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ACTUAL R&D TOPICS IN ROBOTICS

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1. Bricklaying Robot – Functional Architecture

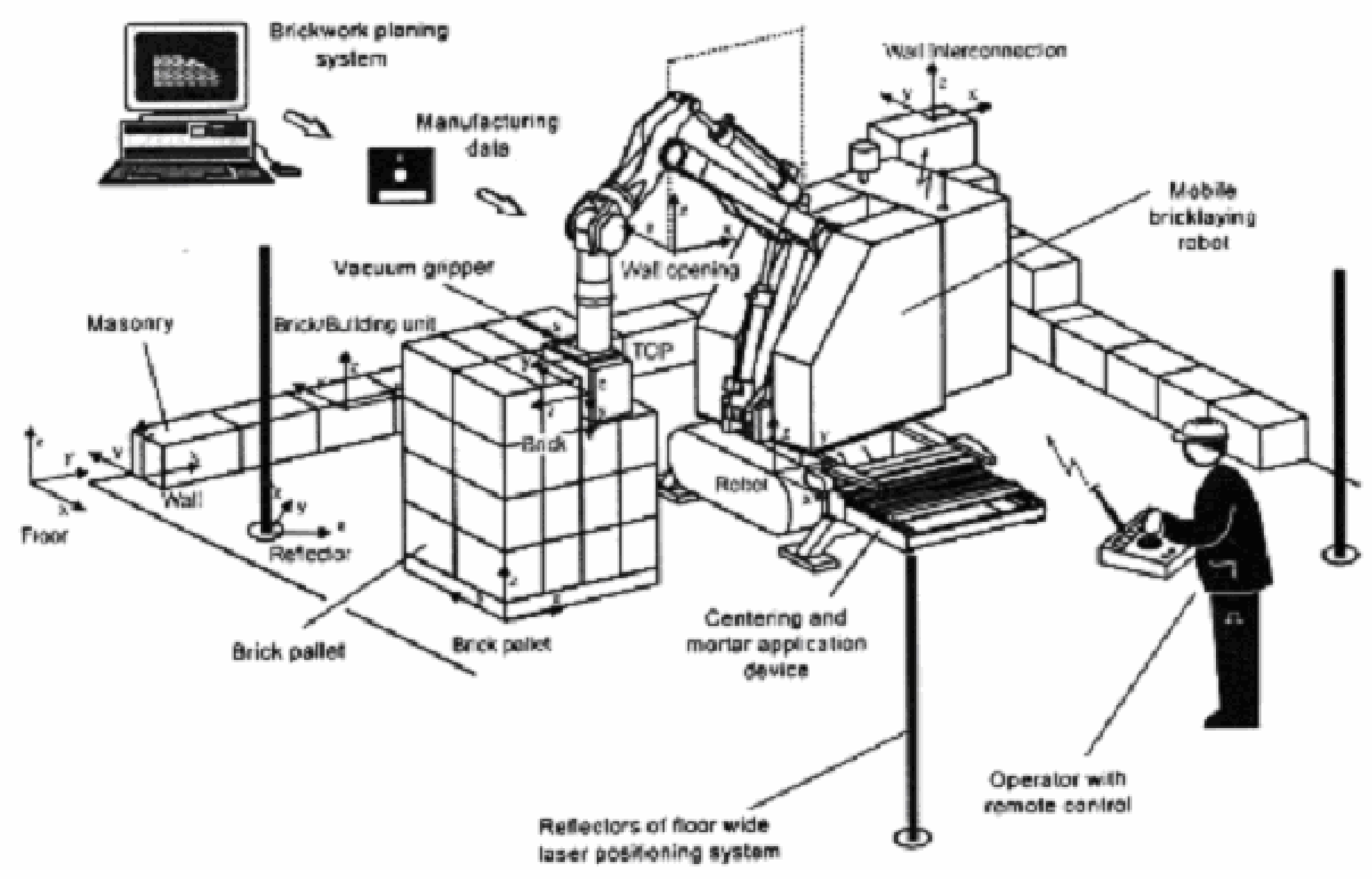


Fig. 1 – The 7-d.o.f. mobile construction robot and its working environment.

Functional architecture:

•The mechanical device consists of a 5-d.o.f. cylindrical, partially closed-chain kinematic structure (having parallel linkages), carried by a mobile wheeled platform.

•The resulting 7-d.o.f. mobile construction robot is able to move on *quasi-horizontal prepared surfaces* (floors), and generate a *workspace of 3.5 m height*.

•The mobile robot is a *free-ranging* (non-guided) *wheeled vehicle*, capable to avoid obstacles (e.g. brick pallets) in a structured environment; its arm performs coordinated movements either in the *Cartesian space* or in the *5-dimension joint space* automatically at program execution or under manual control.

•A *computer-based operator console* (wireless laptop) is used both as:

- *teach pendant* for robot point learning and
- *robot terminal* for execution of monitor commands, program editing, debugging, and execution start-up and monitoring.

•The robot vehicle's design is that of a chassis with *omni directional wheels* attached to it via wheel suspensions. Two wheels (in diagonal locations) are driven by asynchronous motors and generate respectively forward-backward displacements (for identical control) and CW-CCW rotations (for opposite control); the remaining two are loose wheels – the angular displacement of one loose wheel being measured by an encoder.

•A *high-level control* links the world space (in which relative motions of the robot vehicle are specified) with the internal variable (wheel) space.

•High-precision locating of the wheeled platform is done by a *range finder system* with respect to a fixed world frame.

•The 5-d.o.f. cylindrical arm is carried by the mobile vehicle; the movements of the arm and platform may occur *simultaneously*.

2. Geometry Models of the 7-d.o.f. Construction Robot

2.1 Direct Kinematics of the 5-d.o.f. Cylindrical Arm

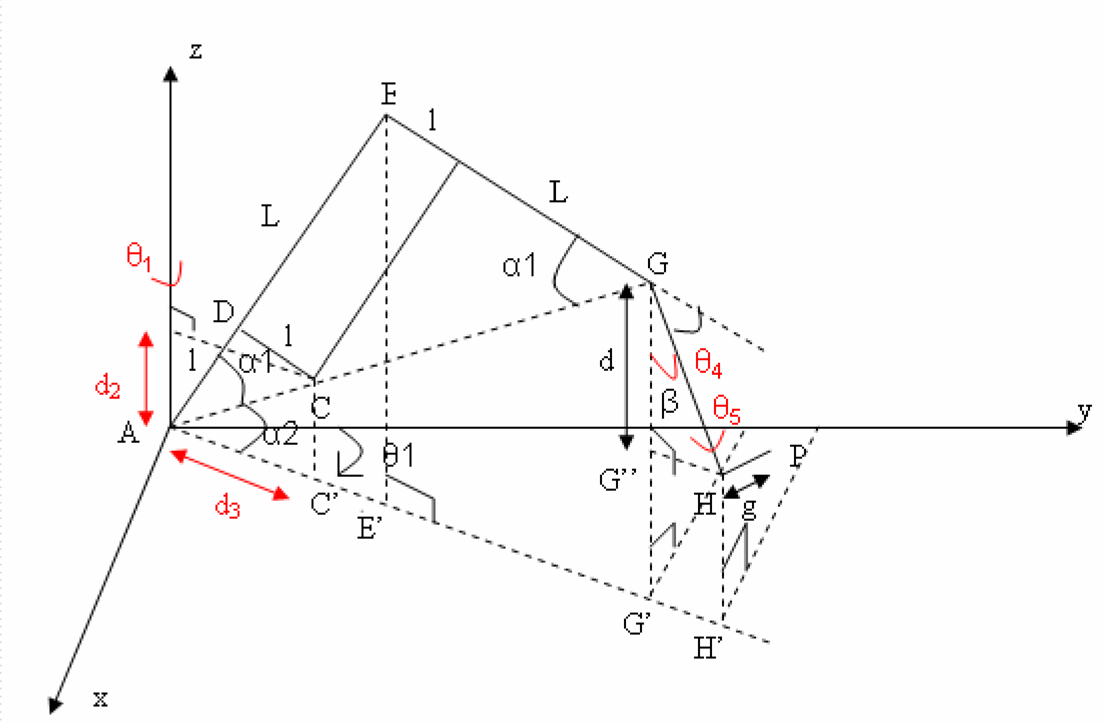


Fig. 2 – The close-chain kinematic structure 5-d.o.f. cylindrical robot manipulator.

3. Generating Production Data for the Bricklaying Robot

The process of generating production data for the bricklaying robot involves three stages:

1. **Extraction of geometry data from the architecture project and construction specifications** (either from AUTOCAD files or manually input). 3D locations and dimensions of the walls, h-stockades (bulwark), wall openings, a.o, represent the input data. The output data computed in this stage refers to:

   (i) the *dimensions* and coordinates of each *elementary masonry zone* relative to a unique world frame, and
   (ii) the *specification of materials* necessary for the construction of these elementary zones.

2. **Partition of the global masonry in wall segments** (relatively to a single floor of the building); this consists in joining several *elementary masonry zones* , , which may be completely included within the dexterous space of the cylindrical robot arm, with respect to a robotic bricklaying task associated to a *wall segment k*.

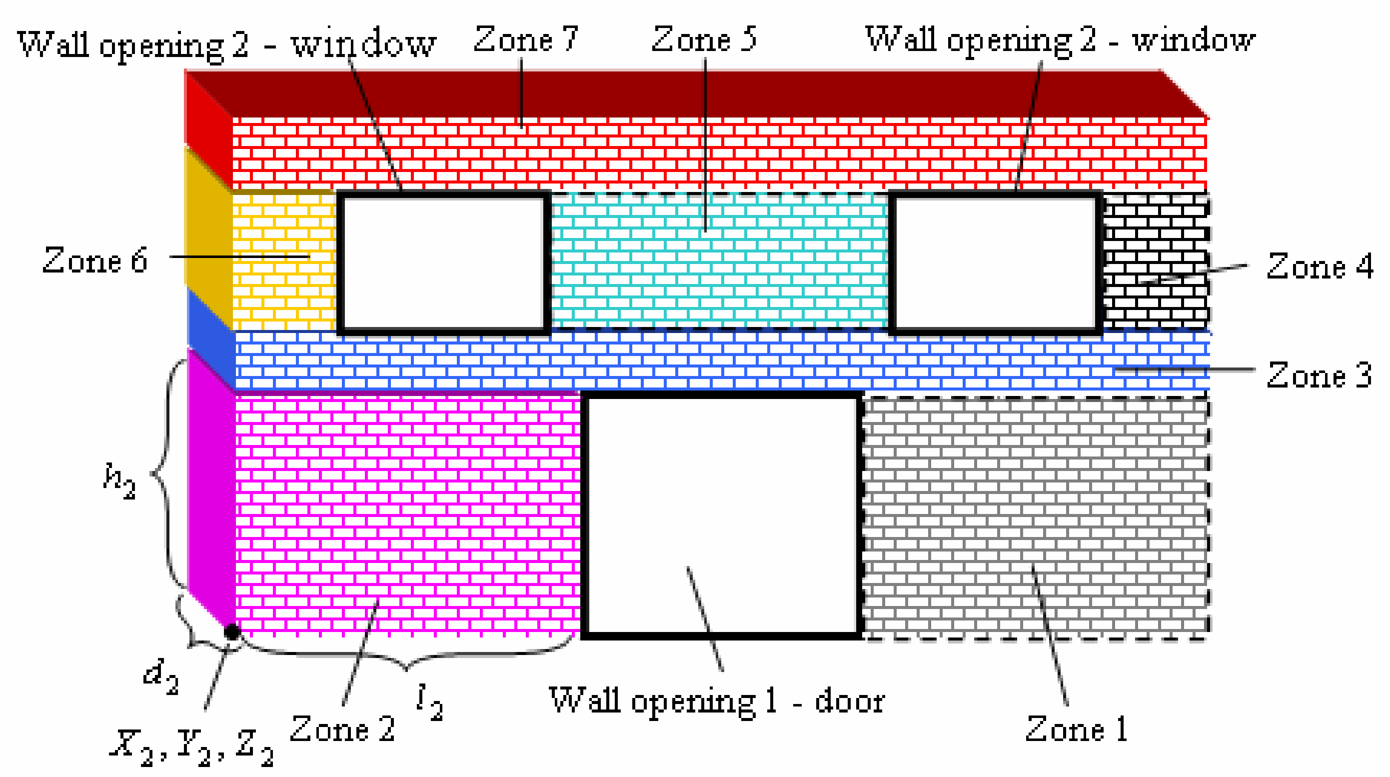


Fig. 3 – Stage 1: extraction of geometry data and locating data for *elementary wall zones* (from architecture plans and construction specs.)

3. Determining the *material requirements* – number and types of bricks, the specification of *brick pallets* – location, size, form, organization, and the *data for application programs* – robot points, parameters of „pick-and-place” routines, execution order for wall segments, *planning of intermediate mobile robot locations* for navigating to successive wall segment locations or exiting the working area.

The **typical robot program sequence** allowing execution of the task associated to a current wall segment eventually provides access to more than one brick pallets. This sequence is:

I. *Manual/automatic guidance of the robot vehicle* to a world location from which access is granted both to the 3D brick pallet and to the ensemble of wall segments included in one elementary masonry zone.

II. *Auto locating of the mobile robot platform* using the laser scanner and range finder device mounted on the robot platform; the sensor scans over 360 degrees in a planar movement and, from the distances measured to three fixed reflectors (of known locations) determines its own location X,Y in the world frame.

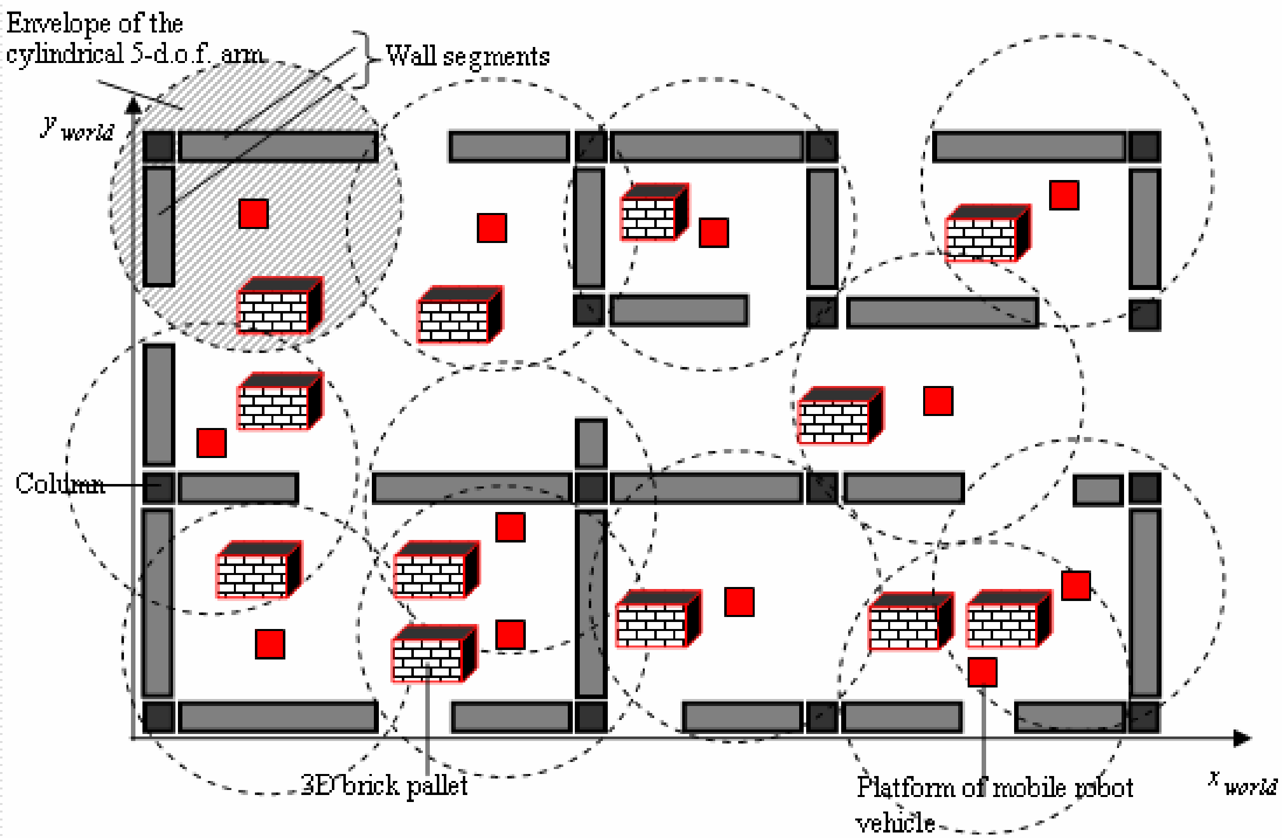


Fig. 4 – Partitioning a global masonry task in 12 bricklaying subtasks each one associated to a wall segment

III. *Computing the relative transformations* to access respectively the base of the brick pallet and the base of the current wall segment:

$$robot\_zid = (robot\_loc)^{-1} : zid\_init$$

$$robot\_stiva = (robot\_loc)^{-1} : stiva\_sz$$

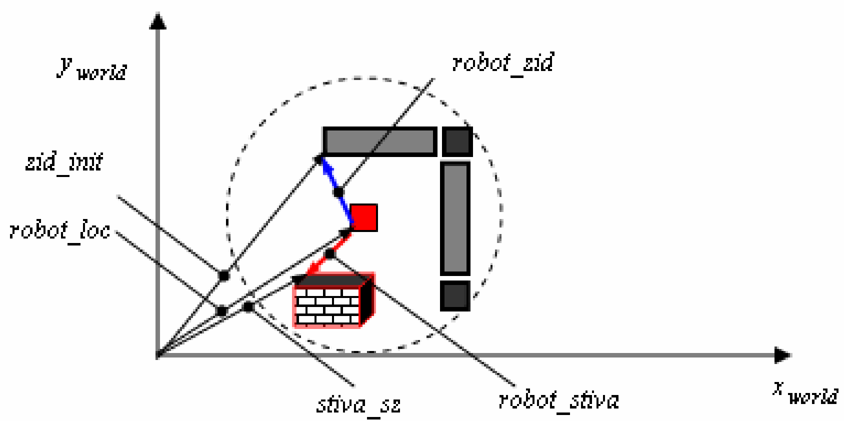


Fig. 5 – Computing the *relative transformations* to access respectively the base of the brick pallet and of the wall segment

IV. *Start program execution* for the current bricklaying robotic task. This program **loops a “pick-and-place” routine** retrieving each time a brick from the 3D pallet, applying mortar on it and then placing it in the current location of the wall segment under construction.

4. Kinematics Simulation

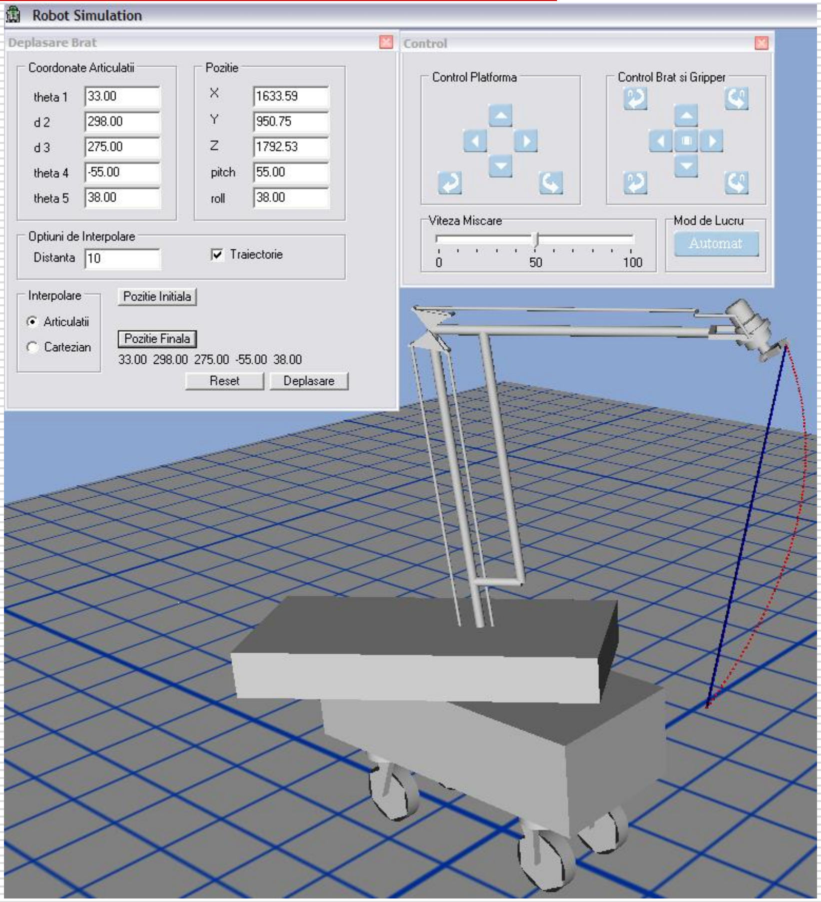
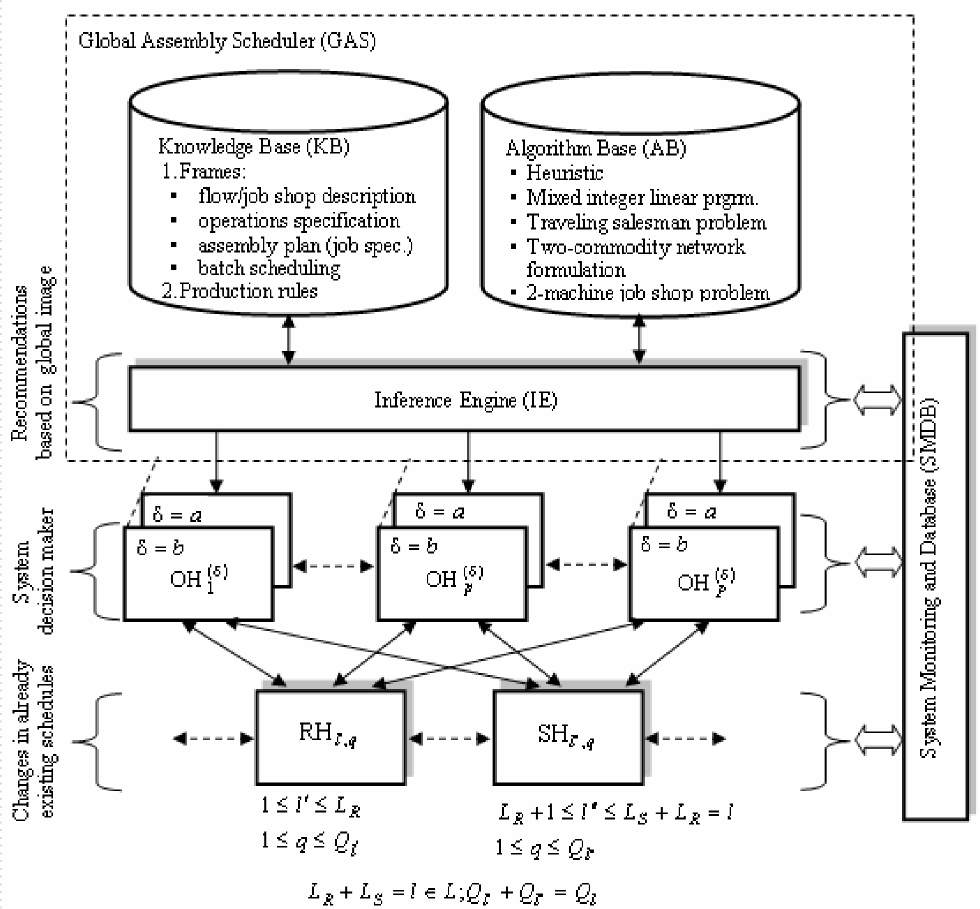
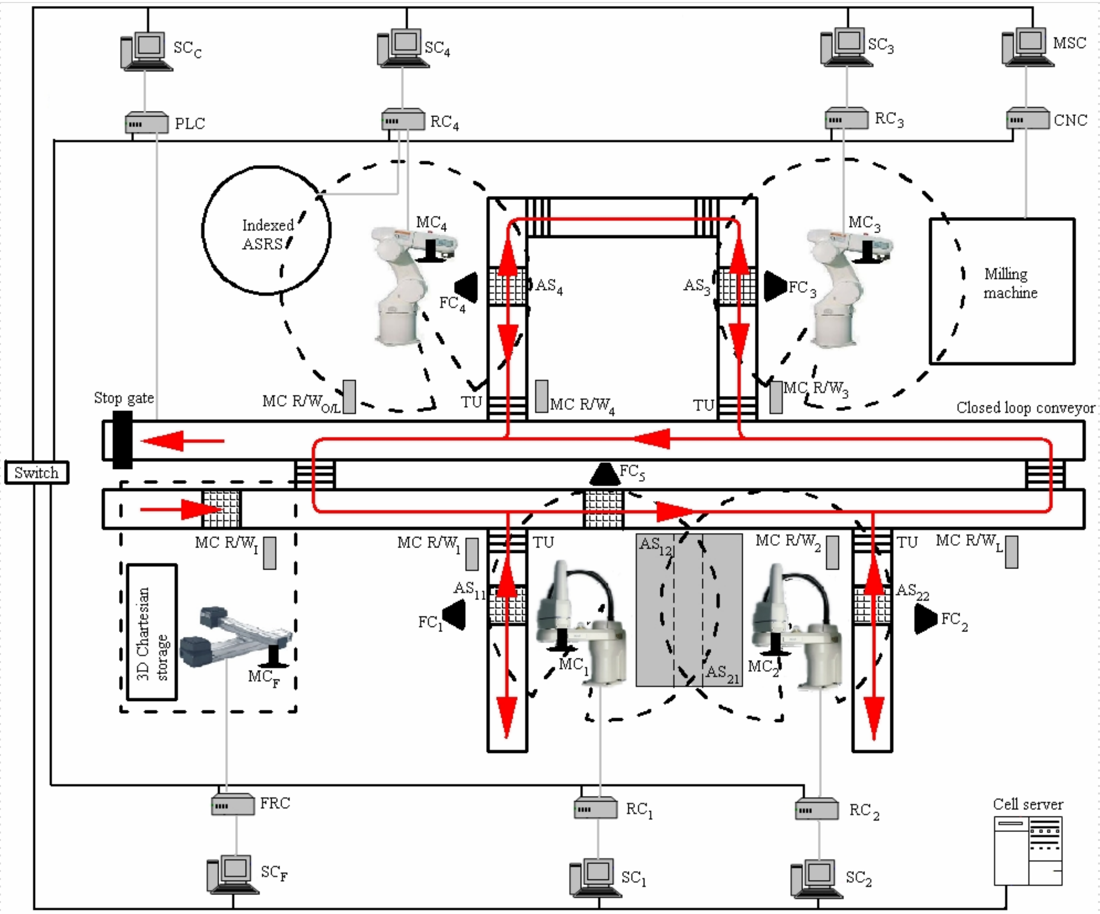


Fig.6 – Simulation results for RMRC and electronic gear path control of the robot arm

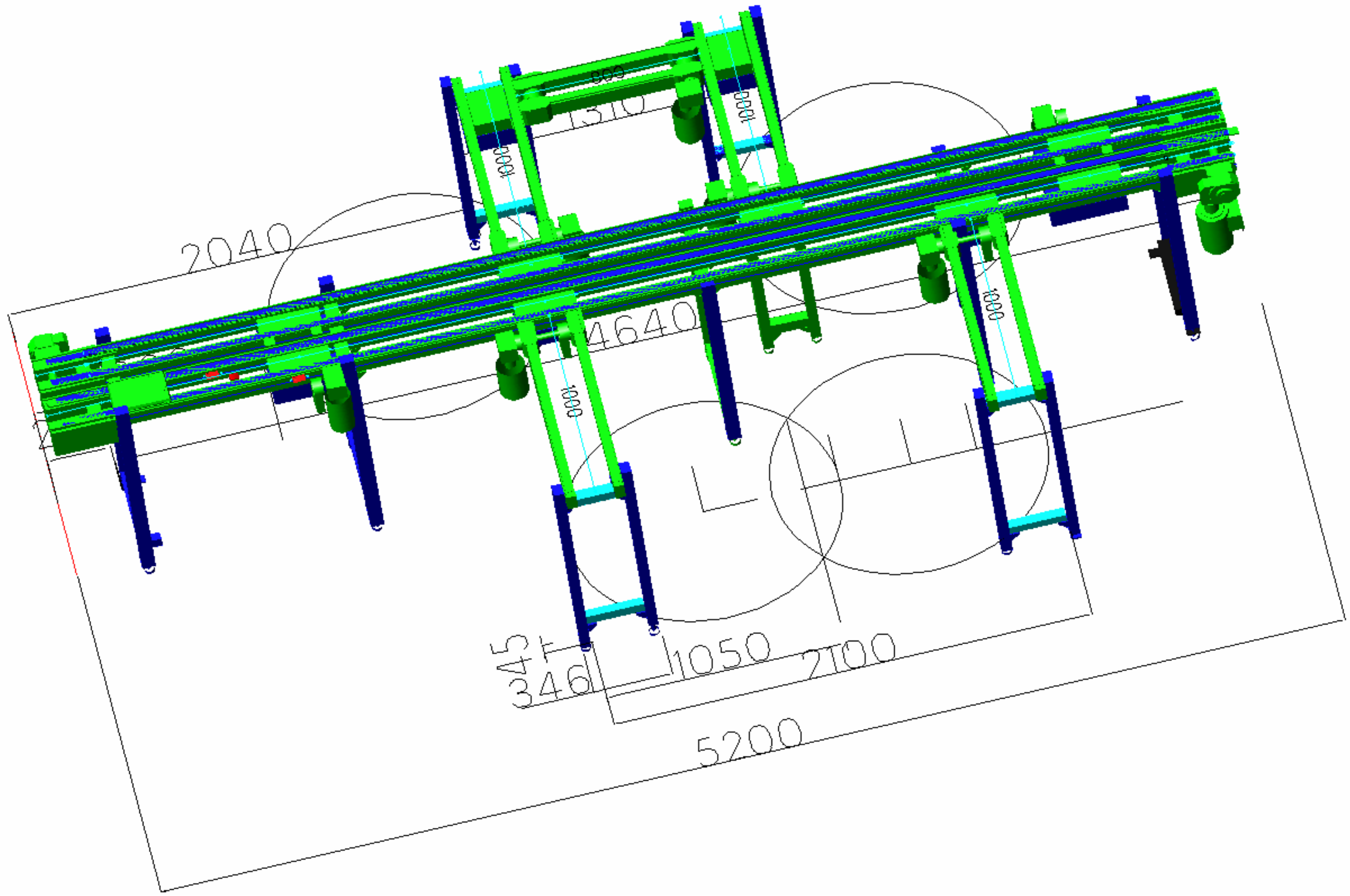
5. Knowledge-based Holonic Architecture for Job Shop Robotized Assembly



6. The Assembly Cell with Networked Robots

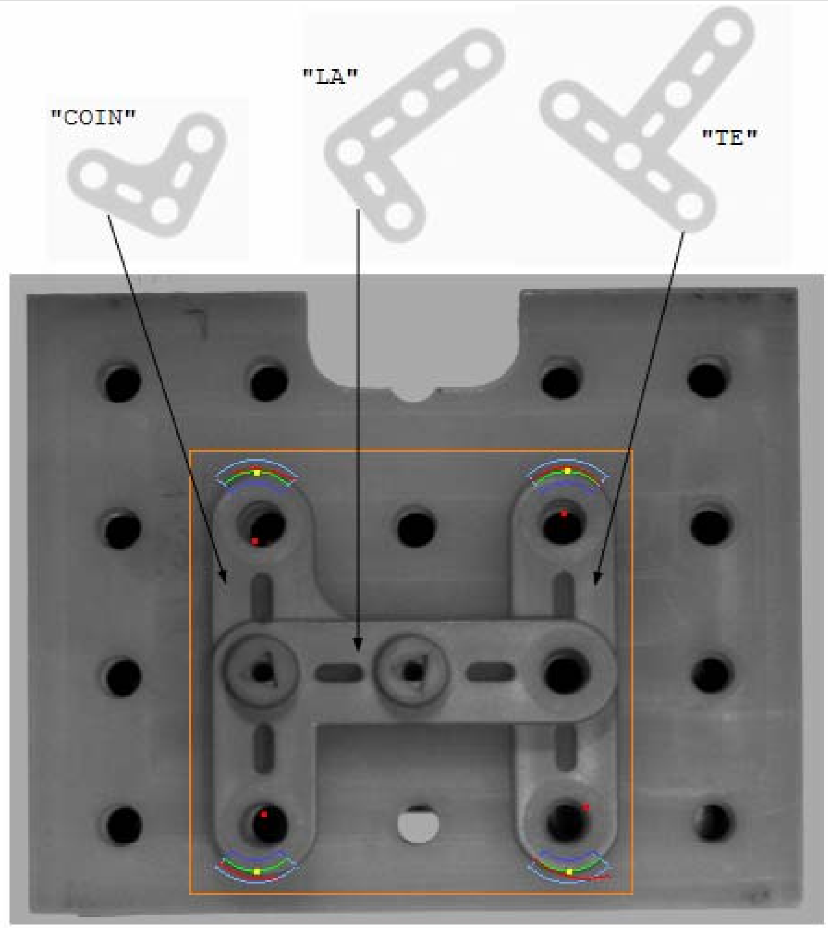


7. Conveyor Structure for Networked Robots



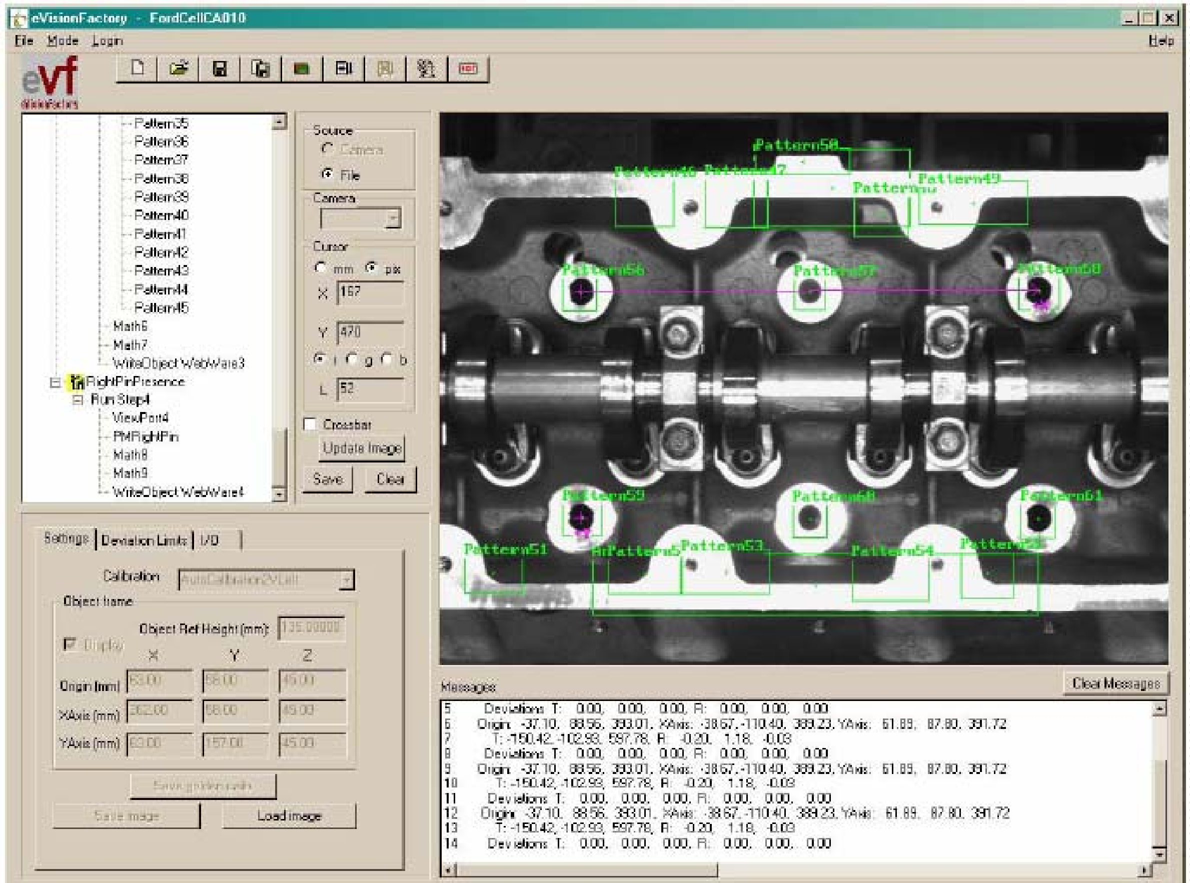
8. Merging Visual Inspection with Robot Guidance

Fig. 7 – Greyscale image of the final assembly of "COIN", "LA", and "TE" components, and graphic overlay of the vision tools used for inspection.



9. Anchor Feature Detection and Measurements

Fig.8 – Screenshot of the vision system user interface during part training, showing a cylinder head and the features used at run time by the 3D part locating kernel to calculate the object's 3D pose.



10. Evolving Strategies for Flexible Part Feeding

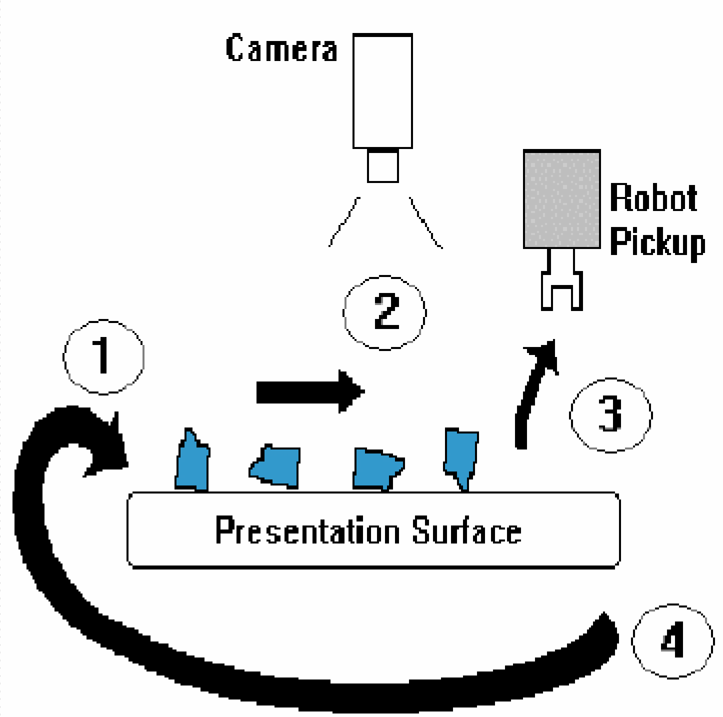


Fig. 9 – Basic flexible feeding concept: 1 – supply parts; 1 – locate desired parts; 3 – pick qualified parts; 4 – recycle parts that are not picked.

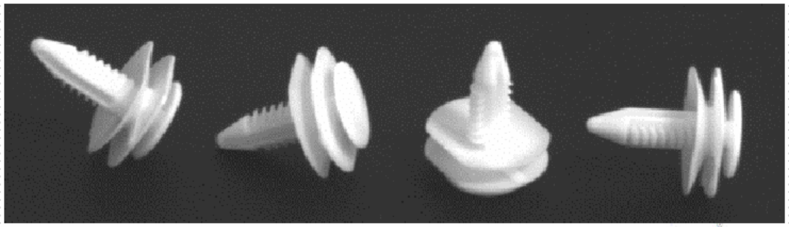


Fig. 10 – Examples of stable states for some type of part on a conveyor belt.

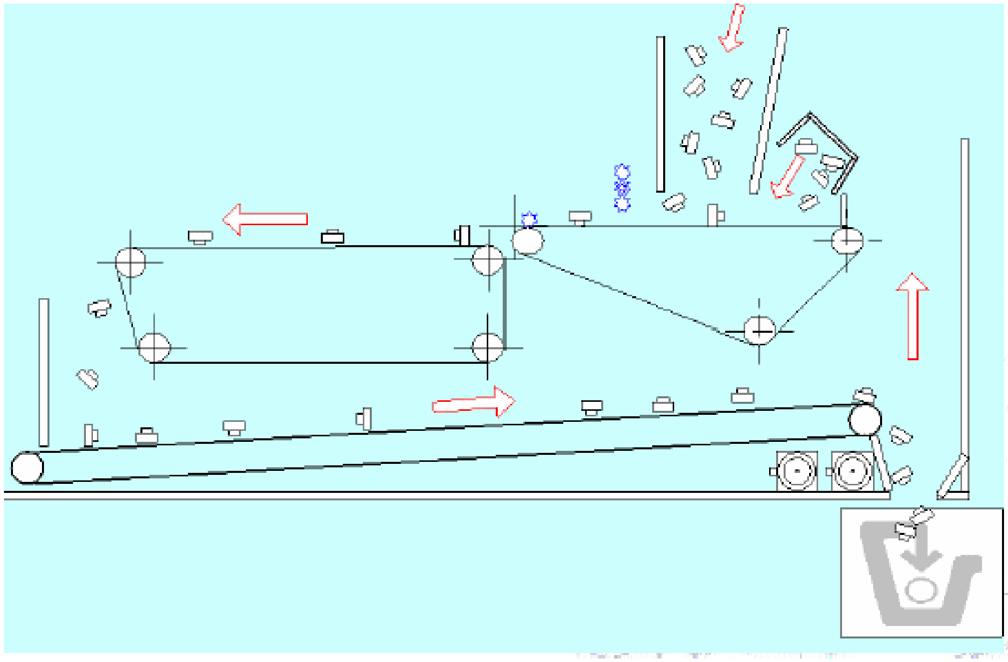


Fig. 11 – The solution for flexible feeding with continuous mode and part reorientation.

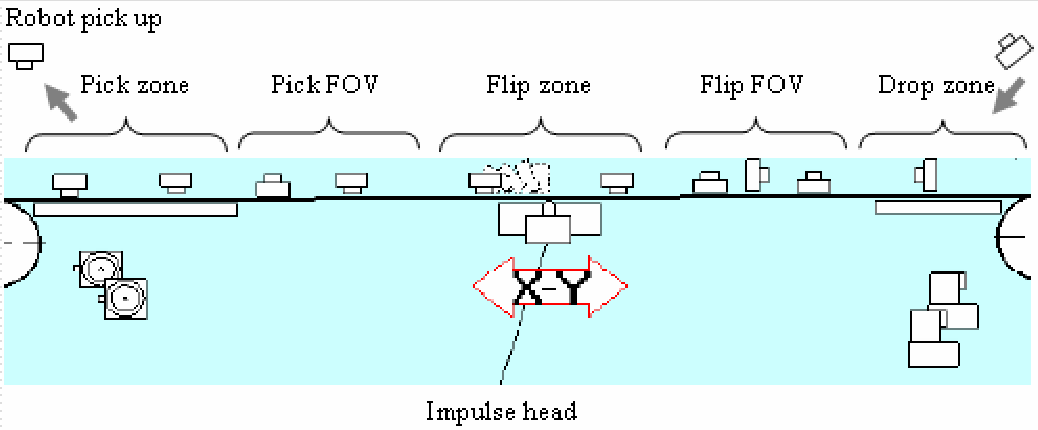


Fig. 12 – *X-Y* flipping mechanism reorients parts for stable states – Structure.

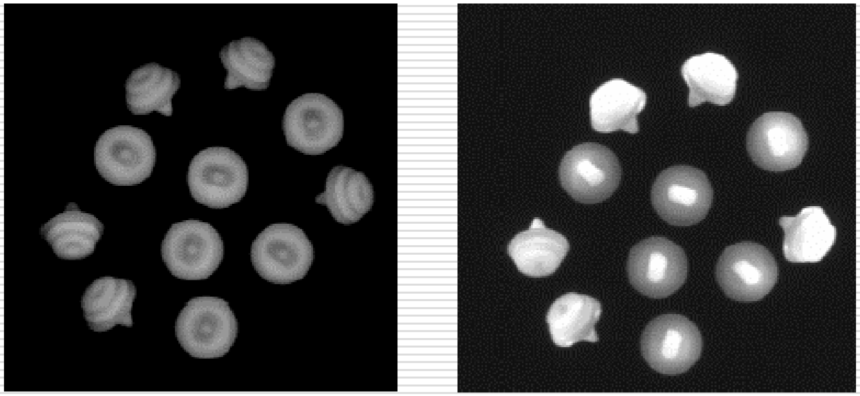


Fig. 13 – *X-Y* flipping mechanism reorients parts for stable states – Results.

Thank you !