Holonic Control and Rapid Deployment Automation in Manufacturing

Theodor Borangiu

University Politehnica of Bucharest, Department of Automation & Applied Informatics
Centre of Research Training in Robotics and CIM - CIMR

E-mail: **borangiu@cimr.pub.ro**

Summary

1. **Intelligent robot control: the RDA solution**
2. **Robot integration in manufacturing: Merged GVR – AVI tasks (Guidance Vision of Robots – Automated Visual Inspection)**
3. **New paradigms in manufacturing control: the holonic approach and implementing solutions**

1. Intelligent Robot Control – the Rapid Deployment Automation solution

Key features of intelligent robot control:

1. Drastically reduce the off-line motion planner (time consuming, inaccurate)
2. Use real-time, high-speed machine vision to condition materials/parts:
   - ✓ Qualify; Recognize; Locate items in the foreground
   - ✓ Grasp invariant to object translation, rotation, mirroring
   - ✓ Avoid collision at part access
3. Define and install virtual cameras to allow task-, lighting- and material flow- oriented robot behaviour
4. Describe material flows by features, extracted from grey scale images
5. Visually guide the robot motion by: Look and Move or Visual Servoing techniques
6. Authorize robot motion by the results of visual measurements and inspection of parts
7. A difficult choice: use software for inspection and robot guidance which is *sufficiently flexible and robust* to acceptably respond to all the needs of manufacturing, or sacrifice performances as a trade-off for *less expensive and easier to exploit* system components.

The solution:

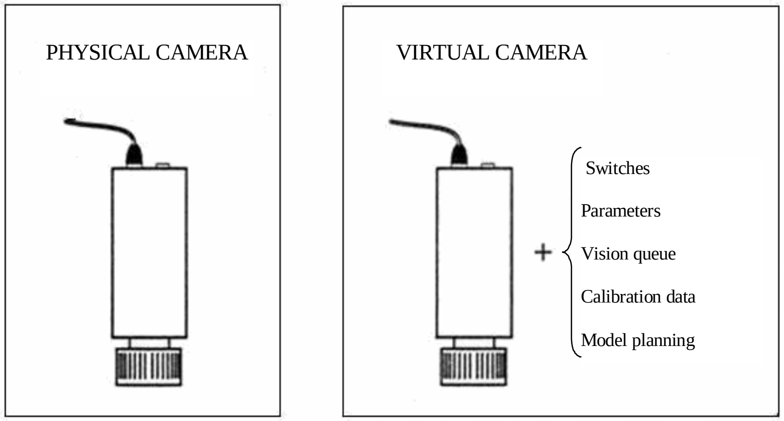
Rapid Deployment Automation (RDA), which considers the design of RV or AVI systems as modular development processes

2. Intelligent Robot Control – the Rapid Deployment Automation solution

RDA:

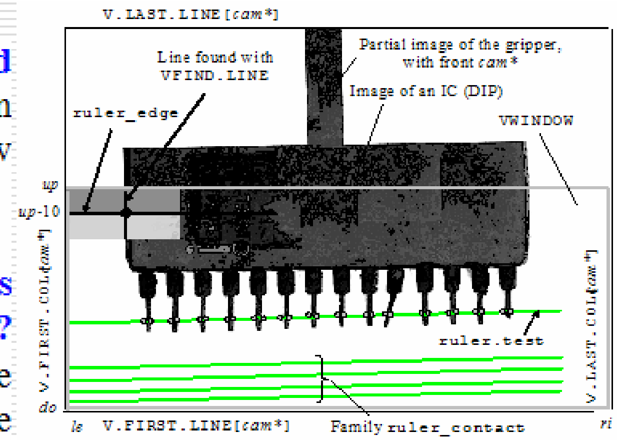
- Instead of dedicating strongly personalized systems to complex material measuring and inspection or robot guidance tasks, each RDA component – camera, vision processor, robot manipulator, controller, conveyor, and even utility, development and debug software – are conceived as **standard parts perfectly adaptable to the puzzle of any flexible manufacturing task**.

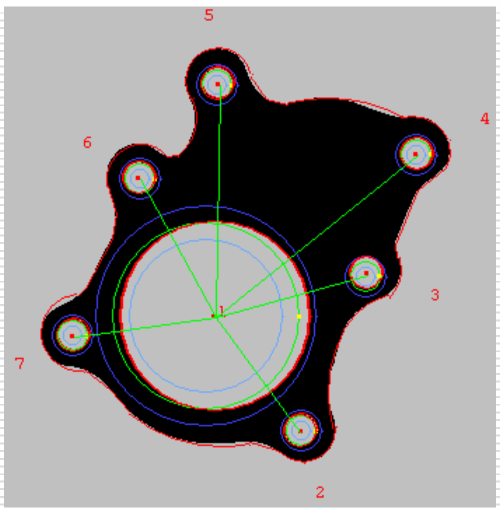
- In this approach, the need of redesign and start again the construction of a complete system which must respond to new functionalities is eliminated; it suffices to remove, add, or update individual RDA components according to the current requirements.



Duality physical camera – virtual camera.

2. Robot Integration in Manufacturing: Merged GVR – AVI Tasks





- **Need for implementing machine vision systems in robotics and manufacturing**: AI techniques are applied to create the best vision environment and adapt processing to lighting variations and part flow characteristics.

- **How did the distinction between Guidance Vision in Robotics (GVR) and Automatic Visual Inspection (AVI) become blurred?** → More and more inspection tasks require manipulation, and more and more component assembling / material processing tasks require quality inspection.

- **Why is intelligence needed for industrial vision systems?** Two technologies that have hitherto been almost disparate: *Image Processing* (**IP**) and *Artificial Intelligence* (**AI**) are currently being integrated. Of special interest are the tasks of *inspecting and manipulating industrial artefacts*.

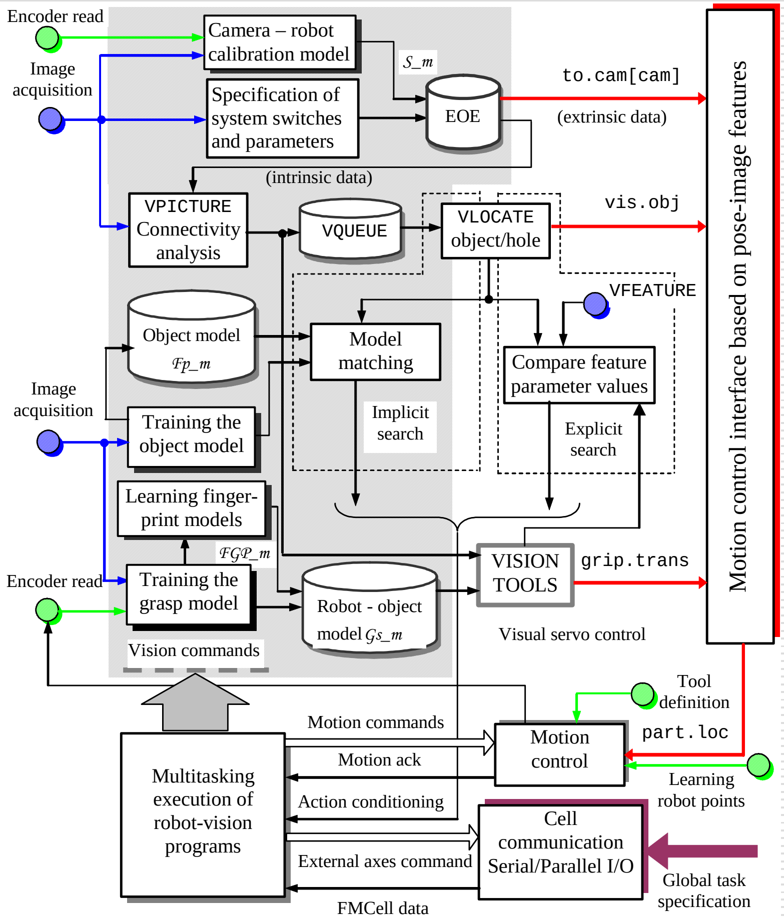
- **Important vision applications in industry**: automotive, electronics, semiconductors, robotics, fabricated metal, printing, food/beverage, and pharmaceutical/medical.

2. Robot Integration in Manufacturing: Merged GVR – AVI Tasks

The **primary role of AI techniques in industrial vision systems** lies in:

1. *Inspecting objects that are very complex*. (Car engine blocks, complicated moulding /castings, populated PCBs, car body panels.)
2. *Inspecting assemblies of objects*. (Air dryer, automobile carburettor.)
3. *Inspecting objects which are very variable in form*. (Processed food items: chocolates, cakes, loaves, pizza, etc.)
4. *Inspecting non-rigid objects* and those which are composed of articulated levers. (Cable harnesses, leather and fabrics.)
5. *Inspecting objects that are made in very small batches*. (It was estimated that 70% of manufactured goods are made in batches of 50 or fewer items.)
6. *Aiding in the design process* for both GVR and AVI systems. (Knowledge-based systems are finding their way into such tasks as choosing the camera, lens, and lighting arrangement.)

2. Robot Integration in Manufacturing: Merged GVR – AVI Tasks

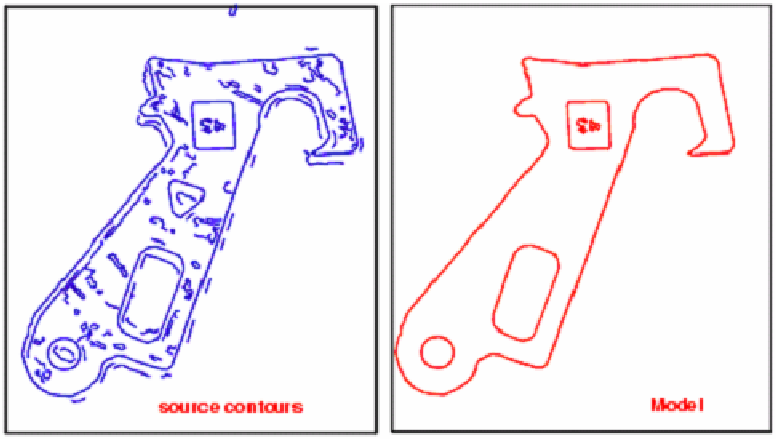


Guidance vision for **robot part grasping** (**RVAVI** function sets):

- **Scene functions**: accessing and use the *camera-robot calibration model* for *visually* blob locating and measuring in *robot world*
- **Scene-object functions**: learn, plan, and use *object models* for recognition
- **Robot-object functions**: learn and apply *object grasp models* for object classes and grasping styles
- **Robot-scene functions**: define, integrate, and check at run time *fingerprint models* against gripper-object related poses and scene occupancy for *collision-free* access to objects

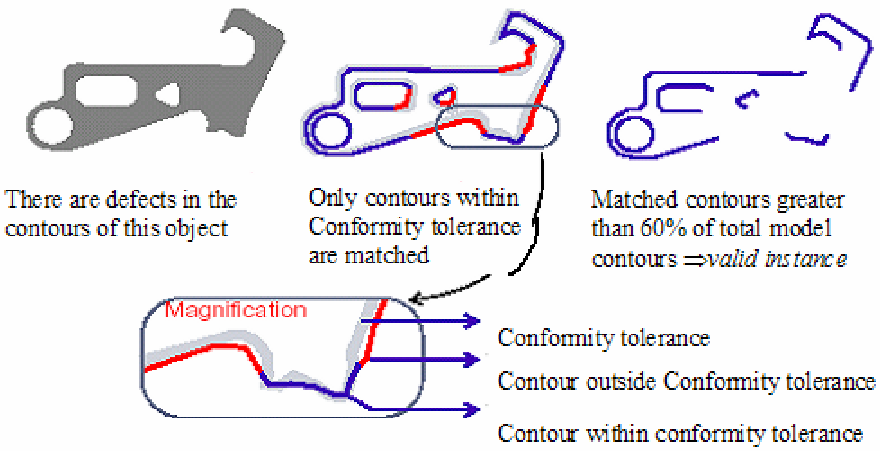
2. Robot Integration in Manufacturing: Merged GVR – AVI Tasks

Object Recognition Models (**ObjectFinder**)



STEP 1. *Source contours* are detected in the input greyscale image.

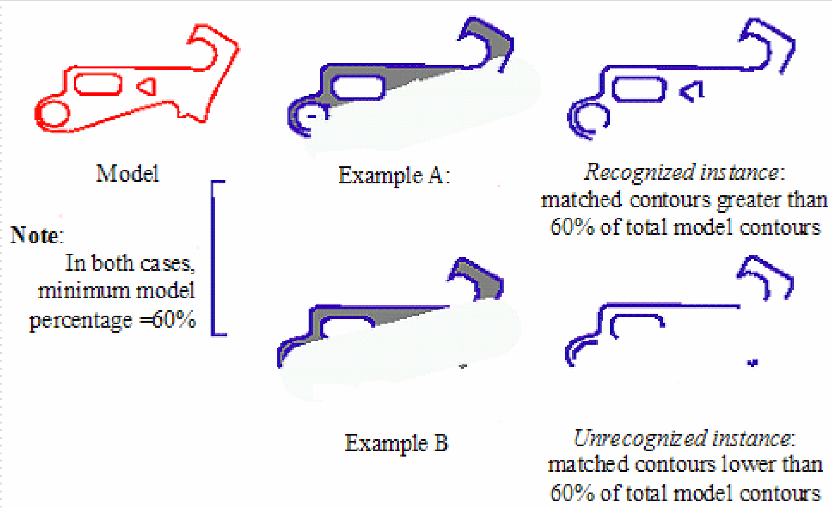
STEP 2. *Appropriate features* are selected to build the model.



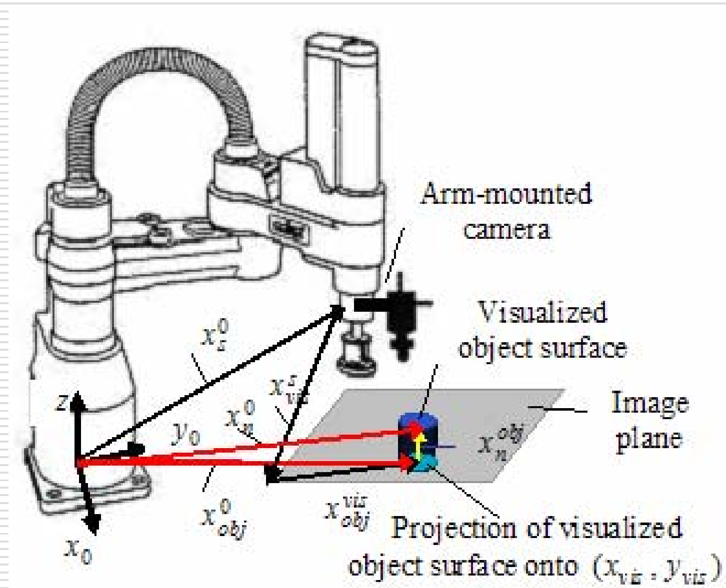
- **Conformity**: maximum local deviation between expected model contours and the contours actually detected in the input image.

2. Robot Integration in Manufacturing: Merged GVR – AVI Tasks

- **Verify%**: minimum percentage of model contours that need to be matched in the input image in order to consider the instance as valid. A higher value ⇒ faster recognition & higher rejection rate.



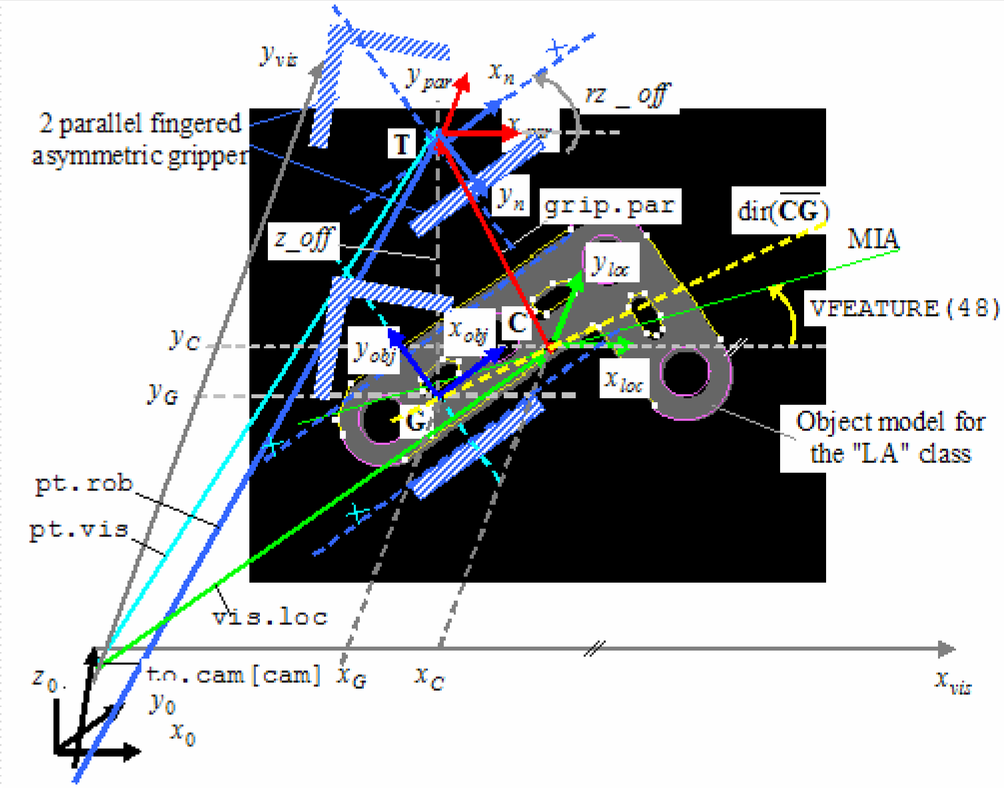
Object Grasping Models



2. Robot Integration in Manufacturing: Merged GVR – AVI Tasks

Object Grasping Models

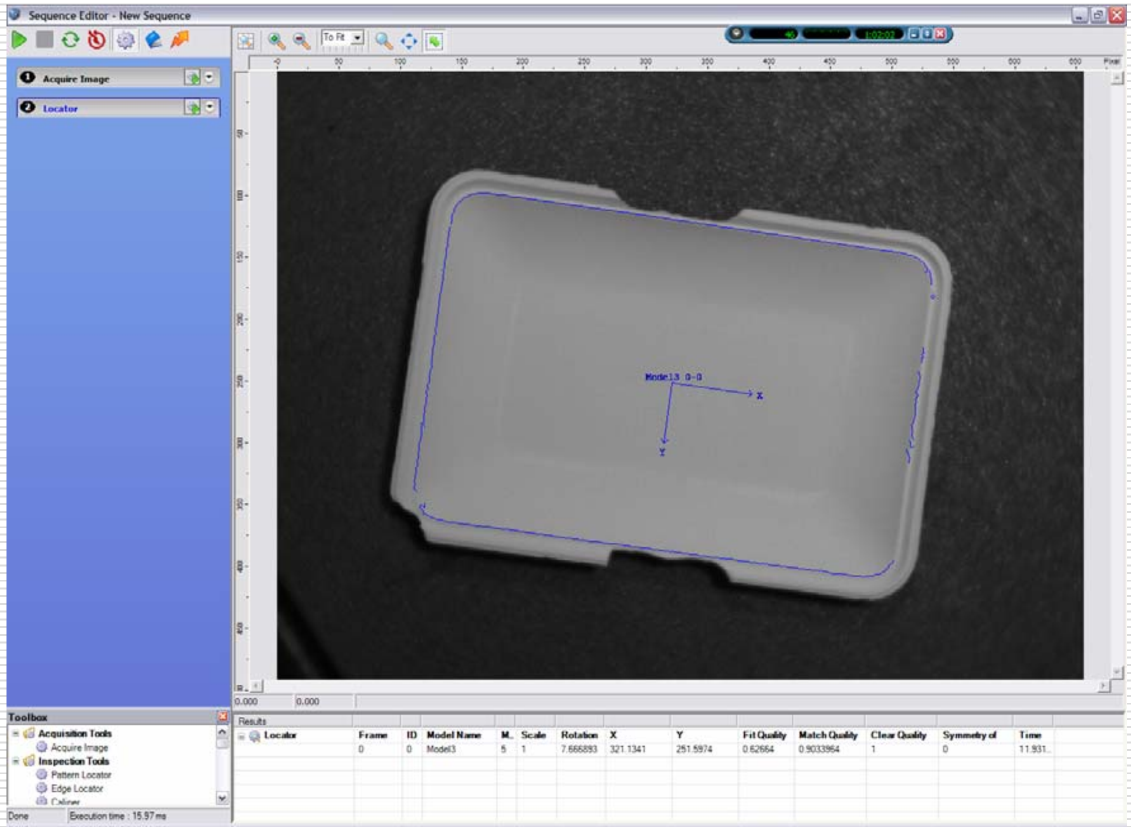
Fingerprints Models for Collision Avoidance



2. Robot Integration in Manufacturing: Merged GVR – AVI Tasks

Correct robot pick-up point relative to current location of shape of interest

- Parts have irregular shape of outer contour
- Interior shape of interest off-line taught
- Parts stop on conveyor in slightly different positions and orientations
- Robot should be moved always in the same pick up location relative to interior shape of interest

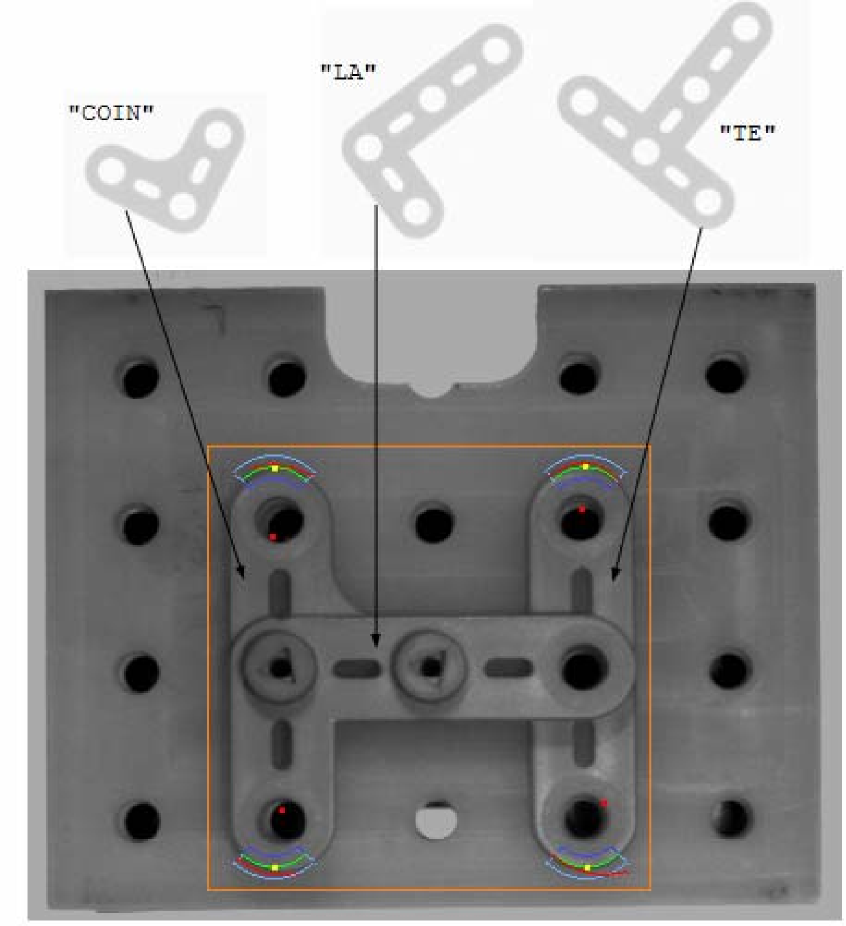


Recognizing interior shape of interest with *incomplete outer part contour* and *random position and orientation of entire object*

2. Robot Integration in Manufacturing: Merged GVR – AVI Tasks

Check proper positioning of assemblies:

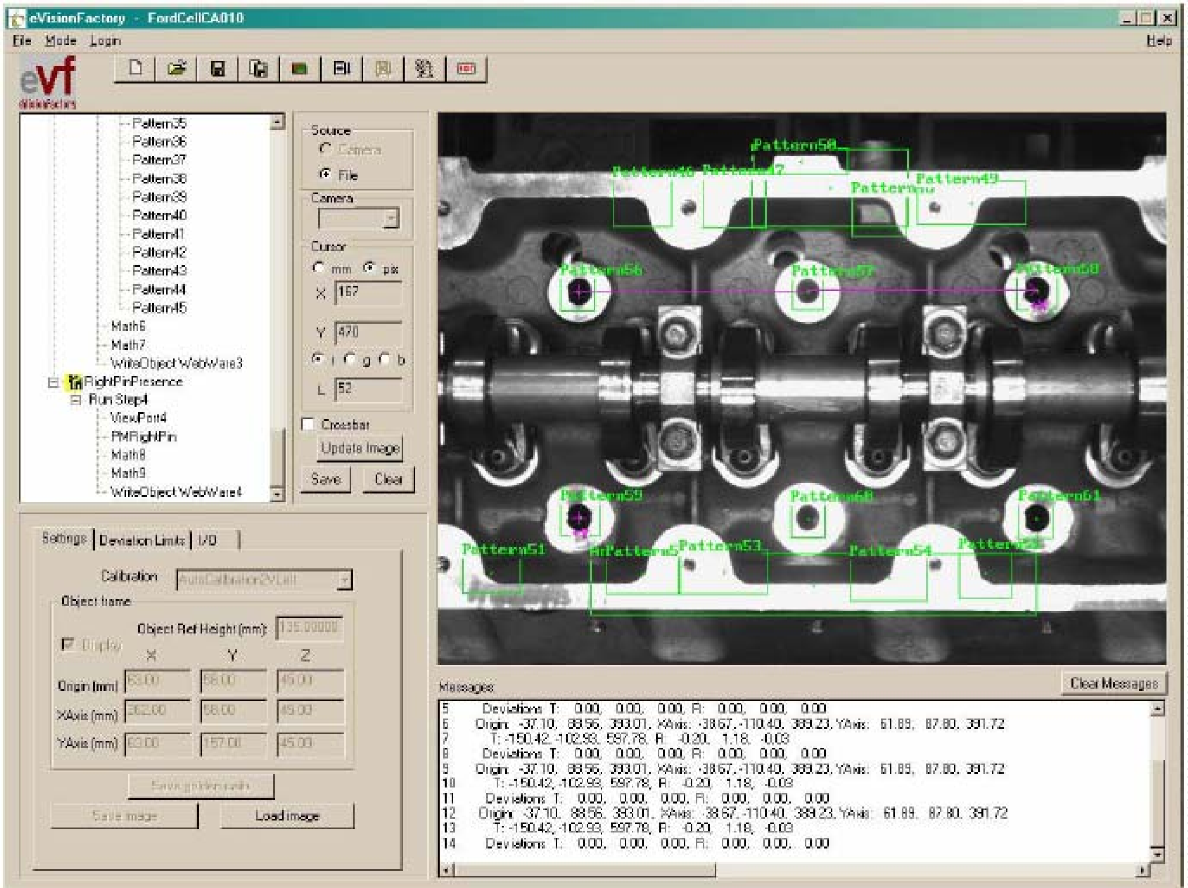
Greyscale image of the final assembly of "COIN", "LA", and "TE" mechanical components, and graphic overlay of 4 arc finder *vision tools* used for inspection.



2. Robot Integration in Manufacturing: Merged GVR – AVI Tasks

Anchor Feature Detection and Measurements

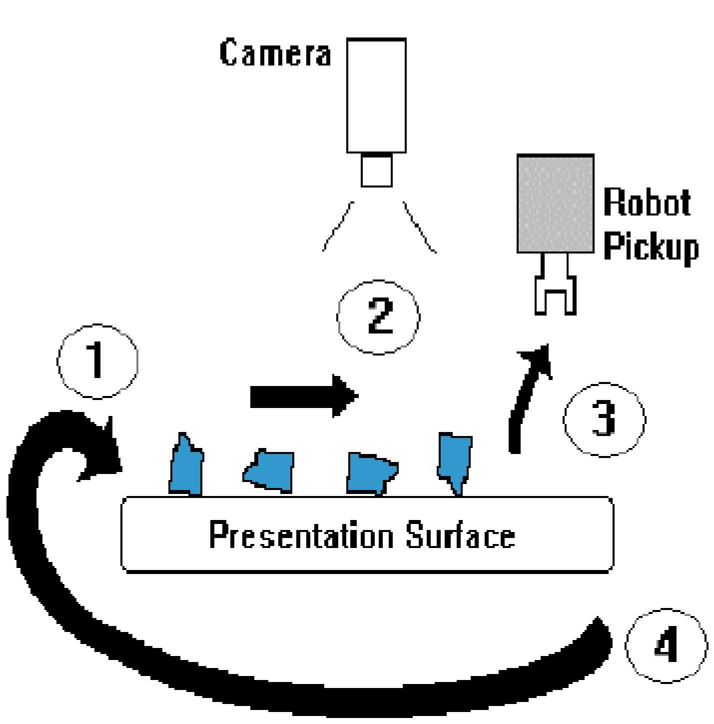
Screenshot of the vision system user interface during part (model) training, showing a cylinder head and the features used at run time by the 3D part locating kernel to calculate the object's 3D pose.



2. Robot Integration in Manufacturing: Merged GVR – AVI Tasks

Evolving Strategies for Flexible Part Feeding

- Vision windows on conveyor belt
- Operate with belt variables
- Model the conveyor as a 3-d.o.f. Cartesian robot
- Move the robot toward a real-time updated destination
- Pick on-the-fly moving parts

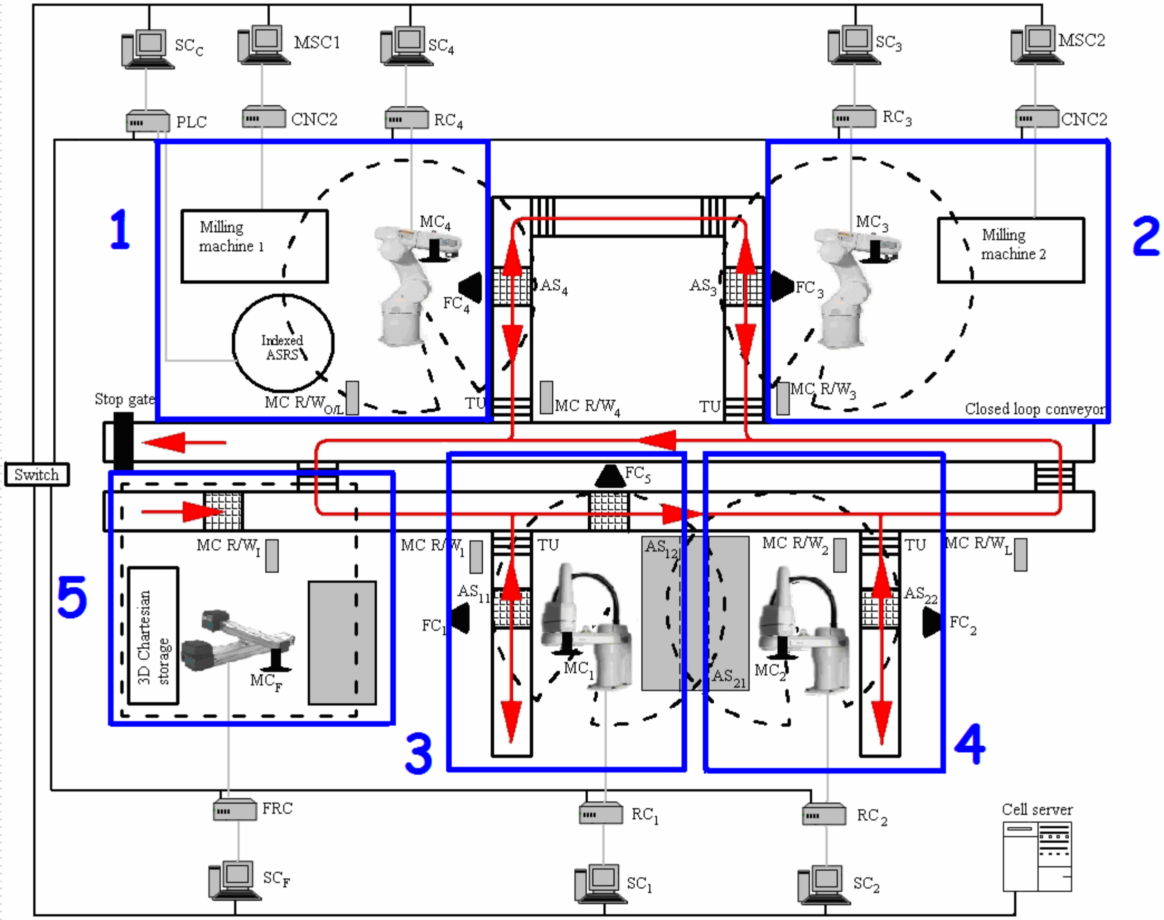


Basic flexible feeding concept: 1 – supply parts; 1 – locate desired parts; 3 – pick qualified parts; 4 – recycle parts that are not picked.

3. New Paradigms in Manufacturing Control: the Holonic Approach

Job Shop Manufacturing with multiple networked Robot Vision stations

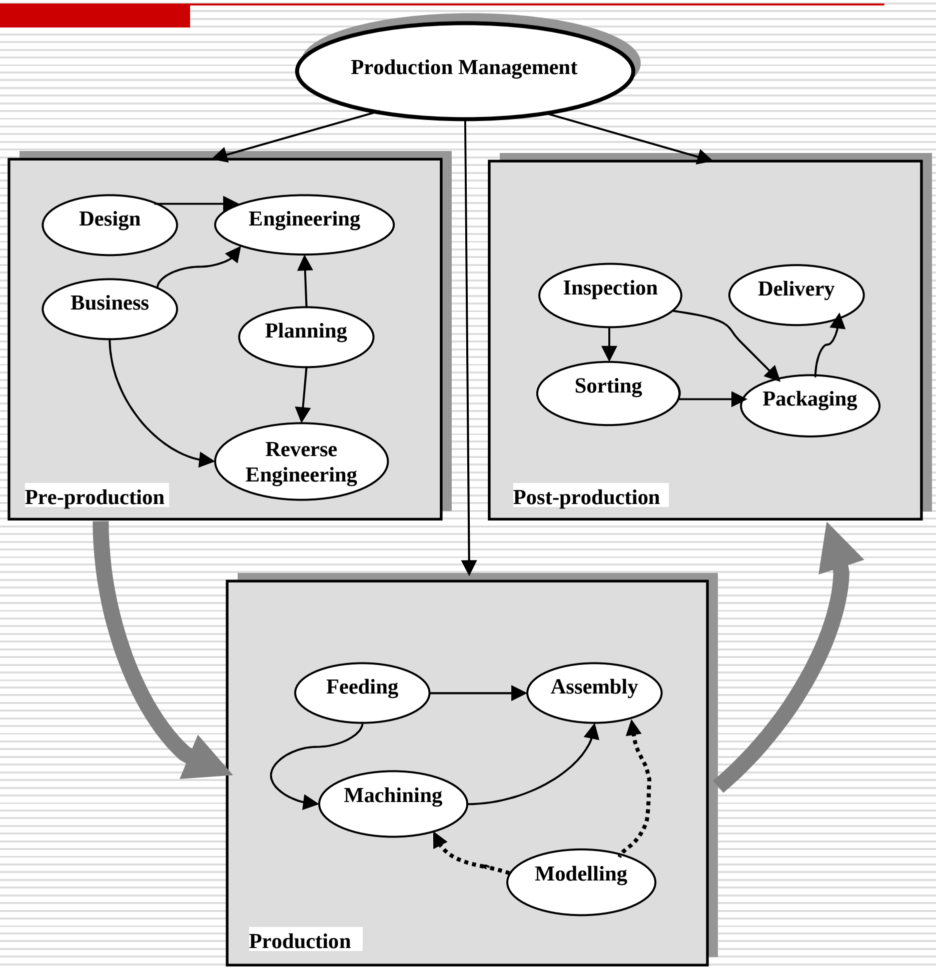
- Closed-loop conveyor
- Networked robot workstations
- Dual-camera robot-vision stations: stationary (down looking) & mobile (arm-mounted)
- CNC machine tools
- Multiple ASRS
- Magnetic RD/WR devices for pallet (product) traceability
- Fault-tolerance



3. New Paradigms in Manufacturing Control: the Holonic Approach

The team-based manufacturing paradigm

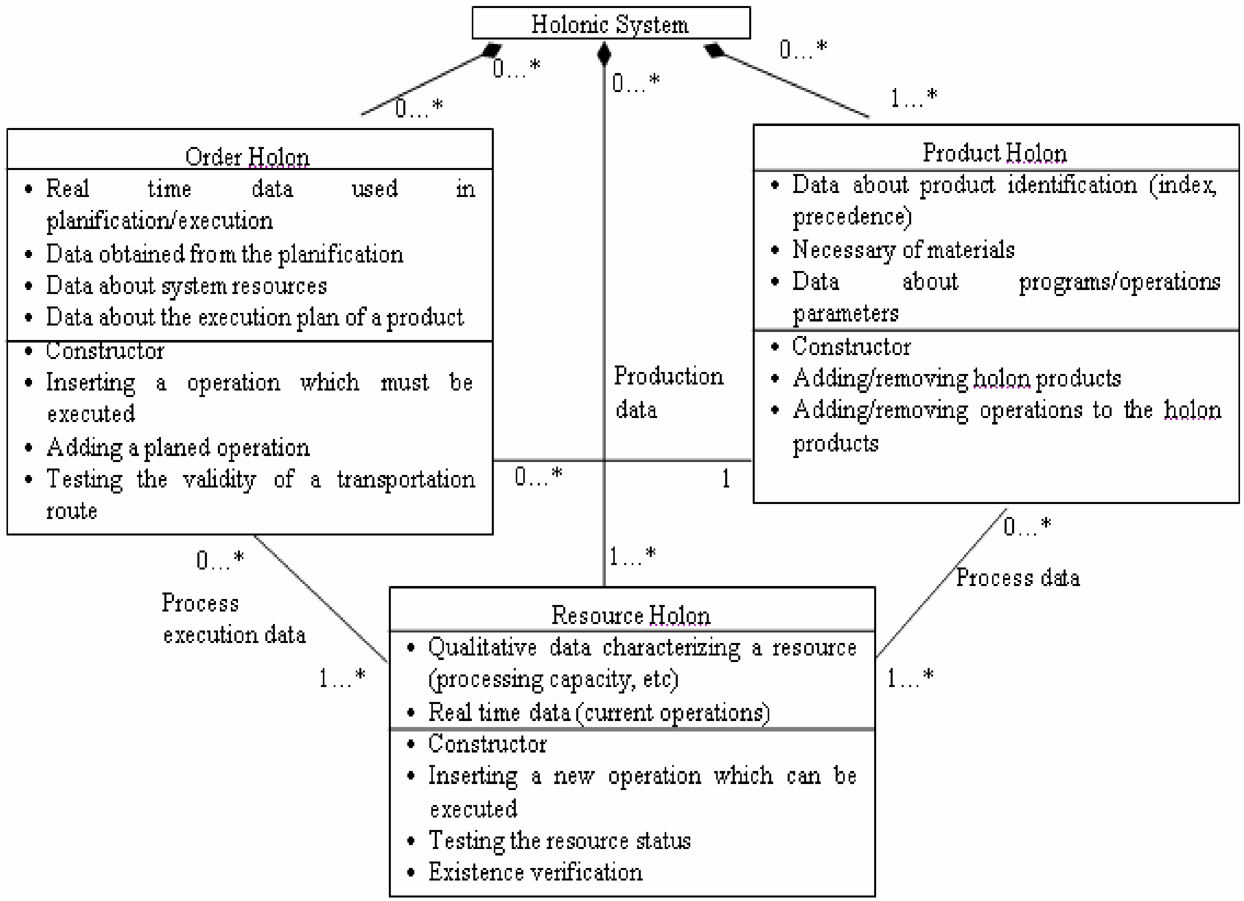
- Adopted to provide the flexibility, agility and responsiveness required to cope with the volatility of production demands
- The process of grouping manufacturing resources to form teams is based on a wide range of criteria, such as similarity of activities, definition of business processes, and production planning and control requirements
- Leads to semi-heterarchical resource control architectures



3. New Paradigms in Manufacturing Control: the Holonic Approach

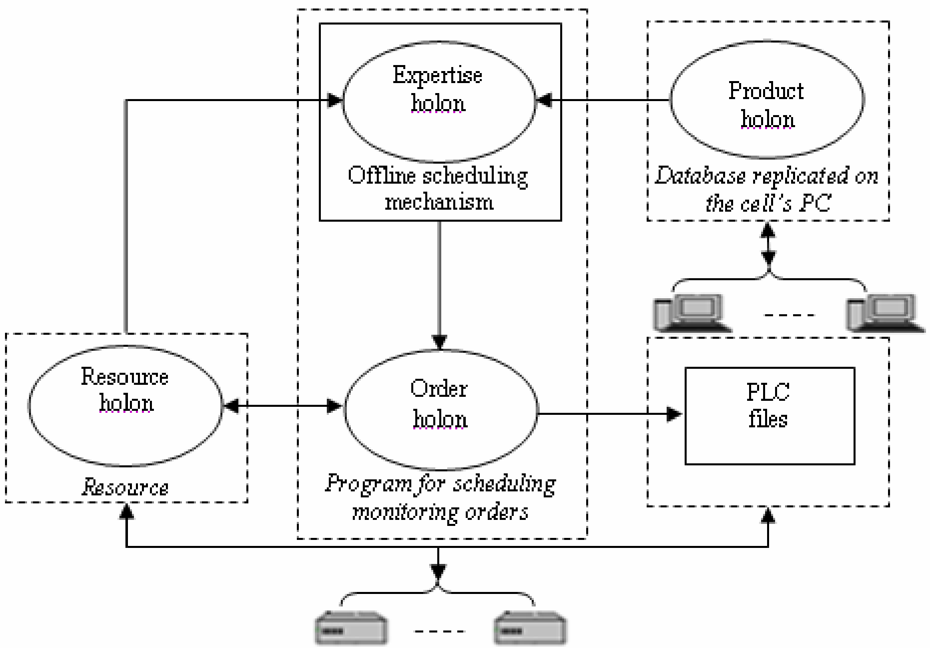
Data and functions embedded in the basic types of holons:

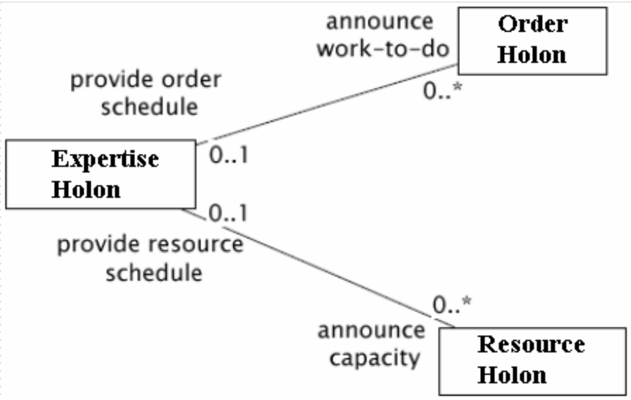
- **product**,
- **resource** and
- **order** (order holons are production plans derived from customer commands, queued by help of **expertise holons**)



3. New Paradigms in Manufacturing Control: the Holonic Approach

Relations between Holons (the Holarchy)





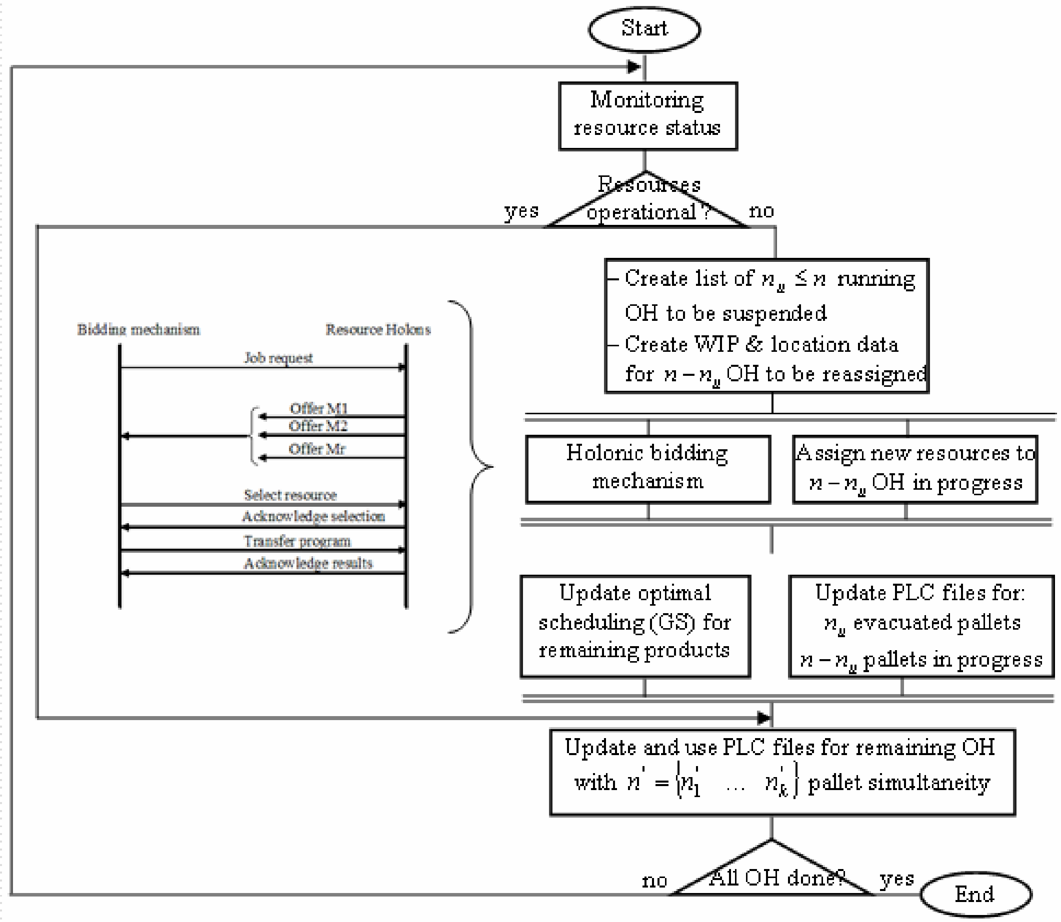
Two *holarchies* (set of basic cooperation rules between holons, integrating all manufacturing tasks were designed to automatically **switch between them** at run time:

- Hierarchical, optimal production planning and control in normal operating mode
- Heterarchical, graceful degraded production re-planning and control, in reaction to a change in customer order, a resource failure or a negative result of operation execution or quality control operation

3. New Paradigms in Manufacturing Control: the Holonic Approach

The real time holonic production control mechanism:

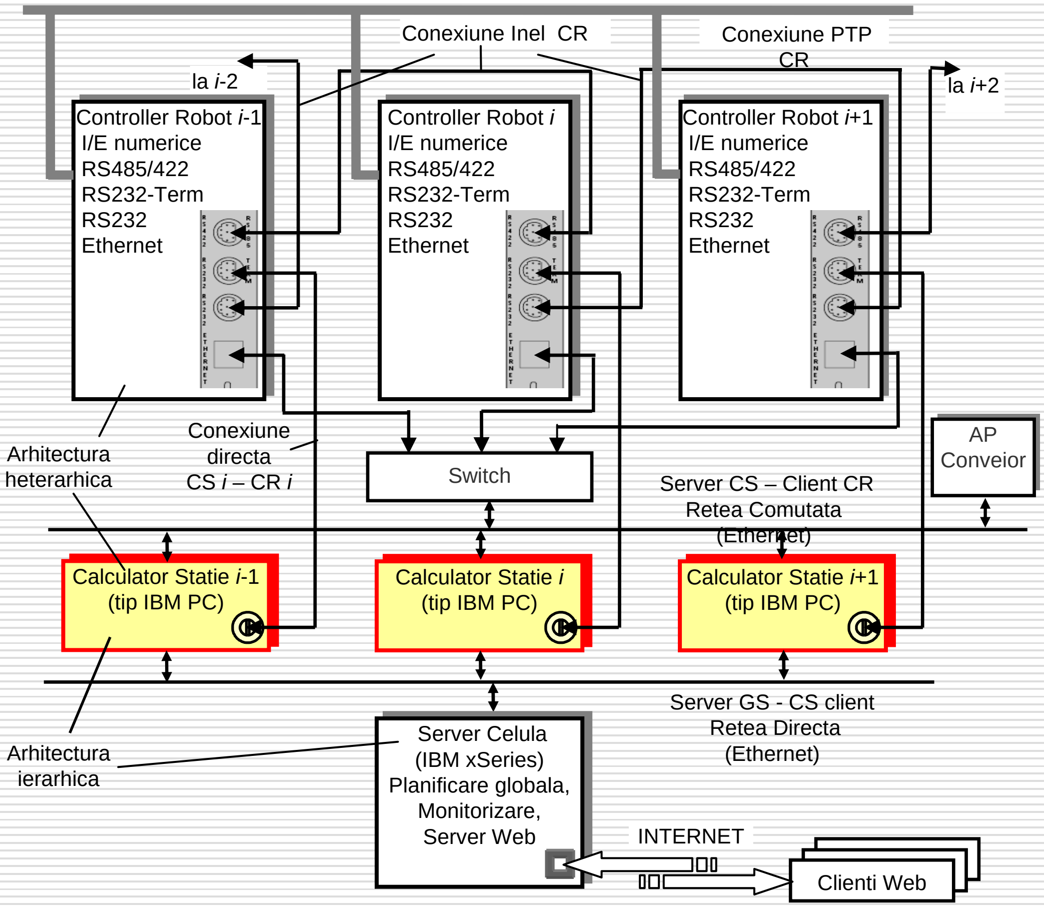
- Offer request
- Bidding for offer
- Awarding order
- Executing Order



3. New Paradigms in Manufacturing Control: the Holonic Approach

Fault tolerant Control and Communication of networked robots:

- Switched Ethernet
- Serial Direct
- Ring Inter Controller
- Point-to-Point I/O



The End

Thank you !