Simulation of processes in a mining enterprise with Tecnomatix Plant Simulation

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Simulation of ore extraction on the open mountain works
Simulation objective

- To verify current control algorithms of the mining complex
- To simulate the mine operation and to predict how changing parameters influence:
  - Overall throughput
  - Bottlenecks
  - Quality of ore dynamics
- To find the set of parameters which provide the proper mine operation
Simulation model include one of technological complex of the mountain works

Simulation model represent the following processes:

- Ore extraction
- Ore storage
- Internal ore transportation
- Ore shipment (to railcar)
Contents:

- Objects
- Ore storage
- Truck motion simulation
- Routing and control
Simulation model include the following objects:

- Truck parking area
- Trucks
- Excavating machines
- Ore storage places
- Shipment excavator
- Transport network

На следующих слайдах объекты рассмотрены более подробно
All trucks are automatically generated at this point in the beginning of simulation and further proceed to the transport network.

All trucks end at this point when simulation finishes (a specified number of shifts passes).

Area contain the full set of truck parameters:

- Number of trucks
- Truck models
- Truck payload
- Truck speed
Trucks

Trucks travel through the mine transport network
Each truck has the following attributes:
- Maximum payload
- Current payload
- Average quality of ore in the truck body
- Speed coefficient
- Assigned number
- Target location
- Starting location

Assumptions:
- Current road situation is not considered in routing methods
- Engine characteristic curve is not considered (computation may not be totally correct, for example when driving along the lengthy ascending grade)
Excavating machines

- Excavator is a stationary equipment (it does not change location during the simulation run)
- Loads extracted ore into a truck and sets a target destination
  - Loading duration 3 minutes
  - Weight of loaded ore depend on truck’s maximum payload (90 tons)
  - Ore quality – from 0 to 70 percent
- All parameters are random values with normal distribution law
- Several trucks may wait for processing in a queue before an excavator
Contents:

- Objects
- Ore storage
- Truck motion simulation
- Routing and control
Ore storage places

Is an intermediate place for ore storage defined with the following attributes:

- Capacity
- Truck processing time (3 minutes)
- Quality of ore (high or average, accept trucks only with target ore quality)

Consists of two zones, for incoming and outgoing ore flow. Each zone is represented by a 3D-matrix:

- Parametric dimensions
- Each element stores a quality of ore in the appropriate volume cell
- The maximum weight of each cell is defined (40 tons)

If outgoing zone is empty and incoming zone is full, they exchange places.
Ore storage – incoming flow

- Zone is filled with extracted ore in the following sequences:
  - By horizontal layers
  - By rows of a layer
  - Be cells of a row

- All cells (except of the last one in each row) are filled completely (40 tons)
- The last cell in a row can be filled partially (weight is computed and known)
- When ore (from the next truck) is added to the partially filled cell, ore quality is averaged
- When the whole layer is full, it’s being floated (ore quality averaging)
Storage areas – quality averaging

Quality averaging is performed by layers:

- Average quality of ore in the layer is calculated (M)
- A new quality for each cell is calculated with the following formula:

\[ f_{av_{ij}} = f_{ij} - (f_{ij} - M) \times k, \]

- \( f_{av_{ij}} \) – average quality in a cell
- \( f_{ij} \) – source quality value
- \( M \) – average ore quality in a layer
- \( k \) – averaging coefficient

Degree of averaging is set with coefficient \( k \):

- when \( k = 0 \) averaging is not performed
- when \( k = 1 \) quality in each cell equals to average layer quality (M)
Excavator takes ore out of a storage by columns, starting from the top cell and loads ore to a truck.

Ore quality inside a truck is averaged.

Loading process continues until a truck is full or storage is empty.
Ore shipment area

- Trucks bring ore with required quality and unload it to the shipment site

  Excavator loads ore from the shipment site into railcars

  Operation process is the same like at storage areas except:

  - Excavator loads ore continuously (while shipment site contains ore)
  
  - Loading time of one railcar is specified
Contents:

- Objects
- Ore storage
- Truck motion simulation
- Routing and control
Network represents a set of roads, each road has two main attributes:

- Length
- Gradient (upslope, downslope, flat)

Trucks’ speed depends on the current gradient and truck load:

- 10 km/h when driving up
- 30 km/h when driving down or up horizontally

Also nominal speed is multiplied by a coefficient which depends on a type of the truck.

Road network object also performs an automatic routing of trucks.
A fragment of road network
Contents:

- Objects
- Ore storage
- Truck motion simulation
- Routing and control
Routing and control

Decision of truck’s destination is made once truck leaves the source object (parking, excavator, storage, disposal or shipment).

For each truck objects which can load and unload it are defined. Current setting is:

- 3 trucks are assigned to transfer ore from each excavator (9 in total)
- 9 trucks transfer ore from storage areas to shipment

When setting new destination for a truck each possible destination object estimates how much it needs this particular truck. Estimation value depends on:

- Weight of ore in truck’s body
- Ore quality
- Object’s status (i.e. how full is the storage)

Object with the maximum estimation value is selected as the new destination.
Some elements of the model

Setting of parameters

Output of results
Main frame

The main frame shows the basic layout with road network.

This view visualizes trucks driving along the network roads.

Control elements are grouped to appropriate buttons and dialogs.
A snapshot during a simulation run
What’s behind the model

Road network inside
What’s behind the model

Objects representing equipment and areas (picture shows a storage area)
What's behind the model

Control algorithms (methods)

```
return;
end;
-- If a truck is from mucker:
QRANGE.SetCursor (1,1);
QRANGE.FindCell ("[2,"], 0.Quality);
iQuality := QRANGE.CursorY;
-- If a quality is low - drive to hillock (closest)
if iQuality = 1 then
  Distance.SetCursor (0,0);
  Distance.find ("[*], 0,");    
  if Distance.CursorX > 0 then
    if Distance[Distance.CursorX, 8] > Distance[Distance.CursorX, 0].Destination := Hillock1;
    else
      0.Destination := Hillock2;
    end;
  end;
return;
end;
-- Drive to appropriate storage
```
What’s behind the model

Object parameters
Simulation model

Some elements of the model

Setting of parameters

Output of results
Parameters of the model can be defined with designed user interface…

… or directly in object properties
Simulation can be controlled from the dialog menu (start/stop/reset, toggle animation etc)
Simulation model

Some elements of the model

Setting of parameters

Output of results
Results of a simulation run is shown in the form of numerical values and also diagrams and charts.

- Quality of ore extracted by excavator
Output of results

Volume of ore shipped

Occupation of storage places

Incoming flow

Outgoing flow

Zone swap

10,000 тонн
The same data set is available for each individual truck

Later this information may be used for many calculations:

- truck wear and amortization
- fuel consumption
- planning of truck maintenance and repair
- many other factors …

Simulation results in the following table with integral truck mileage with division by empty/full trucks driving up/down/flat:

<table>
<thead>
<tr>
<th>string</th>
<th>length [m]</th>
<th>length [m]</th>
<th>length [m]</th>
<th>weight [t]</th>
<th>weight [t]</th>
<th>weight [t]</th>
</tr>
</thead>
<tbody>
<tr>
<td>груз / пустой</td>
<td>200890</td>
<td>322700</td>
<td>157887.8</td>
<td>416674.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Груженый рудой</td>
<td>47760</td>
<td>28960</td>
<td>20659.2</td>
<td>24508</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Output of results

Some results are shown right in dialog windows of individual objects:

- Utilization
- Number of loaded trucks
- Number of trips
- etc
Resources

Operation time

Truck parameters:
- Location
- Truck id number
- weight / quality

GANTT charts
Диаграммы Ганта – заказы (2)

- List of trucks
- Time
- Operation time
- Truck driving time
Conclusion
The prototype model created represents a real mine, however some processes are non fully implemented. Below are some assumptions.

- Quality of ore extracted by excavator is completely random, there is no dependency in sequence of buckets.

- Storage area models does not fully represent the functionality of real storages

- Shipment control logic is simplified

- Truck routing algorithm is simplified and does not represent all regulations in a mine
Created model may be used for:

- Optimization of a set of technological equipment in the mine
- Finding the optimum method to average the quality of ore
- Optimization of throughput and utilization of mine sites
- Planning of repairs and maintenance
- Estimating operational costs
- Planning the quality of ore shippings
Thanks!