

Simulation of the Rigid Body

(Human Figure)

Innovations Project Report

Marcin Kolendo

NCCA 2006

(c1194934)

Contents:	Page:
Abstract.....	3
1. Introduction.....	3
2. Previous work.....	4
3. Implementation of my idea.....	5
4. Research and development, problems and solutions.....	8
5. Pros and cons of the proposed solution, future upgrades.....	12
6. Summary.....	13
References.....	14
APPENDIX 1 (The user manual).....	15
APPENDIX 2 (The source code of the script).....	19

ABSTRACT

It has been a very ambitious goal for the many people involved in the computer graphics industry to create virtual, anatomically correct actors that would possess realistic human motions when under the influence of the various outside forces. It still remains a quite difficult problem to create a dynamic, anatomically correct computer generated figure that would realistically react to the gravity and other various contact forces. The results were either very expensive software or, in the other hand, very complicated [1].

I propose a very basic Maya MEL script with supporting Maya scene which is expected to solve simple problems connected with realistic animation of the human figure exposed to external forces. I propose the system that is expected to accurately compute the animation of the default human skeleton reacting to the gravity and contact forces. The solution is expected to keyframe the animation of the skeleton's joints for the convenience of future use in animations.

Keywords: computer animation, rigid body animation, character animation, physics based animation, rag doll animation

1. INTRODUCTION

How does the human body work? How does it react to the surrounding forces like air, gravity? Our environment is full of such forces that play a vital role in how the human body behaves when exposed to them [2]. As physics suggests, where there is an action (force) there is always reaction to it. It takes an enormously long time to animate, for example, a person falling down the stairs or a person who reacts to the contact forces applied to different parts of his body (punch). The main problem animator has to tackle is to make the animation look believable – whether it is cartoon style animation with exaggerated or realistic movement, it always has to look very convincing to be considered as a good one. The time that is spent on animating such actions pushed people to create different solutions which would aid speeding up the process of an animation. In this report I propose a very simple yet effective solution for creating a framework of an animation of the dynamic character. The Maya MEL script I propose is simple in use, quick to learn and very effective to solve issues connected with realistic animation of the human figure exposed to contact forces and gravity.

In the next section I review the previous related work and have a quick overview of the different techniques of capturing the motion of the human body. Then I present my own research and experiments carried out in relation to the problem and implementation of my own idea. Later I discuss problems I encountered during development of the system and the solutions to them. Finally I compare my solution to different approaches and assess the pros and cons of my final piece.

2. PREVIOUS WORK

The computer simulation of the anatomically correct human figure is challenging in many ways. Depending on the desired outcome, comprehensive solutions must meet different standards regarding the complexity of the human figure, skeleton, behaviour.

The idea to replicate accurate human motion for computer generated figures is not new. To get convincing motion for the human characters in Snow White, Disney studios traced animation over film footage of live actors playing out the scenes. This method, called rotoscoping, has been successfully used for human characters ever since [3].

Probably the most popular technique to capture the motion of the human figure is system called motion capture. The use of motion capture for computer character animation is quite new. It begun in the late 1970's and generally it involves capturing the position of the human body in real space and mapping the data onto the computer generated character either in real time or later on in the production process. Having said that, although motion capture systems are very complex and sophisticated and give fantastic results, they have their own limits. It would be very hard to convince the motion capture actors to, for example, jump down 100 feet in order to catch the animation of the body or even tumble down the stairs not to mention apply different forces to the actor's body. Actions that may potentially include dangerous movements are hard to capture using motion capture systems due to the safety of the actors. The motion capture system is excellent for capturing the every day movement of the body, where more exaggerated or dramatic actions (such as a human figure being hit by the train) will usually involve using different solutions. Also for the individual animators the access to the motion capture facilities is somewhat restricted and they need to rely on the different solutions to tackle some animation problems. Generally, motion capture systems are based on the optical sensors attached to the real actor's body although some variations of the motion capture systems exist like special gloves that control the virtual puppet, joysticks etc.

A different solution to capture the movement of the human body is proposed by the Natural Motion and its Endorphin Dynamic Motion Synthesis software. It is relatively new and it includes many excellent features to produce believable animation of the computer generated human figures exposed to external forces like gravity or contact forces. The main difference between this approach and the motion capture systems using optical sensors is that Endorphin does not require actors – all the animation capturing is done on the monitor screen. It involves computer generated puppets which are reacting to each other or the surrounding environment in a very realistic manner. The user is able to create the animation of the people being hit, kicked, tackled, people falling down the stairs, interacting with other rigid bodies within the scene. These are only a few options that this software delivers to the user. At the moment this system is very expensive and virtually out of reach for individual animators and is used mainly by big animation companies. Also the system, unlike motion capture, is unable to produce any animations that will require actors (or very good animating skills) such as walk cycles etc.

There are various solutions for accurate capturing of the human body motion [4], [5] implemented into game engines and there are several papers covering this area in theory as well as in practice. For me, as I am a Maya software user, the most popular system that is under constant development and upgrading is Novodex for Maya (Nima) plug-in [6]. Developed by Feeling Software this system covers rigid body dynamics, rigid constraints and rag dolls. The solution is fairly easy to use for animators with some rigid body knowledge but quite hard to understand for people with no experience in the field.

3. IMPLEMENTATION OF MY IDEA

The field of rigid body dynamic (more generally, multibody dynamics) is all about designing mathematical models and algorithms to predict the motions of bodies and the contact forces, including friction, that arise between them. The two most exciting applications of rigid body dynamics are robotics and computer games (or computer animation). In robotics, the goal is to build a robot with the capability to plan and autonomously carry out dexterous manipulation tasks - like doing the dishes. More and more, computer games contain physics engines to improve realism - for example, dropping a stone into the gears of a machine could cause jamming, thus stopping the knife blades from swinging across your path, and allowing you to escape the collapsing building [7].

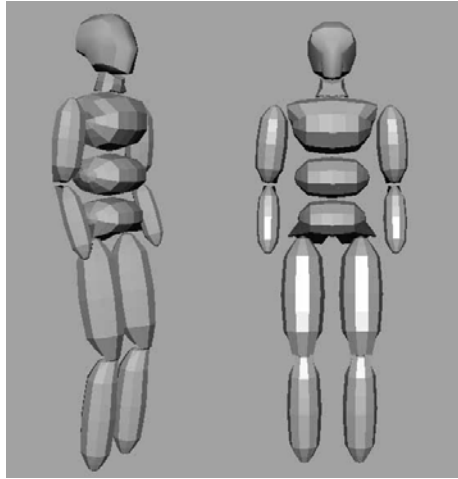
Bearing in mind all of the problems that animators have to solve when animating rigid bodies I started to think of a way of producing a believable and accurate human body in Maya. In order to do so, I needed to understand the principles behind the shape and proportions of the human body and its skeleton. The most common visual presentation of human body proportions is Leonardo Da Vinci's diagram:



<http://www.globalgallery.com> (accessed 08 March 2006)

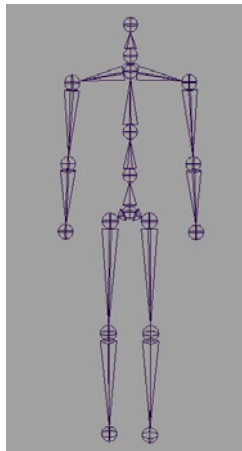
A very valuable source of information about this subject comes from the life drawing lessons where a student becomes familiar with the shape of the human body

by making sketches of the nude model. This helps with understanding basic principles of the proportions of the human body and aids drawing and modeling from imagination. Having established main concepts behind the task of creating accurate human body shape in Maya I created the following figure:



Human body created with Maya

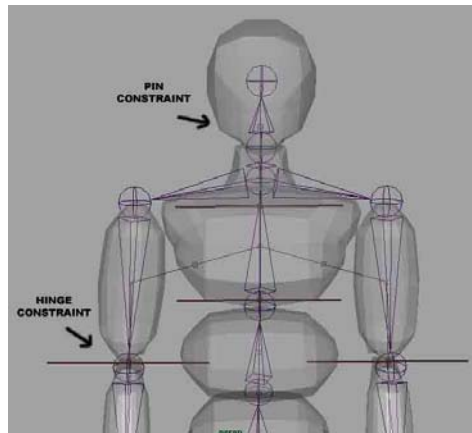
This figure of the human body was accurate enough to use it in the further development of the project. It also enabled me to outline basic skeleton system that would be used to create animations of the body exposed to different contact forces and gravity. The skeleton system was created using Maya:



Skeleton system created with Maya

The creation of the accurate human body using Maya was challenging but my previous modeling experience helped in this process. The next step was to make sure that the body I created would react to contact forces and gravity in the way that the real human body does. This task required research into rigid body simulations papers and some available source codes of the previous work (like, for example, the

aforementioned Novodex plug-in for Maya). The final solution to the problem of connecting particular body parts together (for example trunk, arm and forearm chain) was to use hinge and pin constraints. Hinge constraints were used to connect the parts of the body that have certain limitations regarding movement, like for example the knee joint can be moved only in two directions. The pin constraint was used for the joint connecting the head and the neck as the head can be moved freely in various directions (forward, backward and on the left and right sides).

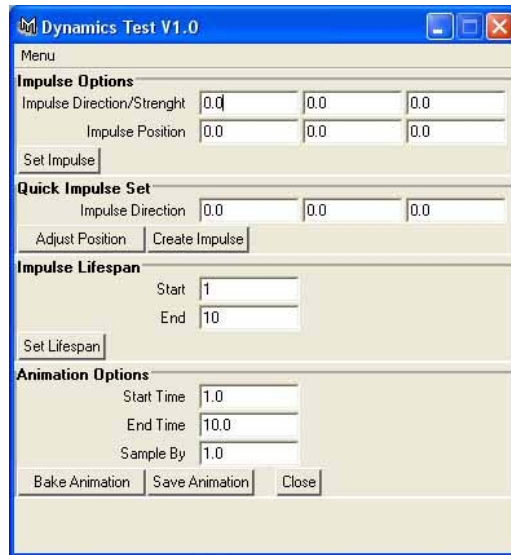


Pin and hinge constraints used for particular joints in the body,
created with Maya

All of the parts of the created human body were converted into the Active Rigid Bodies to enable interaction with applied different forces. Also the particular body parts were parented to corresponding bones in the skeleton and the bones were orient constrained to the corresponding body parts. This meant that with the movement of the body part the bone that corresponds to it will be moving as well in the accurate and realistic manner.

In order to realistically visualize accurate human body reacting to the various forces applied, every part of the created body needed to have similar weight to the body parts in the real life. The final figure that I created weighs the same as an average male human (approximately 70 kg) where the head is 4.7 kg and the trunk is 15 kg.

The final figure could react accurately to the gravity force and other forces applied to it (like air or impulse-contact forces). To make the concept as user friendly as possible, considering that it may be required by animators without in-depth knowledge of the rigid body simulation, the use of Maya MEL scripting language became very helpful. The final script presents the user with the pop-up window with several options that aid the animation of the rigid bodies, in this example, human body. The final window that the user is presented with:



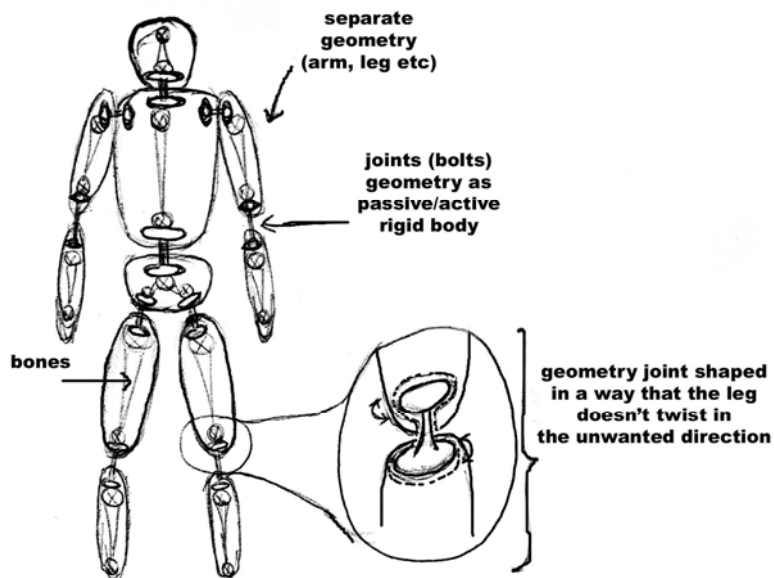
The final look of the script window,
Created with Maya MEL

The user manual on how to use the script in the most efficient way is included in the Appendix 1.

The source code of the script Dynamics Test is included in the Appendix 2.

4. RESEARCH AND DEVELOPMENT, PROBLEMS AND SOLUTIONS

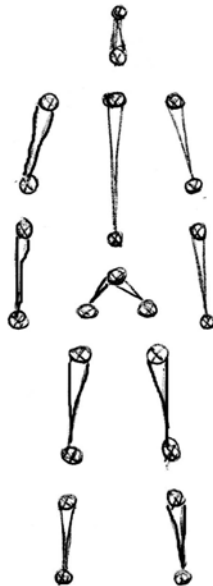
The main problem I had to solve was to create the human body with Maya software capable of reacting to the contact forces and gravity in an accurate manner. Below is my first design:



One of the ideas on how to create the body and connectors

This idea incorporates different approaches as to how to build and then connect different parts of the human figure. The main parts of the body like forearm, head, chest etc are separate meshes (geometries) shaped in the way where at the ends there is a hollow space that would enable the joint bolt to be placed in. The bolt itself is a different mesh. Each joint is shaped in the way that doesn't allow the body parts to go in the unwanted directions (knee joint or elbow joint have quite restricted field of movement). Each of the body parts as well as the bolts are then converted into active rigid bodies. In theory, this approach should work fine but brings many problems. For example there would be many intersections between the parts of the body and the bolts which would greatly slow down the computing time. The bounciness, friction and other important attributes would have to be very specific in order not to allow the geometry of the bolts to penetrate the geometry of the body parts. Also the number of the rigid bodies would contribute to slowing down the computing process. Apart from that, the geometry itself would not be keyframed as it was made of rigid bodies. The bolts and the hollow spaces at the end of each of the body parts would have to be modelled separately for each of the different connections, like elbow and knee. Because of these issues I found this solution unacceptable.

My other idea on how to construct the body and its skeleton system was to produce the skeleton with joints that are not connected with each other. User would have to connect them together later after the animation (simulation) is performed. In this example, the skeleton system would have to look like this:



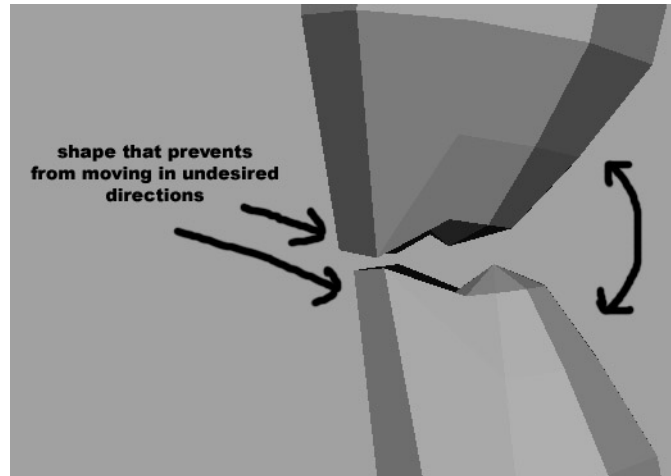
One of the ideas on how to create a skeleton

This approach was considered due to the facts that when using the system with all the joints connected together there were unexpected problems to solve. I tried to apply forces not for the geometry parented to particular joints but for the joints themselves. That caused the joint to snap in an unpredicted direction so “freeze transformations” option had to be applied before that. When the force was applied to the geometry parented to the particular joint (bone), everything seemed to work fine only for that particular body part, where the other bones remained in the same position. That’s why I came up with the idea of separating joints (see above picture).

After several tests that I carried out on how to create dynamic rigid human body I researched more on the following, final option. This is how the body has been constructed:

1. Create full skeleton.
2. Create geometry (body parts), move it to the desired place.
3. Delete mesh and bones history and Freeze Transformations on the mesh and bones.
4. Geometry Constraint the mesh to the corresponding bones (it ensures that the rotation values of the geometry are the same as the bones). After this operation constraints can be deleted in order to adjust the position of the body parts.
5. Orient Constraint each of the body parts to the corresponding bones.
6. Make the body parts Active Rigid Body.
7. Apply hinge/pin constraints to rigid bodies to chain them together.
8. Apply forces (such as gravity and contact forces) and create passive rigid body objects as obstacles.

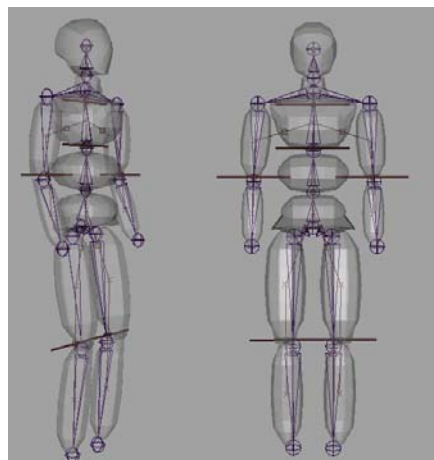
This final solution appeared to be the most efficient and the least complicated to implement into my project. However, several problems arose whilst developing this concept. The limits that I wanted to apply to the particular joints to prevent them from turning in unwanted directions proved to be very unstable. After applying any limits to the joints, these joints started to snap in unpredictable directions (even in the directions forbidden by the characteristic features of the Hinge Constraint and also forbidden by limits applied). To solve this problem I decided to create artificial rigid limits. After deleting all the limits that were applied to the joints I shaped the geometry of the body in a way so as to prevent it from moving in undesired directions:



Final idea on how to make the body parts move in desired directions

Although this method played its role perfectly for the knee joints and elbows, it proved to be unrealistic for the arm joints or places where legs join the body. The only solution for this problem was to arrange the body geometry as accurately as possible and use pin constraints for these joints.

Another problem was how to create the body parts (geometry) with realistic weight and size. I spent hours trying to find out proper weights for particular parts of the body and finally came up with the optimal solution: I had to give up on the geometry that represented feet and hands. This was due to the body weight issues and also long rigid collisions calculation times when baking the animation and many collision problems encountered. Because of the additional bones and geometry created for hands and feet there were many interpenetrations of the rigid bodies occurring during playback and that slowed down the calculation times greatly and generated quite inaccurate results (like poor animation). The final human figure I created with skeleton and hinge/pin constraints:



Final figure with skeleton system and hinge/pin constraints

Having the human body figure ready I started to write the Maya MEL script that would allow me to set up desired options quickly and easily. The final script code is included in the Appendix 2.

The first part of the script sets up a basic pop-up window with all the options and buttons required. What follows is a set of functions which are responsible for setting various attributes for the contact force and some useful functions that aid production of the final animation.

The following is an example of the function that enables the user to set up the life span of the applied force:

```
global proc impulseLifespan()
{
    string $selectspan[]=`ls -sl`; //holds name of the rigid
body
    string $selectsp;

    for($selectsp in $selectspan)
    {
        int $zero=0;

        int $start=`intFieldGrp -q -v1 startSpan`;
        int $end=`intFieldGrp -q -v1 endSpan`;
        setKeyframe -t $start ($selectsp+".impulse");
        setKeyframe -t $end ($selectsp+".impulse");

        setAttr ($selectsp+".impulseX") $zero;
        setAttr ($selectsp+".impulseY") $zero;
        setAttr ($selectsp+".impulseZ") $zero;

        setKeyframe -t ($start-1) ($selectsp+".impulse");
        setKeyframe -t ($end+1) ($selectsp+".impulse");

    }
}
```

5. PROS AND CONS OF THE PROPOSED SOLUTION, FUTURE UPGRADES

The solutions and different approaches mentioned earlier on how to capture the human body motion are very different to each other. They are either very expensive or very complicated. My aim has been successfully accomplished by producing a system tackling basic problems connected with animating sequences involving gravity and various contact forces. The script is easy to use and quick to learn. The main feature of it is that it speeds up the animation process greatly. It produces the animations that never look the same even if the user does not change any settings.

Known problems and errors:

The system I proposed is not free of some errors. For example from time to time, depending on the strength and direction of the force applied, some parts of the body seem to snap in unpredictable directions. In this case the user has to either adjust the force or make some corrections to the animated skeleton. Also there is a difficulty connected with enormous calculation times when the figure gets to the very complicated position involving many collision calculations. From time to time, some of the joints will twist (move) in the direction that is impossible for the human body. This is due to the fact that there are no limits applied to the joints and the only thing that makes them move in the desired directions is the shapes of the geometry. This problem I mentioned earlier and have not found the solution to it as yet.

Possible upgrades:

The proposed solution would benefit greatly from some upgrades I was considering while developing the project. One of the upgrades and probably the most important would be to create an interactive force adjuster on the main Maya window which would allow the user to see the direction of the force (represented for example by an arrow). Then with the click of the button the force would be applied to the particular part of the body and filling in the fields with the values would be no longer necessary. I was also considering implementing some various behaviours for the virtual character that would greatly improve the accuracy and realism of the human body. I carried out some tests with the springs acting as the muscles attached to different bones but they produced very strange results and forced me to abandon this idea for the moment. Also when saving animation, it would be beneficial to have a pop-up window that would allow the user to choose a desired directory as where to save and how to name newly created animation.

6. SUMMARY

I believe that the script I wrote to simulate human body animation after applying contact forces is a success and will help some animators to produce believable animations. Although the script is simple it is capable of producing good effects. Its simplicity allows the users to change / upgrade the script according to the requirements. Personally it was a great challenge for me as I have never had any scripting experience before and the Innovations Project was a great opportunity for me to explore the scripting aspect in a deeper way. My original reason for exploring the rigid body simulation was to use the script for a scene of a bomb explosion in my major project animation but due to various reasons this scene will not appear in my final major piece. I have learned basics of MEL scripting and consider it very enjoyable. I hope to add some new features to the solution and improve its performance and efficiency issues. My script has been tested by friends with little knowledge of Maya who were happy with their created animations.

REFERENCES

- [1] Stephen Ehhman, 1999, Rigid Body Simulation Tutorial,
www.cs.unc.edu/~ehmann/RigidTutorial/
- [2] David Stewart, J.C. Trinkle, An Implicit Time-Stepping Scheme for Rigid Body Dynamics with Coulomb Friction,
<http://www.cs.rpi.edu/~trink/Papers/STicra.pdf>
- [3] A Brief History of Motion Capture for Computer Character Animation.
www.siggraph.org
- [4] David Baraff, Fast Contact Force Computation for Nonpenetrating Rigid Bodies, <http://www.cs.cmu.edu/afs/cs/user/baraff/www/papers/sig94.pdf>
- [5] David Baraff, Physically Based Modeling,
<http://www.pixar.com/companyinfo/research/pbm2001/notesg.pdf>
- [6] Feeling Software documentation,
www.feelingsoftware.com/Files/Nima/nima.html
- [7] J. Trinkle, Trinkle's Rigid Body Dynamics,
www.cs.rpi.edu/~trink/rigid_body_dynamics.html

Additional Reading and Research:

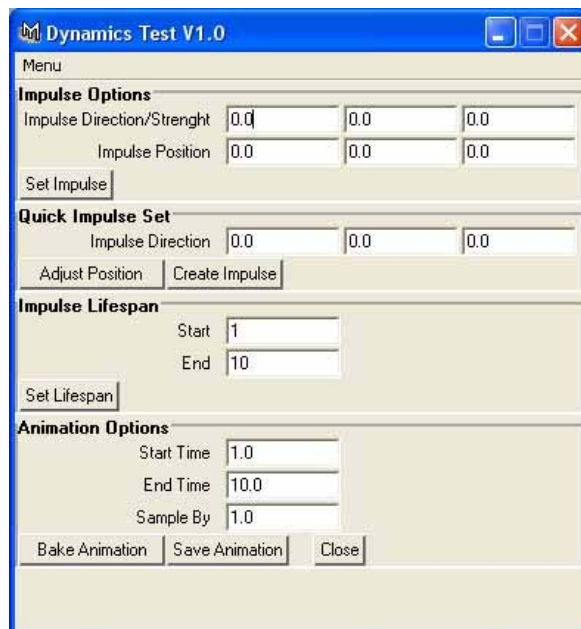
- 1. Wayne Wooten. *Simulation of Leaping, Tumbling, Landing, and Balancing Humans*. PhD thesis, Georgia Institute of Technology, March 1998.
- 2. <http://www.myphysicslab.com/collision.html>
- 3. Rachel Weinstein, Joseph Teran, Ron Fedkiw, Dynamic Simulation of Articulated Rigid Bodies with Contact and Collision,
<http://graphics.stanford.edu/~rachellw/files/articulated.pdf>
- 4. <http://www.codercorner.com/Rigid.htm>
- 5. Kevin Egan, Techniques for Real-Time Rigid Body Simulation,
<http://www.cs.brown.edu/publications/theses/ugrad/2003/ktegan.pdf>

All the internet sources of the reports, papers, tutorials and notes were checked on the 8th of March 2006,

APPENDIX 1

User Manual for the Dynamics Test v.1.0

To create desired animation open the scene called human_body.ma included on the CD. From the Maya options, go to Window → General Editors → Script Editor. The Script Editor window will open. From the top menu choose File → Open Script and navigate to the script file called dynamicsV1.mel on the CD. After opening the script, the new window will appear:



Options available in the window:

1. Impulse Options

This option works exactly like the Impulse option in the Maya Attribute Editor (Rigid Body options). To set the impulse (contact force), select the particular body part the user wants the force to be affecting in the main Maya window (e.g. perspective window).

The **Impulse Direction/Strength** field enables the user to enter the values (the higher value, the greater strength of the force). First field relates to the X axis, second to the Y axis and third to the Z axis (the XYZ rule applies to the other options with three fields within the script). The **Impulse Position** field enables the user to position the force within the 3D space (starting from the origin). Button **Set Impulse** creates the impulse with all the values entered by the user.

Example:

Impulse Direction/Strength: 0.0 0.0 -10
Impulse Position : 10 10 5

This setup will create the impulse (contact force) in the position X=10, Y=10 and Z=5 relatively to the origin. The direction of the impulse will be $-Z$ with the strength 10.

2. Quick Impulse Set

This option enables the user to apply the force in a more accurate manner and it is recommended for most animations. Start by clicking on the button called **Adjust Position**. This will create the object (pSphere1) in the origin of the scene that will resemble the point where the force is coming out from. By using Maya Translate Tool, move the object in the desired location (for example, if the user wants the force to be coming out from the point just opposite the figure's head, the object pSphere1 should be moved to the location just opposite the head – see Fig. 1). Input the desired values into the provided fields (XYZ rule), where the higher value will represent greater strength of the force. Select the body part you want the force to be affecting in the main window and click on the **Create Impulse** to finalise the action of creating the force.

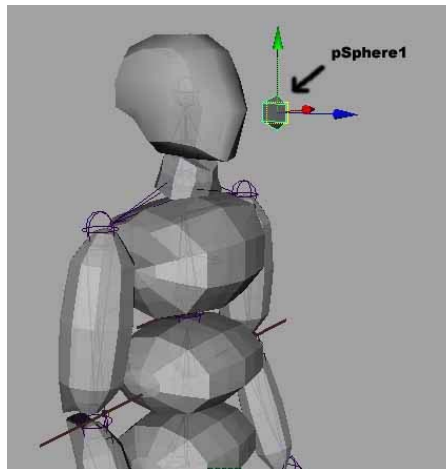


Fig.1.

Example:

Impulse Direction: 0.0 0.0 10

This setup will create the impulse coming out of the pSphere1 location with the strength 10 and direction Z.

3. Impulse Lifespan

This option allows the user to set the lifespan (duration of the force affecting the body) of the contact forces (in frames). In the field **Start** enter the number of the frame from which the force should start working and in the **End** field input the number of the frame on which the force should stop affecting the body. This option enables user to flexibly set the force – whether it is just quick impulse (for example punch or kick) or long lasting impulse (for example drag).

Example:

Start: 3

End : 10

This setup will set the length of the contact force to 7 frames (between frames 3 and 10 of the animation).

4. Animation Options

This option enables the user to define the length of the whole simulation by entering the numbers of the first (**Start Time**) and the last (**End Time**) frames of the animation. It also gives the opportunity to keyframe the animation (in this example joints of the skeleton) by entering the **Sample By** value in the provided field. The recommended simulation time is between 100 and 200 frames as it increases computing time significantly for the longer animations.

Example:

Start Time: 20

End Time : 50

Sample By: 4

This Setup will produce the animation starting on the frame 20 and ending on the frame 50 where the animation of the joints will be keyframed every 4 frames.

Bake Animation option will start simulating the action taking into account all the options and values entered by the user. After the simulation is complete and user is happy with the outcome, **Save Animation** option will save the animation of the whole skeleton to the file called animation.ma.

Button **Close** will close the Dynamics Test script window.

NOTES:

This script is in a testing stage where some unpredictable things may take place within Maya (the most common problem is when Maya stops responding for very long period of time when trying to calculate very complicated simulations).

Within the scene human_body.ma user is encouraged to create additional props and turning them into active/passive rigid bodies so the human figure can interact with them (for example chairs, stairs, walls etc.).

The output file name animation.ma should be renamed to something else in order to avoid overwriting by newly created animations.

The project comes with the support of the CD where the user can find all the files necessary to create animations (human_body.ma and dynamicsV1.mel) and also the movie file presenting the features of the system showing some of the finished animations using the script.

APPENDIX 2

Source code for the Dynamics Test MEL script

```
/*-----
Dynamics Test V1.0 by Marcin Kolendo 2006
-----*/

global proc make_body()
{
    string $window = "make_body";
    if(`window -exists $window`)
    deleteUI $window;
    dynamics_window($window);
    window -e -wh 415 430 $window;
}

global proc dynamics_window(string $window)
{
    window -title "Dynamics Test V1.0"
    -maximizeButton false
    -menuBar true $window;
    showWindow $window;

    menu -label "Menu" -tearOff true;
    menuItem -label "Instructions" -c("confirmDialog -title \"Instructions\" -
    message \"1.Set the strenght and direction of the impulse.\\n2.Click 'Create
    Animation' button.\\n3.Click 'Save Animation' button.\\n4.Refer to the Readme
    file for more options.\" -button \"OK\";");
    menuItem -label "About" -c("confirmDialog -title \"About\" -message
    \"Dynamics Test V1.0\\nemail: marcinkolendo@hotmail.com\" -button \"OK\";");

    columnLayout -adjustableColumn true;
    frameLayout -label "Impulse Options" -labelAlign "top" -borderStyle "in";
    columnLayout;

    floatFieldGrp -l "Impulse Direction/Strenght" -numberOfFields 3 -value1 0 -
    value2 0 -value3 0 impulse_Strenght;
    floatFieldGrp -l "Impulse Position" -numberOfFields 3 -value1 0 -value2 0 -
    value3 0 impulse_Position;
    button -label "Set Impulse" -command ("change_impulse");

    setParent ..;
    setParent ..;

    frameLayout -label "Quick Impulse Set" -labelAlign "top" -borderStyle "in";
    columnLayout;

    floatFieldGrp -l "Impulse Direction" -numberOfFields 3 -value1 0 -value2 0 -
    value3 0 impulse_Strenghtx;
    rowLayout -numberOfColumns 2 -adj 2 -columnAlign2 "center" "center" -
    columnAttach2 "both" "both";
    button -label "Adjust Position" -command ("impulse_position_set");
    button -label "Create Impulse" -command ("impulse_position");

    setParent ..;
    setParent ..;
    setParent ..;

    frameLayout -label "Impulse Lifespan" -labelAlign "top" -borderStyle "in";
```

```

columnLayout;

intFieldGrp -l "Start" -numberOfFields 1 -value1 1 startSpan;
intFieldGrp -l "End" -numberOfFields 1 -value1 10 endSpan;
button -label "Set Lifespan" -command ("impulseLifespan");

setParent .;
setParent .;

frameLayout -label "Animation Options" -labelAlign "top" -borderStyle "in";
columnLayout;

floatFieldGrp -l "Start Time" -numberOfFields 1 -value1 1 start_Time;
floatFieldGrp -l "End Time" -numberOfFields 1 -value1 10 end_Time;
floatFieldGrp -l "Sample By" -numberOfFields 1 -value1 1 sample;

rowLayout -numberOfColumns 3 -adj 3 -columnAlign3 "center" "center" "center"
-columnAttach3 "both" "left" "right";
button -l "Bake Animation" -c "create";
button -l "Save Animation" -c "save";
button -l "Close" -c ("deleteUI " + $window);
}

global proc change_impulse()
{
string $selects[]=`ls -sl`;
string $select;
for($select in $selects)
{
float $ix=`floatFieldGrp -q -v1 impulse_Strenght`;
float $iy=`floatFieldGrp -q -v2 impulse_Strenght`;
float $iz=`floatFieldGrp -q -v3 impulse_Strenght`;
setAttr ($select+".impulseX") $ix;
setAttr ($select+".impulseY") $iy;
setAttr ($select+".impulseZ") $iz;

float $px=`floatFieldGrp -q -v1 impulse_Position`;
float $py=`floatFieldGrp -q -v2 impulse_Position`;
float $pz=`floatFieldGrp -q -v3 impulse_Position`;
setAttr ($select+".impulsePositionX") $px;
setAttr ($select+".impulsePositionY") $py;
setAttr ($select+".impulsePositionZ") $pz;

}
}

global proc create()
{
select -r joint7 ;
float $start=`floatFieldGrp -q -v1 start_Time`;
float $end=`floatFieldGrp -q -v1 end_Time`;
float $sample=`floatFieldGrp -q -v1 sample`;
bakeResults -simulation true -t ($start+"."+ $end) -hierarchy below -
sampleBy $sample -disableImplicitControl false -preserveOutsideKeys false -
sparseAnimCurveBake false -controlPoints false -shape false {"joint7"};
}

global proc save()
{
select -cl ;
select -add lowerneck ;
select -add head ;
}

```

```

select -add left_tigh ;
select -add right_tigh ;
select -add right_calf ;
select -add left_calf ;
select -add right_arm ;
select -add left_arm ;
select -add right_forearm ;
select -add left_forearm ;
select -add bowel ;
select -add stomach ;
select -add chest ;
select -add gravityField1 ;
delete;

        select -r joint7;
        select -add joint1 joint2 joint3 joint4 joint5 joint6 joint8 joint9
joint10 joint11 joint12 joint13 joint14 joint15 joint16 joint17 joint18;
        file -rename "animation.ma";
        file -typ "mayaAscii" -es -chn 1;
}

global proc impulse_position_set()
{
polySphere -r 0.2 -sx 3 -sy 3 -ax 0 1 0 -tx 1 -ch 1; //creates sphere
}

global proc impulse_position()
{
string $selectrigid[]=`ls -sl`; //holds name of the rigid body
string $selectrig;
select -r pSphere1;
string $selectsphere[]=`ls -sl`; //holds name of the sphere
string $selectsph;
for($selectrig in $selectrigid)
{

        //get select's xyz
        float $selectX=`getAttr $selectsphere.tx`;
        float $selectY=`getAttr $selectsphere.ty`;
        float $selectZ=`getAttr $selectsphere.tz`;

        setAttr ($selectrig+".impulsePositionX") $selectX;
        setAttr ($selectrig+".impulsePositionY") $selectY;
        setAttr ($selectrig+".impulsePositionZ") $selectZ;

}

select -r $selectrig;
string $selectsx[]=`ls -sl`;
string $selectx;

for($selectx in $selectsx)
{
        float $ix=`floatFieldGrp -q -v1 impulse_Strenghtx`;
        float $iy=`floatFieldGrp -q -v2 impulse_Strenghtx`;
        float $iz=`floatFieldGrp -q -v3 impulse_Strenghtx`;
        setAttr ($selectx+".impulseX") $ix;
        setAttr ($selectx+".impulseY") $iy;
        setAttr ($selectx+".impulseZ") $iz;
}

}

```

```

global proc impulseLifespan()
{
    string $selectspan[]=`ls -sl`; //holds name of the rigid body
    string $selectsp;

    for($selectsp in $selectspan)
    {
        int $zero=0;

        int $start=`intFieldGrp -q -v1 startSpan`;
        int $end=`intFieldGrp -q -v1 endSpan`;
        setKeyframe -t $start ($selectsp+".impulse");
        setKeyframe -t $end ($selectsp+".impulse");

        setAttr ($selectsp+".impulseX") $zero;
        setAttr ($selectsp+".impulseY") $zero;
        setAttr ($selectsp+".impulseZ") $zero;

        setKeyframe -t ($start-1) ($selectsp+".impulse");
        setKeyframe -t ($end+1) ($selectsp+".impulse");

    }
}

make_body()

```