ABB

Published Technical Disclosure

Method of using shared 3D models between multiple robots

Authors: Remus Boca, Nick Hunt and Srinivas Nidamarthi

Published: September 21, 2015 at:
http://new.abb.com/us/about/intellectual-property/intellectual-property-publications

Keywords: multiple robots, 3D models, sharing or shared, multi robot cell, manufacturing, training, flowchart, global frame

Background:

This innovation relates to a method of scanning and sharing one or more 3D models between multiple robots. In order to reduce the manufacturing costs and increase efficiency, multiple robot arms in different configurations can be used to replace hard fixtures.

Statement of the Problem:

When multiple robot arms work together, there are complex manual operations involved in setting up the system. If vision systems are used in such configurations they are usually difficult to train and use. In some operations for example two needed to pick up a part or one robot has to work on a part held by another robot it may not be possible to synchronize the robots. When the robots are far away from each other a theodolite is needed to synchronize the robots and this involves using a complex manual procedure. When two or more robots have to work together on the same area a manual procedure has to be used to reference them to each other. Where there are variation in parts it is expensive to build fixtures that accommodate the varying parts.

Benefits:

This use of 3D models of the part allows each of the robots to see the sections of the part and the correlations between sections, part and robots can be calculated. This allows the robots to move synchronously. The sharing of the 3D models allows for efficient setup and runtime of the multiple robots.

Detailed Description:

This description is with reference to Figures 1 to 7 on pages 4 to 10 of this Technical Disclosure.

Figure 1 shows an example of a multi robot cell where seven robots are used to complete a manufacturing task. Two robots handle the frame (rail part) with one robot at each end of the rail part. One robot has a 3D scanner mounted on it that is used to scan the frame and generate the 3D models of the frame. Four robots work in pairs of two, each pair has a plate part robot shown in green in Figure 1. The working robot pairs are used to position the plate part on the rail and a tool robot, the middle robot of the three robots identified in Fig. 1 as working robots, is used to weld the plate to the rail. This is one example, but any multi robot configurations can be used to perform the same functions as one or more scanning robots, one or more holding robots and one or more working robots.

While Figure 1 shows one robot performing a particular function, one robot can perform multiple functions such as for example scanning, holding a part.

If the working robots within the pair or system are not referenced one to the other, then a vision system is required per each pair of working robots that follows the method described herein and this is sufficient to get the working robots collaborating with the rail holding robots.

More complex situation can be solved with sharing the 3D models between multiple robots and the work cell. For example, if there is a requirement to move the rail so that the working robot can access the location of the plate on the rail, then all robots involved can be synchronized so that the desired motion for rail and plate pair can be performed. Each working robot pair needs a vision system so that that pair can be provided with both the position of the rail in the working robots and the plate position in the tool and then the synchronization & reference with other robots in the system can be calculated.

3D models generated in one station can be transferred and used in a different station down the production line. After the plate parts are added to the rail, then the model can be scanned locally, the 3D models are updated with the new information and the 3D models can be transferred to other stations on the production line that will further perform operations on the rail.

The flowchart in Figure 2 shows the procedure for training the vision system. The main steps are: a) scanning & generating the 3D models of the rail and b) train the 3D features (areas of interest), 3D features that are used by robots later in the process to position or reference themselves with other robots or known components in the system so that a. calibration of the holding robots can be calculated, b. working robots can collaborate and c. position plates parts / tools accurately on the rail.

The flowchart shown in Figure 2 can be used to generate 3D models of a rail. There can be variations to the above procedure, depending on which components are moved, for example it can be the rail or the robot. If the 3D image acquisition is continuous then there is no need for synchronization, otherwise the motion of the rail or robot has to be synchronized with the acquisition. In the case of a robot movement, robot mounted 3D sensor and when the 3D sensor is calibrated to the robot, the 3D models do not have to be continuous, the can cover only areas of interest because the partials 3D models can be referenced together using the known robot position and 3D sensor to robot calibration.

The flowchart of Figure 3 shows a procedure that can be used to generate 3D models of a rail. There can be variations to the above procedure, depending which component is moved, it can be the rail or the robot. If the 3D image acquisition is continuous then there is no need for synchronization between the image and the part being moved. If the 3D image acquisition is not continuous then the motion of the rail or robot has to be synchronized with the image acquisition.

In the case of the movement of a robot that has mounted on it a 3D sensor then when the 3D sensor is calibrated to the robot, the 3D models do not have to be continuous. The models can cover only areas of interest because the partials 3D models can be referenced together using the known robot position and 3D sensor to robot calibration.

The flowchart of Figure 4 shows a procedure for transferring the 3D models between multiple stations.

The flowchart in Figure 5 shows an example of calibrating or calculating the reference of two robots using a 3D vision system and a 3D model of the rail that is generated at the "Find feature(s) in 3D data step in the flowchart. The robots can execute the tasks for the "Take Image", "Find features" and "Reference found" steps in parallel and then synchronize the two robots when all of the robots finish referencing them one to another. If the global rail reference system is used, then the robots do not have to be synchronized as each other is synchronized to the global rail coordinate system.

Figure 6 shows an example of a multi-robot cell with the frames displayed for the holding robots 1 and 2, working robot pairs 1 and 2 and the global frame for the rail.

The flowchart Figure 7 shows an example of using the known 3D models of the rail to reference the working robots by using a vision system as described above. One or more vision systems are required so that the following functions are available for the working pair:

a. the reference of each working robot to the rail. In the case above, robot holding the plate, the rail and the weld tool robot need to be referenced to a global frame;
b. if the plate is grasped firm in the robot but the plate is not accurately positioned in the robot hand, then the accurate position of the plate in robot hand needs to be determined; and
c. if the solution requires, each working robot can be referenced to each other.

While the working robots are referenced to one another, they can be referenced to any other robot in the system providing that the other robots have means to reference themselves to a global frame.

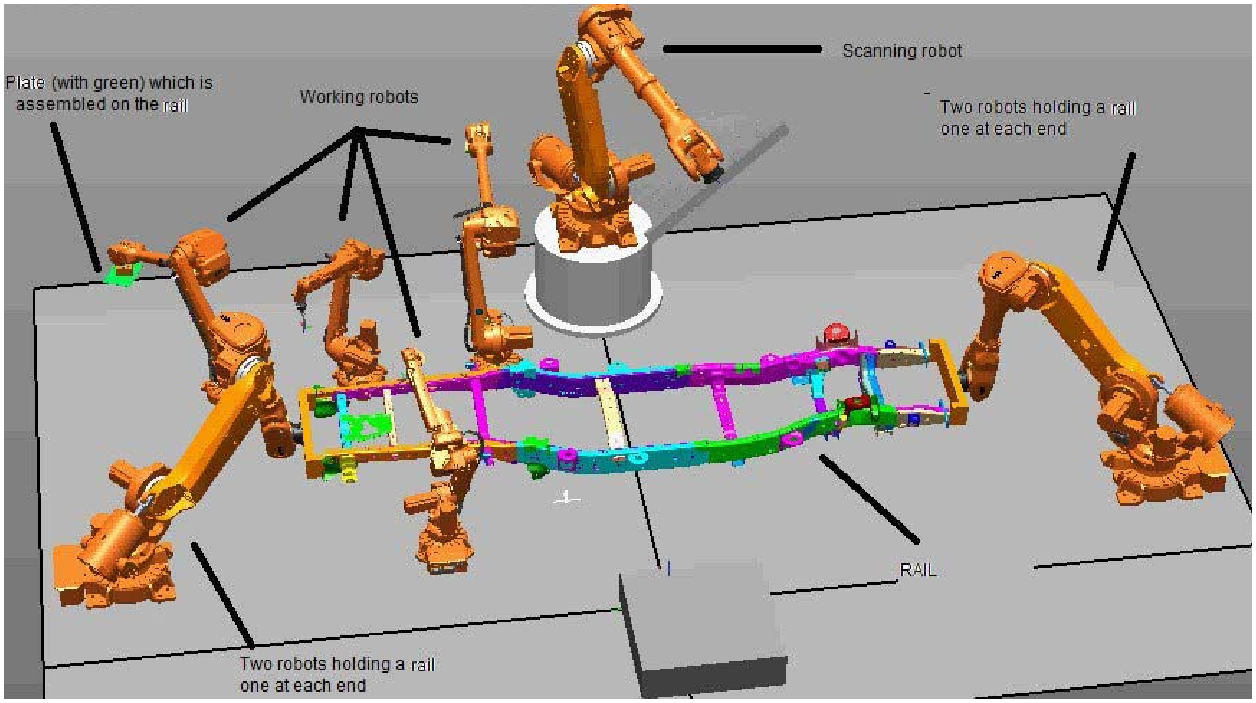
Scanning robot
Plate (with green) which is assembled on the rail
Working robots
Two robots holding a rail one at each end
RAIL
Two robots holding a rail one at each end

Figure 1

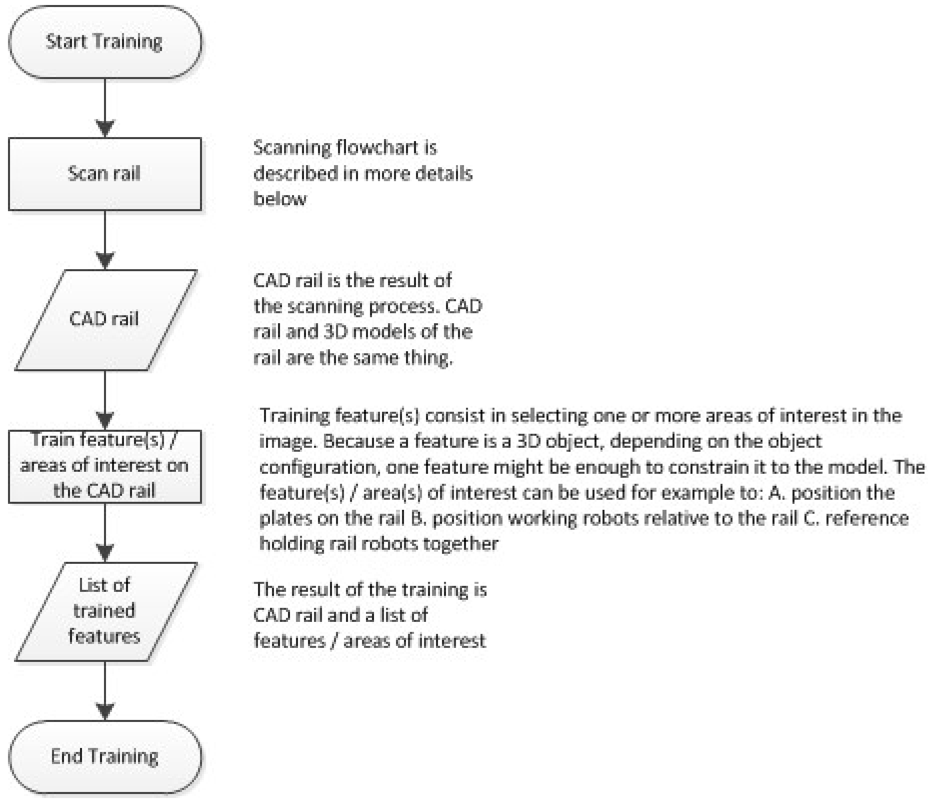
Start Training
Scan rail
Scanning flowchart is described in more details below
CAD rail
CAD rail is the result of the scanning process. CAD rail and 3D models of the rail are the same thing.
Train feature(s) / areas of interest on the CAD rail
Training feature(s) consist in selecting one or more areas of interest in the image. Because a feature is a 3D object, depending on the object configuration, one feature might be enough to constrain it to the model. The feature(s) / area(s) of interest can be used for example to: A. position the plates on the rail B. position working robots relative to the rail C. reference holding rail robots together
List of trained features
The result of the training is CAD rail and a list of features / areas of interest
End Training

Figure 2

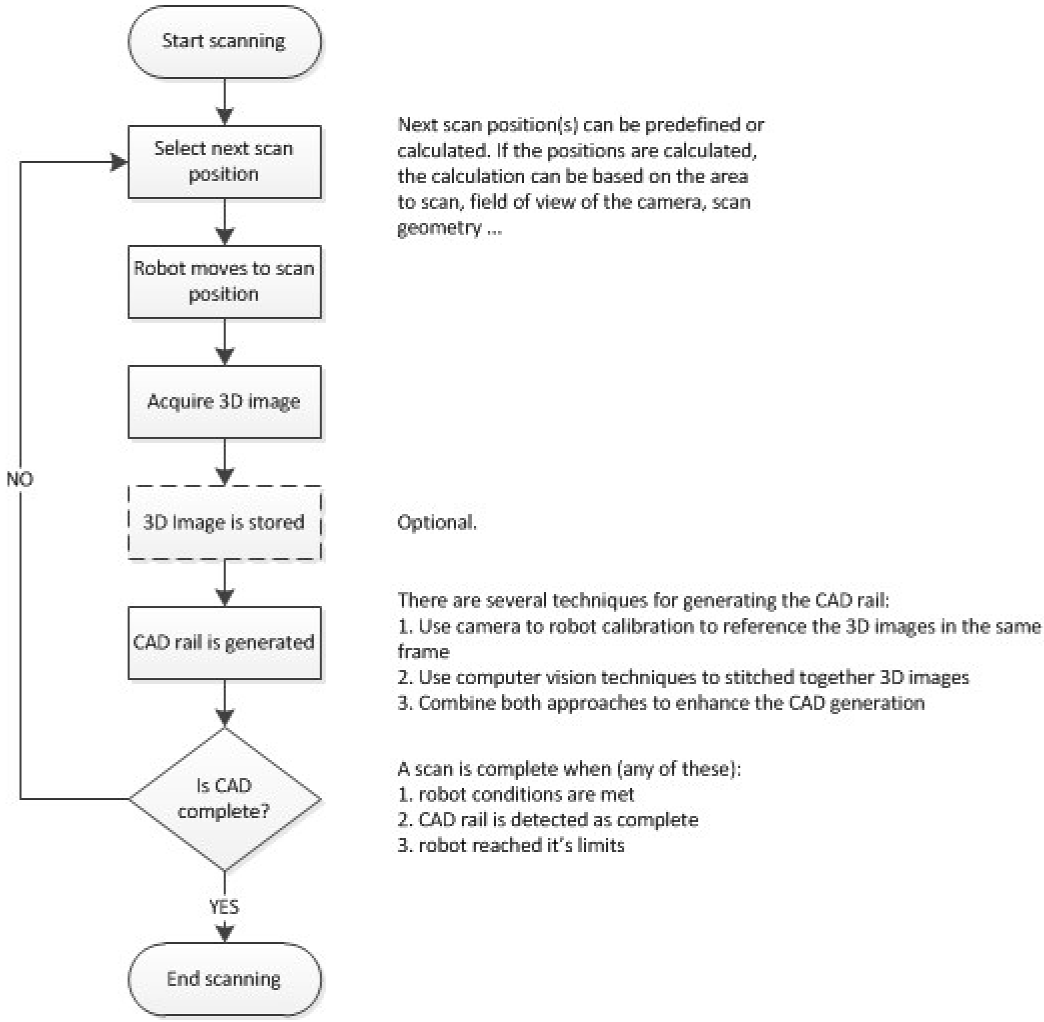
Start scanning
Select next scan position
Robot moves to scan position
Acquire 3D image
3D Image is stored
CAD rail is generated
Is CAD complete?
NO
YES
End scanning
Next scan position(s) can be predefined or calculated. If the positions are calculated, the calculation can be based on the area to scan, field of view of the camera, scan geometry ...
Optional.
There are several techniques for generating the CAD rail:
1. Use camera to robot calibration to reference the 3D images in the same frame
2. Use computer vision techniques to stitched together 3D images
3. Combine both approaches to enhance the CAD generation
A scan is complete when (any of these):
1. robot conditions are met
2. CAD rail is detected as complete
3. robot reached it's limits

Figure 3

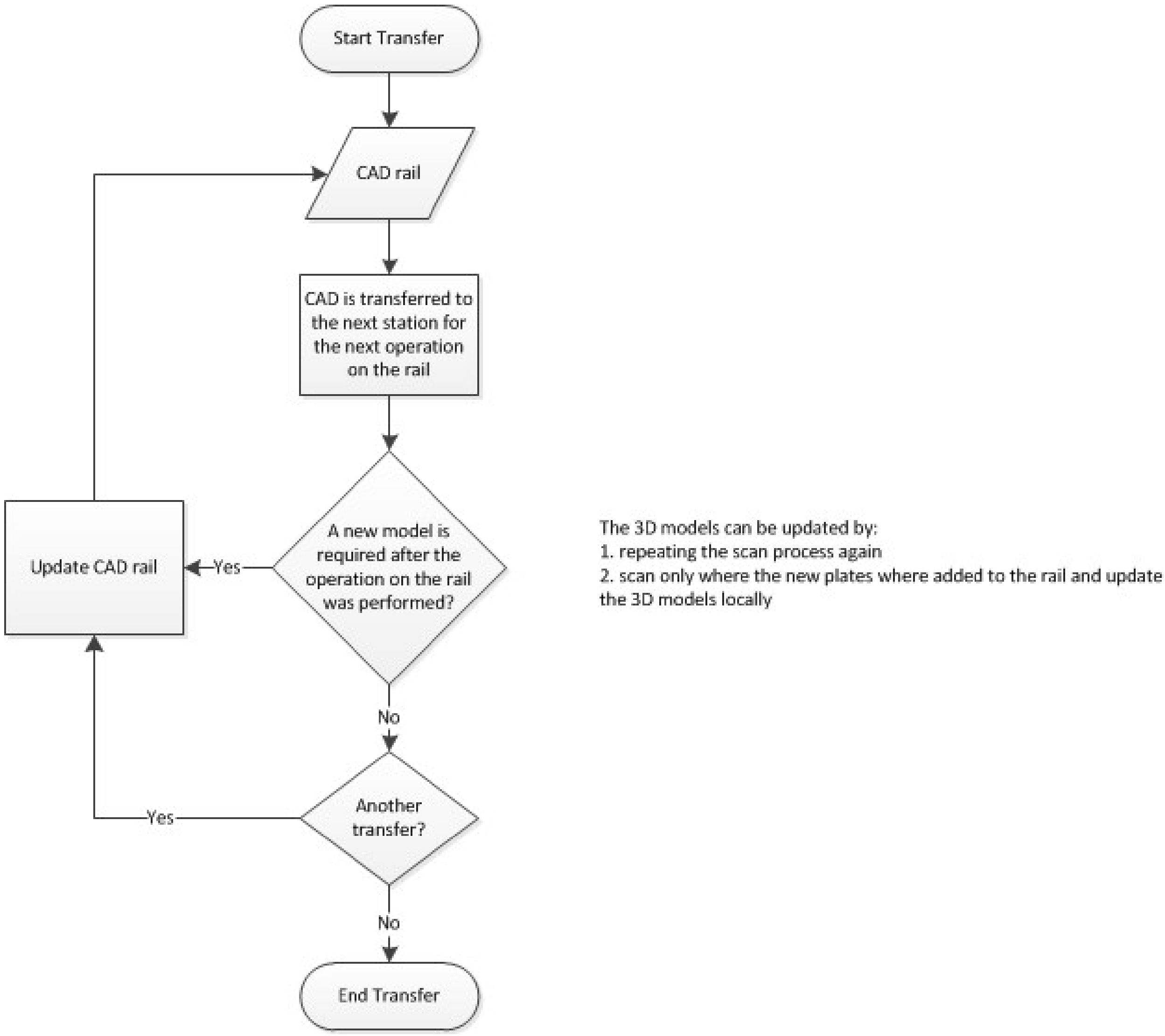
Start Transfer
CAD rail
CAD is transferred to the next station for the next operation on the rail
A new model is required after the operation on the rail was performed?
Yes
Update CAD rail
No
Another transfer?
Yes
No
End Transfer
The 3D models can be updated by:
1. repeating the scan process again
2. scan only where the new plates where added to the rail and update the 3D models locally

Figure 4

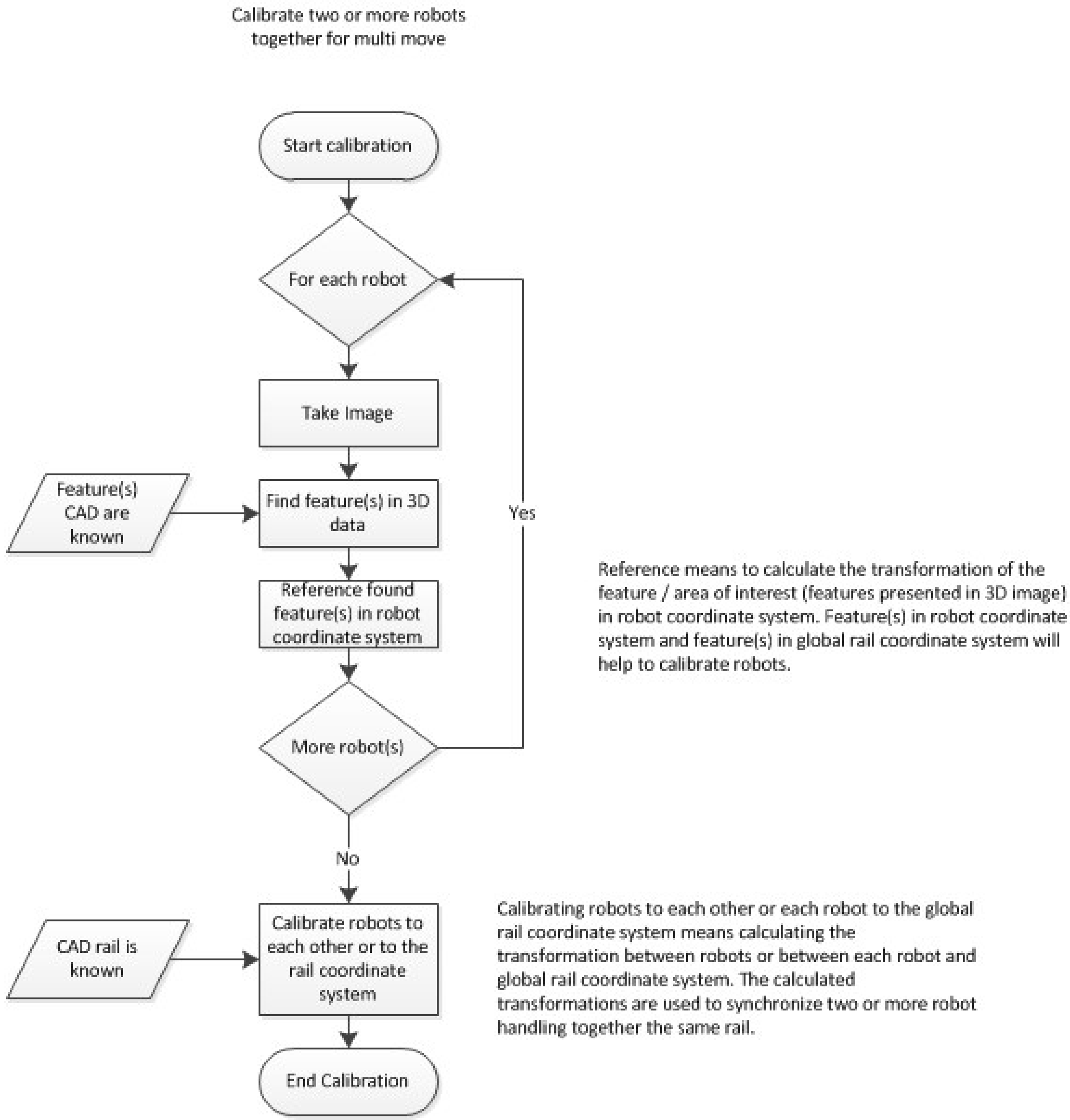
Calibrate two or more robots together for multi move
Start calibration
For each robot
Take Image
Feature(s) CAD are known
Find feature(s) in 3D data
Yes
Reference found feature(s) in robot coordinate system
Reference means to calculate the transformation of the feature / area of interest (features presented in 3D image) in robot coordinate system. Feature(s) in robot coordinate system and feature(s) in global rail coordinate system will help to calibrate robots.
More robot(s)
No
CAD rail is known
Calibrate robots to each other or to the rail coordinate system
Calibrating robots to each other or each robot to the global rail coordinate system means calculating the transformation between robots or between each robot and global rail coordinate system. The calculated transformations are used to synchronize two or more robot handling together the same rail.
End Calibration

Figure 5

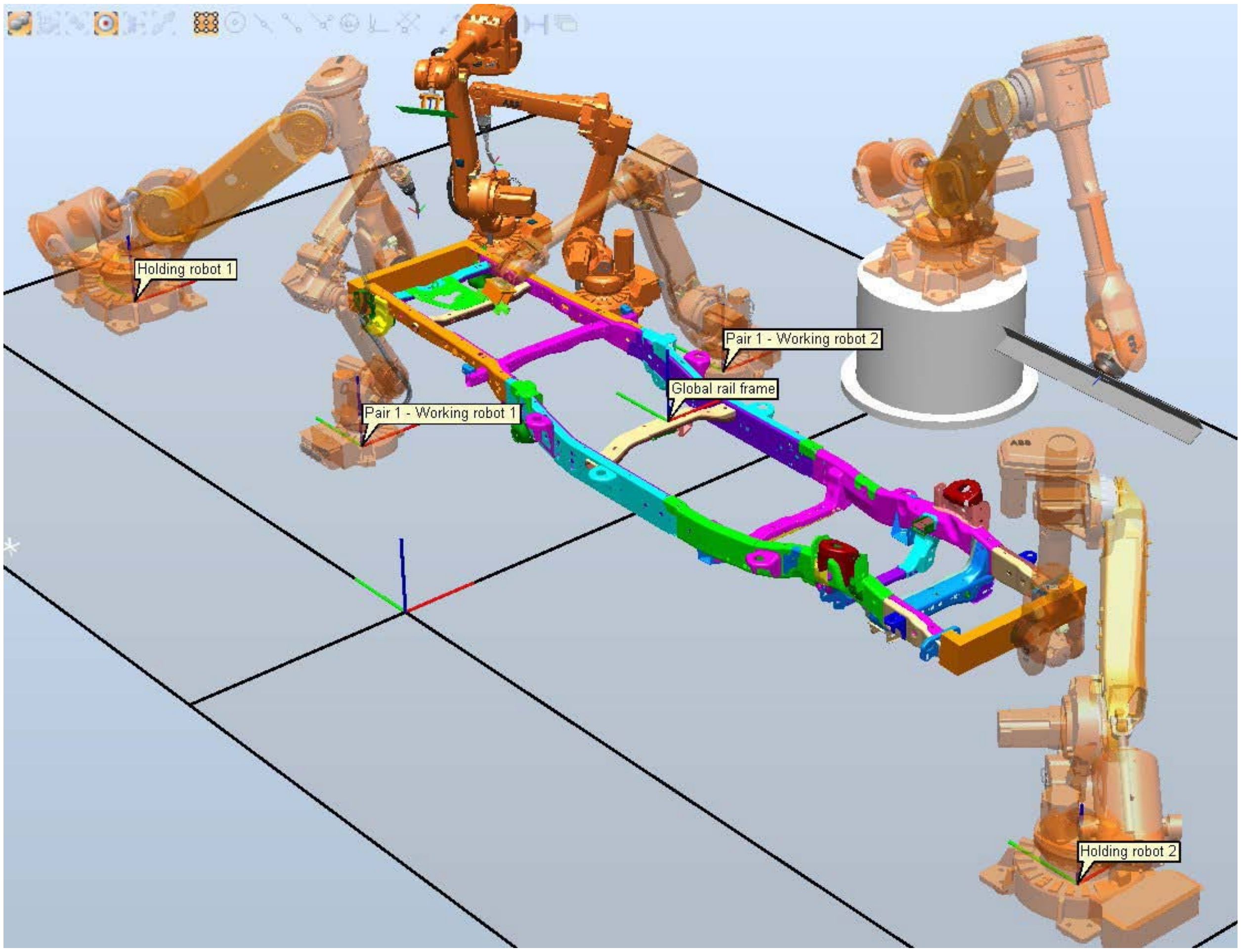
Holding robot 1
Pair 1 - Working robot 2
Global rail frame
Pair 1 - Working robot 1
Holding robot 2

Figure 6

Published Technical Disclosure

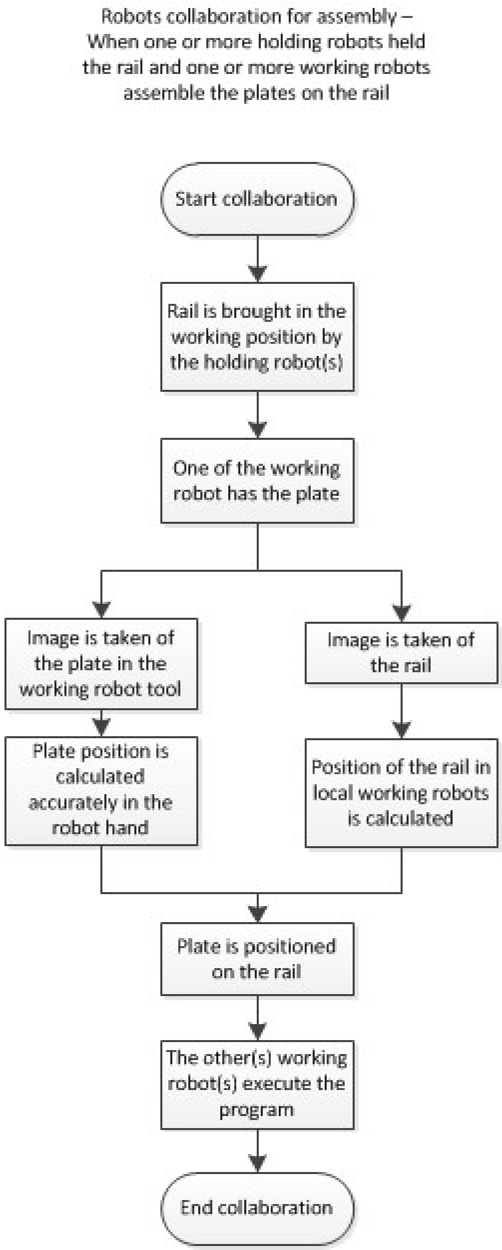

Figure 7