NASA Lunar Excavation Simulation Report

April 5 2007 In-Progress Deliverable

The Phase I scope of work called for DigitalSpace to conduct the following tasks:

DS1: Develop driveable, real-time simulation models for four distinct mobile lunar excavation platforms.

DS2: Develop tool to capture statistical / engineering data from real-time lunar excavation simulation.

DS3: Create and integrate new DigitalSpace platform tool to enable variability of physics parameters (e.g., wheel torque, soil parameters, etc.)

DS4: Create and implement approximations of excavator-soil interaction in DigitalSpace simulation

DS5: Create and implement a waypoint capture tool

DS6: Create and implement a failure model using mean time between failure (MTBF) criteria that disables system components

DS7: Investigate the feasibility of implementing a terrain modification

This In-Progress deliverable demonstrates the current development towards DS1, DS2, DS3 and DS4.

DS1: Drivable simulation models of excavation platforms

The In-Progress Deliverable provides three excavation platforms. Using a common mobility design, the Clam-Shell, Front End Loader and Bucket Wheel excavator designs are available. The Bucket Ladder design is in development.

Each of these excavators is manually controlled. The excavation system can be controlled using the keyboard keys, as specified on the simulation GUI.

These models are still in development status and can easily be taken outside their stable range. Examples of this is digging too deep causing flipping, gradual lowering of excavator arms, and body rotation due to collisions. Due to these and other issues we do not currently encourage "driving" of the excavators, ie powering the wheels to move the chassis.

DS2: Capture statistical/engineering data from simulation

The In-Progress Deliverable uses a rewritten log system from the first drivable excavation simulation (delivered 8th March), and logs much more data then available previously.

This includes joint velocities, target velocities, forces applied by motors, and friction forces. More forms of data may be available, after review from the data consumer.

Logging Specification

The Logging System outputs collected statistics every 100ms (10 heartbeats). Values provided are the average for that 100ms (from samples taken up to every 10ms, ie each heartbeat).

There are three types of samples being tracked in the logging system. All types of samples are prefixed with a timestamp and the name of the sample source. We have not yet moved to the naming convention that was suggested to us.

Updated April 5th: Logging now presents an option to be enabled or disabled. It starts in the disabled state.

Joints

For every joint in the simulation, these properties are tracked:
Motor Force - The force or torque being applied to this joint
Linear Velocity - In the case of a linear joint (slider), the speed of the joints motion along its axis. In the case of an angular joint (hinge) this will be zero.
Angular Velocity - In the case of an angular joint (hinge), the speed of the joints motion around its axis. In the case of a linear joint (slider) this will be zero.
NOTE: In the current simulation, all the joints are hinge joints.
Motor Velocity - This is the speed the joint "should" be moving at. The physics simulation uses a force up to the value of Motor Force to accelerate/decelerate the joint to this velocity.
The setting of Motor Velocity is set by the system in response to user input, i.e. controlling the joints. These samples are provided continuously.

Linear Friction

Applied only to rocks, this is the parameters of the force being used against the object.
Velocity - This is the current velocity of the object, and is used to calculate the direction the resistance force should be applied
Resistance - This is the maximum force that the physics simulation is to use to attempt to keep the object stationary.
The Resistance value is specified per "jello volume" in the simulation. Each of these volumes is represented by a translucent area, with the areas opacity indicative of its relative resistance.
These samples are only provided for objects that are currently within a friction volume. Specifically, if a rock is removed from the volume by an excavator, linear friction will no longer be applied to it, and there will be no logged entry for it, until it is dropped into the volume again.

Balovnev Resistance

Applied only to the cutting surfaces of the excavator buckets. In this case, the Name entry for the sample has an identifier for the "blade" appended. In the case of multiple blade buckets (ie the Bucket Wheel) this identifies which blade the calculated force is applied to.
Depth - The distance between the surface of the regolith and the cutting edge of the bucket blade.
Beta - The angle of the bucket blade. An important point is that this is always in the range of 5 degrees to 90 degrees (although it is displayed in radians).
Resistance - This is specified as (H, V, T), where these are Horizontal and Vertical components of the Total force being applied. It should also be noted that these are not specified in world coordinates, but in the local coordinate system used in the Balovnev calculation.
These values are only output when Balovnev friction is being applied to buckets. Due to the range of values accepted by the Balovnev calculation, no values are applied (or logged) when Beta is below the radian equivalent of 5 degrees. Thus, when the blade of a bucket is almost parallel with the surface, no Balovnev friction is applied.

DS3: Enable variability of physics parameters

A GUI is presented allowing adjustment of the Parameter Set used for calculation of Balovnev friction forces. Existing GUI allow adjustment of excavator wheel to regolith interactions.

The only parameters for the Balovnev equation that are adjusted in real time are Depth and Beta, which are the depth and angle of the bucket blade. All other parameters are common across the simulation. This includes parameters that relate to bucket dimensions, which are not visually consistent across all excavator models.

DS4: Approximate excavator-soil interaction

The Balovnev friction model is being used in real time to calculate the friction forces applied to the excavator buckets when interacting with the regolith.

Issues with the appropriateness of this method of force modeling have been identified.

Also there is currently a speed issue with the calculation of soil interaction. This is a known issue with the current implementation and improvements have been designed, but not implemented due to time constraints.

Updated April 5th: The most immediate improvements have been implemented, generally doubling performance (as measured by frame rate). Further increases are possible, but will take longer to implement and will reduce development flexibility.