JTLS-2021-15214 Include Maximum Arc Size In GIS Tool

Harold Yamauchi, Ellen Roland

1.0 Summary of Model Change Request

The JTLS-GO Geographic Information System (GIS) Tool provides a capability to "trim" a network by combining smaller arcs to reduce the overall number of arcs and nodes in the network. A capability that does the opposite is desired: If an arc is too long the arc will be divided to create multiple arcs. This is needed because objects can only get on a network at nodes. If nodes are too widely separated by long arcs, the object will not be close enough to a node, and therefore it will not be able to get on the network. Dividing long arcs into smaller arcs will create additional nodes that will give the object a better chance to enter the network.

2.0 Design Summary

A Road, River or Rail network is currently trimmed by specifying the Minimum Arc Length and Maximum Deviation. These are entered in the Enter Node Reduction Constraints dialog. Figure 1 shows the dialog for trimming Road and River networks and Figure 2 shows the dialog for trimming Rail networks. Sea Lane and Air Corridor networks are currently not trimmed because their nodes tend to be far apart (50 Km or more).
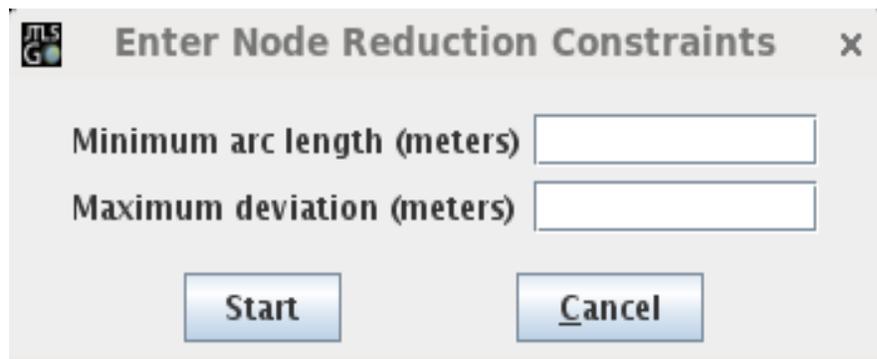

Figure 1. Enter Node Reduction Constraints Dialog for Road and River Networks
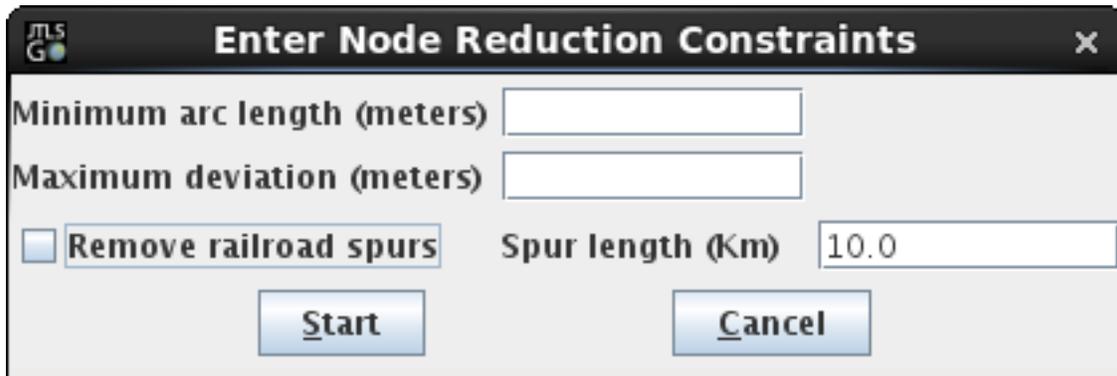
Figure 2. Enter Node Reduction Constraints Dialog for Rail Networks

For Road, River and Rail networks the new desired capability requires a new Maximum Arc Length field to be added to the dialog. As a result of adding the new field the dialog will be renamed the Merge/Divide Arc Constraints dialog. The trimming process will be expanded to take into account the constraint.

As stated previously, Sea Lane and Air Corridor arcs tend to be long, so combining arcs to reduce the number of nodes and arcs in these networks is not desirable. However, there is a need to address the inability of objects to access either the sea or air network because the arcs are too long. For these networks a new Divide Arc Constraint dialog will be created. The dialog will contain only one field called Maximum Arc Length.

3.0 Detailed Design

Adding the Maximum Arc Length constraint requires a change in the user interface and the trimming process. These changes are described in the following sections.

3.1 User Interface Changes

The user interface requires a modification of an existing dialog (Enter Node Reduction Constraints) to handle Road, River and Rail networks and the creation of a new dialog (Divide Arc Constraints) to handle Sea Lane and Air Corridor networks. These changes are described below.

3.1.1 Road. River and Rail Networks

A new field, Maximum Arc Length, will be added to the Enter Node Reduction Constraints dialog and the dialog will be renamed Merge/Divide Arc Constraints. Table 1 summarizes the fields in the Merge/Divide Arc Constraints dialog. The new field is shaded green.

Table 1. Merge/Divide Arc Constraints Dialog Fields

FIELD	UNIT OF MEASURE	ALLOWABLE VALUES
Minimum Arc Length	Meters	• <= 0 means do not apply constraint • > 0 means apply constraint using the entered value. Example: if 10000 is entered, the Minimum Arc Length constraint will be applied and the constraint value will be 10000 meters
Maximum Deviation	Meters	• <= 0 means do not apply constraint • > 0 means apply constraint using the entered value
Maximum Arc Length	Meters	• <= 0 means do not apply constraint • > 0 means apply constraint using the entered value • if Maximum Arc Length > 0 and Minimum Arc Length > 0, then Maximum Arc Length > Minimum Arc Length must be true. If this is not the case, an error message will be generated and the user will have to correct either the Maximum Arc Length or Maximum Arc Length in order to proceed.
Remove Railroad Spurs	N/A	• A selected check box means railroad spurs less than Spur Length will be removed. • An unselected check box means all railroad spurs will remain in place.
Spur Length	Kilometers	• 0.01 - 18000.0 • The range is taken from the range of the global data variable COLOCATED DISTANCE. • The value should be close to the actual COLOCATED DISTANCE entered in the scenario database.

Note: If the user enters Minimum Arc Length <= 0 and Maximum Deviation <= 0 and Maximum Arc Length <= 0, meaning "do not apply any constraint", the user will be prompted to either enter at least one positive constraint, or cancel the operation altogether.

3.1.2 Sea Lane and Air Corridor Networks

The new Divide Arc Constraints dialog will contain only one field, Maximum Arc Length. It is described in Table 2.

Table 2. Divide Arc Constraints Dialog

FIELD	UNIT OF MEASURE	ALLOWABLE VALUES
Maximum Arc Length	Meters	• > 0 • If Maximum Arc Length <= 0, the user will be prompted to either enter a positive value or cancel the operation altogether.

3.1.3 Node and Arc Naming Convention

If a Road, River or Rail arc is split into smaller arcs, the naming convention for the newly created nodes and arcs is as follows:

- A newly created node will be named NODE_<node_id>_<Network_Name>. The <node_id> is a unique node index number assigned by the GIS Tool.

- A newly created arc will be named ARC_<arc_id>_<Network_Name>. The <arc_id> is a unique arc index number assigned by the GIS Tool.

There is only one Sea Lane network and one Air Corridor network in a JTLS-GO scenario. If an arc from either network is split into smaller arcs, the naming convention for the newly created nodes and arcs is as follows:

- A newly created Sea Lane node will be named SEANODE_<node_id>. The <node_id> is a unique node index number assigned by the GIS Tool.

- A newly created Sea Lane arc will be named SEAARC_<arc_id>. The <arc_id> is a unique arc index number assigned by the GIS Tool.

- A newly created Air Corridor node will be named AIRNODE_<node_id>. The <node_id> is a unique node index number assigned by the GIS Tool.

- A newly created Air Corridor arc will be named AIRARC_<arc_id>. The <arc_id> is a unique arc index number assigned by the GIS Tool.

3.2 Trimming Process Changes

The Maximum Arc Length, Minimum Arc Length and Maximum Deviation constraints will be applied to Road, River and Rail arcs. Only the Maximum Arc Length constraint will be applied to

Sea Lane and Air Corridor arcs. The following sections describe how these constraints will be applied.

3.2.1 Road, River and Rail Networks

Given an arc, the process will basically apply the Maximum Arc Length constraint first before considering the Minimum Arc Length and Maximum Deviation constraints. The steps below outline how the constraints will be applied to each.arc.

Step 1. Get the arc's length based on its great circle distance from endpoint to endpoint. Go to Step 2.

Step 2. If the user specified that the Maximum Arc Length constraint should not be applied, skip to Step 3. Otherwise compare the arc's length against the Maximum Arc Length constraint. If the length is less than or equal to the constraint go to Step 3. Otherwise follow Steps 2A and 2B to divide the arc:

Step 2A. Determine the number of segments the arc will be divided into and the length of each segment.

```
Determine the number of segments the arc will be divided into
int nSegments        -----> number of segments
double lengthArc     -----> length of the arc
double maxArcLength -----> Maximum Arc Length constraint

nSegments = (int)(lengthArc / maxArcLength) + 1

Determine the length of each segment
double lengthSegment

lengthSegment = lengthArc/nSegments
```

Step 2B. Replace the original arc with `nSegments` new arcs. Each new arc will be `lengthSegment` long and oriented in the same direction as the original arc. This will require `nSegments - 1` new nodes to connect the arcs. Go to the next arc and repeat Step 1.

Step 3. If the user specified that the Minimum Arc Length constraint should not be applied, skip to Step 4. Otherwise go to Step 3A.

Step 3A. Compare the arc's length against the Minimum Arc Length constraint. If the length is greater than the constraint go to the next arc and repeat Step 1. Otherwise go to Step 3B.

Step 3B. If the user specified that the Maximum Arc Length constraint should not be applied go to Step 3C. Otherwise check whether removing either node attached to the arc will cause the lengthened arc to exceed the Maximum Arc Length. If it does not go to Step 3C. Otherwise go to the next arc and repeat Step 1.

Step 3C. If the user specified that the Maximum Deviation constraint should not be applied go to Step 3D. Otherwise check whether removing the node from Step 3B will cause a deviation from the original polyline that exceeds the Maximum Deviation. If it does not go to Step 3D. Otherwise go to the next arc and repeat Step 1.

Step 3D. Remove the node and merge the adjoining arcs. Go to the next arc and repeat Step 1.

Step 4. This step is only executed from Step 3 if that step finds that the Minimum Arc Length constraint is not being applied. Go to Step 4A.

Step 4A. If the user specified that the Maximum Arc Length constraint should not be applied go to Step 4B. Otherwise check whether removing either node attached to the arc will cause the lengthened arc to exceed the Maximum Arc Length. If it does not go to Step 4B. Otherwise go to the next arc and repeat Step 1.

Step 4B. If the user specified that the Maximum Deviation constraint should not be applied go to Step 4C. Otherwise check whether removing the node from Step 4A will cause a deviation from the original polyline that exceeds the Maximum Deviation. If it does not go to Step 4C. Otherwise go to the next arc and repeat Step 1.

Step 4C. Remove the node and merge the adjoining arcs. Go to the next arc and repeat Step 1.

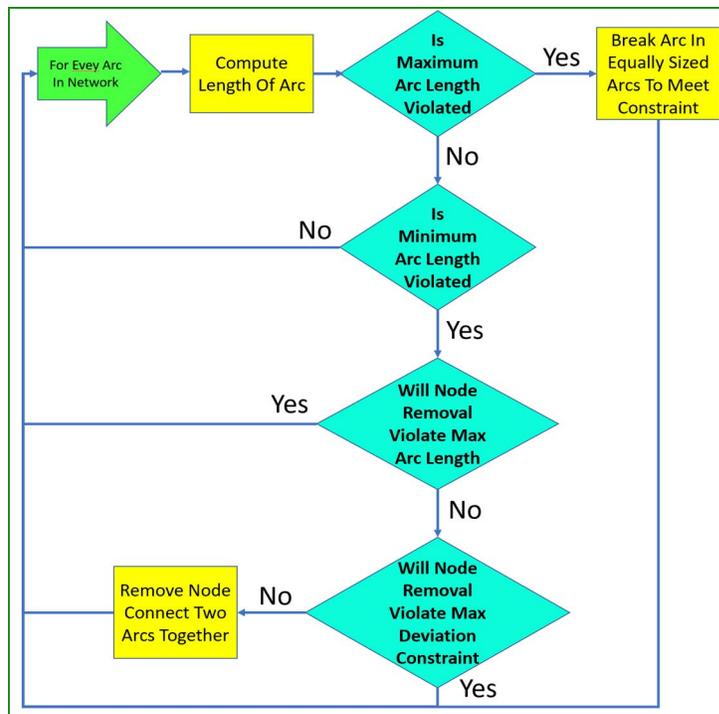Figure 3 summarizes this logic in a simplified flowchart.

Figure 3. Simplified Logic Flowchart

Note: The following nodes are never considered for removal:

- The first and last nodes of a polyline.

- A road or rail node serving as an end point to a bridge or tunnel arc.

- A river node linked to a river arc that crosses a road or rail arc.

3.2.2 Sea Lane and Air Corridor Networks

Given an arc, the process will apply the Maximum Arc Length constraint using the steps outlined below.

Step 1. Get the arc's length based on its great circle distance from endpoint to endpoint. Go to Step 2.

Step 2. Compare the arc's length against the Maximum Arc Length constraint. If the length is less than or equal to the constraint go to the next arc and repeat Step 1. Otherwise follow Steps 2A and 2B to divide the arc:

Step 2A. Determine the number of segments the arc will be divided into and the length of each segment.

```
Determine the number of segments the arc will be divided into
int nSegments          -----> number of segments
double lengthArc       -----> length of the arc
double maxArcLength -----> Maximum Arc Length constraint

nSegments = (int)(lengthArc / maxArcLength) + 1

Determine the length of each segment
double lengthSegment

lengthSegment = lengthArc/nSegments
```

Step 2B. Replace the original arc with `nSegments` new arcs. Each new arc will be `lengthSegment` long and oriented in the same direction as the original arc. This will require `nSegments – 1` new nodes to connect the arcs. Go to the next arc and repeat Step 1.

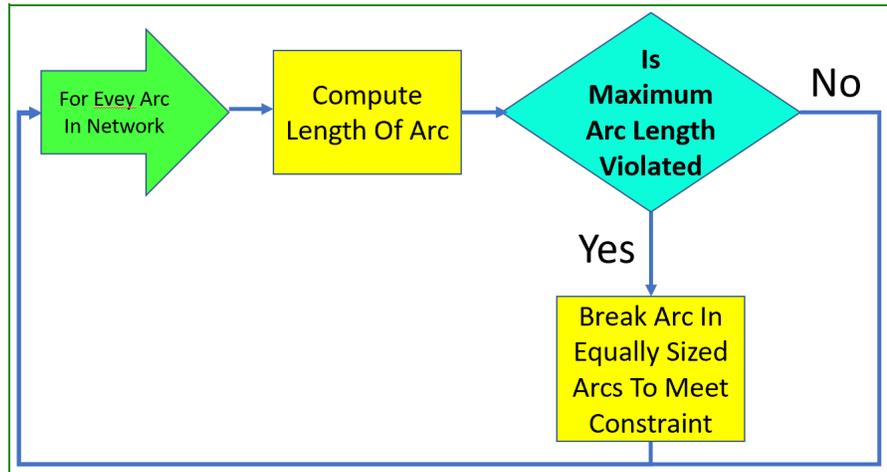Figure 4 summarizes the Sealane and Air Corridor logic in the form of a flowchart.

Figure 4. Simplified Air Corridor and Sealane Logic Flowchart

3.2.3 National Boundaries

This new algorithm will not be applied to national boundaries. The accuracy of national boundaries is important and adding this algorithm has no modeling advantage.

4.0 Data Changes

No database parameter or structure changes are required to implement this design.

5.0 Order Changes

No order parameter or structure changes are required to implement this design.

6.0 JODA Changes

No JODA Data System parameter, structure, or protocol changes are required to implement this design.

7.0 Test Plan

To conduct these tests, the tester will need a fairly significant network database. Bring up the GIS tool and select an fairly large area, such as India, China, Western Europe, or the United States

7.1 Test Maximum Arc Length On Polyline

Purpose: The purpose of this test is to ensure the new Maximum Arc Length algorithm works on polylines.

Step 1: Bring up the River network and select an area a few hundred miles wide.

Step 2: Run the trim algorithm indicating that the minimum arc length should be 20000 meters. Do NOT enter a Maximum arc length.

Step 3: Continue to execute the algorithm until the GIS tool says it can not deleted anymore nodes and arcs.

Expected Results: The GIS tool should removed arcs and nodes as indicated.

Step 4: Run the algorithm again, but this time specify a maximum arc length of 10000 Meters

Expected Results: The tool should indicate the error because the Maximum Arc Length specified is less than the Minimum

Step 5: Clear out the minimum arc length. In other words, set the value to zero.

Step 6: Run the algorithm again.

Expected Results: The tool should add arcs and nodes as specified.

7.2 Test Maximum Arc Length On Network

Purpose: The purpose of this test is to ensure the new Maximum Arc Length algorithm works on networks

Step 1: Repeat Test 7.1

Expected Results: The same results from Test 7.1 apply to this test.

7.3 Test Maximum Arc Length On Sealane Network

Purpose: The purpose of this test is to ensure that the new Maximum Arc Length algorithm works on networks.

Step 1: Query the DDS for the value of COLOCATED DISTANCE parameter in the scenario being used.

Step 2: Using the GIS Tool, display the Sealane Network.

Step 3: Go to the world view

Step 4: Run the Sealane Network Divide Arc Length algorithm with a maximum arc length equal to the COLOCATED DISTANCE parameter.

Expected Results: The sealanes should become more populated with nodes and arcs.

Step 5: Save the Sealane network

Step 6: Move them into the selected scenario

Step 7: Run the SVP and select the check terrain option.

Expected Results: The SVP should not report any no Sealane arcs greater than COLOCATED DISTANCE.