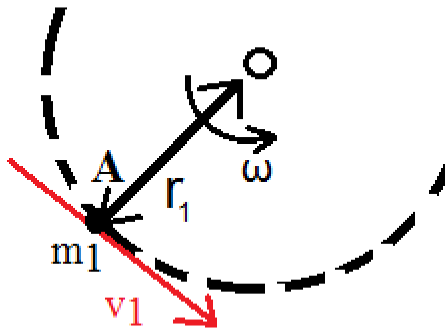

Fig 1.1

In the linear movement, considering the linear momentum of objects is very useful. In rotational motion, the angular momentum is important. Consider a rigid body rotation around the O axis, and at some point with the angular velocity ω, as shown in (Figure 1.1). Let A be the object of a particle, the distance to the O r_1, and has a linear velocity v_1, so

A line momentum =
$m_1v_1 = m\omega r_1$ (as $v_1 = \omega r_1$).

A of O is defined as the angular momentum of the O, A moment of momentum, so

Angular momentum of A = $r_1 * m_1 \omega r_1 = \omega m_1 r_1^2$
Hence: the total Angular momentum

$$= \sum \omega m r^2$$
$$= \omega \sum m r^2$$
$$= I\omega$$

O where I is the object of moment of inertia. Therefore, the angular momentum and the linear momentum share similarities of *mv* and Iω . i.e. ω class in similar to m.

Then combine the rotational inertia and angular velocity together, expression for angular momentum, *L* can be present in this equation:

$$L = I\omega$$

So, as explained from the previous paragraph in the angular momentum if one factor of *I* changes, the other factor ω must change to compensate if there is conservation

2.2 Implementation Background of the Model

After defending the physical law of momentum, the above equation can be implement into the model, in the simulation environment , when the figure skater pull his arms and a leg inward, The distance between the axis of rotation and some of his mass reduced and then also reduced his moment of inertia. In this case, the angular momentum is conserved, his rotational velocity have to be increase in order to compensate the changes. In the simulation model desired to estimate how much speed the skater can get by changing of the skater's rotational inertia. Before implementation in tkeden, the inertia of his arms and legs are out should be determined, set to *Iout.* And also determine the situation when his arms and legs are pulled in completely which is *Iin*. At this state of the simulation, in order to make the model to implement in a less error prone, assume that the skater is similar to the solid cylinder with his mass and with his arms and legs to make it less complex in implementation, and consider less about other variables. After this make a scenario related to the assume above, set that the moment of inertial of his body is *Ibody* and mass is *M*, *distance as rbody* and justify the moment of inertia as *1/2*Mbody*r* $^{2\,*}$*body* by the fact that his both arms distance and mass when he spin related to his central point of circle assume to be halfway in average of his whole body. In continuing the scenario, putting some assumption of figures and value can help to estimate the simulation compare to the reality in the model. [6] Made a clear assumption in estimated the speed increase in angular momentum in spinning

First, making assumption that the skater has the mass of around 60 kg, and assume that with his legs is out and mass of his body would be 50kg. and the body width(radius) of the figure skater is 1.5/2 (r^2)= 0.7(r) so the body moment of inertia would be Ibody = $0.5*(50)(0.1)^2 = 0.25$ kg $m^{2,}$ when his arms and legs are pulled in, just by adding extra mass at a distance rbody away from the axis, m = 10 kg r = 0.7m then *Iin* (inertia of arms and leg in) = Ibody + $mr^2 = 4.9$ kg m^2 . After that determine the situation when arms and a leg are out, when skater's arms straight out assume that the moment of inertia of 1/2(2Marm) r^2 arm, rarm is the distance of hands from his axis. Assume that rarm = 0.6m, and the formula of leg straight out would be 1/2 Mlegr^2leg. Assume that rleg = 1m. The final assumption is that for the remain 10 kg of his leg and arms, assume that 1 leg is equal to two arm, which is mleg = 5kg and marm = 2.5 kg.

The forumalar of *Iout* would be
Ibody + 1/2(2Marm)r^2 *arm + 1/2 Mleg*
From the above formula the conservation of angular momentum can be present as

Lin = Lout

Iinωin = Ioutωout -→ ωin/ωout = Iout/lin

so by the calculation of Iout/Iin, the result answer is meaning the speed that the skater gain when his arms and a leg are pull in when practicing one foot spin. In the tkeden environment user can observe significant change on the changing of speed of the skater spinning hand movement, which will further explain in the next section

2.3 Application of EM tool on Model

In creating this model, in simulation of the figure skater spinning which is the subject-oriented modeling. The role of this model frame work is to enhance concurrent activities between agents. The aim of this model as explain in previous section and abstract is to provide a direct changing environment to the users within the model. It is expected that certain patterns of behavior can be observed. The basic GUI layout is produce by the scout and the internal figure in the SCOUT windows or box is produce using DONALD. The figure of the model is in 2D style. On the main frame in the middle of the screen layout is the current mode of figure skater action, the figure that below the main frame is demonstration of the speed of rotation indicated in a clock-hand liked line to represent the spinning movement in a clock-wise manner. (Figure2.3) The left hand side of the screen layout there are some vertical slide bar, which user can change the Mass of the skater and the distance(radius^2)(Figure 2.5)

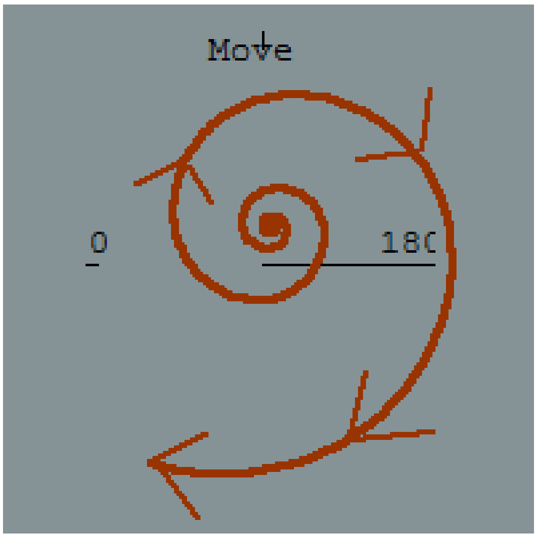

Fig 2.3(shows the direction of spin movement in the spinning frame.)

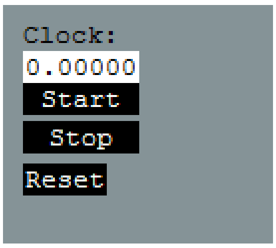

Fig 2.4(shows the box of clock section)

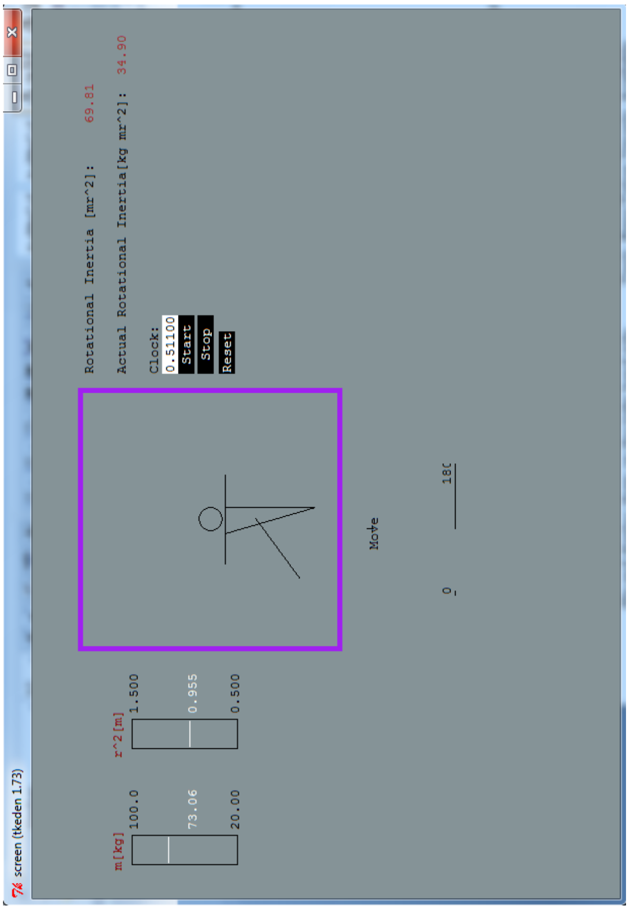

Fig 2.2 (The layout of the Model)

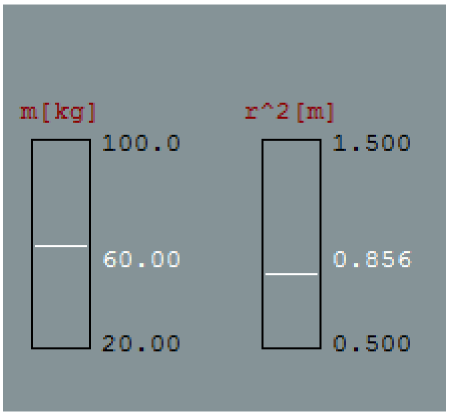

Fig 2.5(The mass bar and distance(r^2) bar)

Which these two value can be put into formula and calculate the rotational inertial of the skater. The final calculate result is perform by equations implemented in EDEN file and display them on the right hand side of the screen layout. The formula must follow these two laws:

Rotational inertia of mass at distance

r: $I = mr^2$

Angular momentum: $L = I$

There is a timer beside the main frame, which user can click on the start button and initialise the spinning movement, the user can have option to stop and reset the clock anytime when using the model. When the spinning movement is intialised, the user can apply direct influence on the model to observe the simulation.(Figure 2.3)

3. Conclusion

In conclusion this project is working in a good progress, but the fact is that the jumping movement that explain in the abstract before still need further research of achieving that function on Eden. It can be conclude that the current model have been finished in a first phase, as the modeling building schedule is according to the physic calculation that explained in the previous section, now the model can calculate the exact rotational behavior of skater when the skater have his arms and leg out i.e.(*Iin*) .The second phase of is the figure that indicate the spinning line, further improvement of this function will be extended to the future work section. The mode is build successful in the Empirical Modelling principal which user cans interaction with the model and experience how changes in dependency can be useful for exploration of a modelling environment. The advantages of using Eden is that it provide a object orientated environment to give the user a more interact and flexible view of the simulation rather than learning it in a traditional way.

4. Future extensions

As explained in the conclusion section, the second phase of figure spin speed indicator, there is a problem on achieving steady clock-wise move in 360 degrees and this will be improve in adjusting formula that implemented in Eden. The third phase is that adding calculation function on measuring the speed of spinning when figure skater pulls his both arms and leg inward. Which is

$Ibody + 1/2(2Marm)r^2\, arm + 1/2\, Mleg$

The implementation idea is that same as phase 1, by creating some slide bar on the sides to use the body mass, arm and leg mass and distance from the axis to measure the speed.
The other function such as in achieving the jumping action in the simulation, the friction idea can use the Newton's third law whereas is for every action, there is equal and opposite reaction to apply to the abreaction of the equation to build the model. Further research is needed.

5. References

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