

Rapid Deployment Automation Using RV Equipment

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Abstract. In conventional robot system development the different robot parts (sensors, processing elements and actuators) are combined together in a compact, self contained system. The need for faster development and deployment, system reconfigurability and flexibility required the introduction of rapid deployment automation for robot systems in flexible manufacturing cells. Vision sensors are one of the most important sensors in robot systems. When constructing a new robot system, it is desirable that vision and image processing components are just as easily integrated as any other robot components. In some situations robot stations must be upgraded with vision systems in order to accomplish new tasks or to enhance the current work, here the Rapid Deployment Automation concept is the base to solve such problems in a shorter time having the smallest impact over the production flow in terms of production downtime. The paper describes an RDA solution of vision upgrade for robot stations in a china objects production plant.

Keywords. Rapid Deployment Automation, Robot-Vision, open contour object model, flexible manufacturing cells, shared robot workspace

1. Introduction

The paper describes a process of upgrading a plate production line which uses ABB robots by adding artificial vision systems.

The production line uses raw materials which are feeding a stencil. The stencil applies pressure on the material and result the moulds (raw material having the shape of the plates). Before the plates to be transported to the oven for the baking process, they are routed to multi-robot stations where the robots are

used for polishing the plates and to remove the material in excess (small irregularities on the edges of the plate).

The stations are using groups of 4 ABB robots. The problem was that the plates are not stopped precisely in the same position each time when the robots must take them to be polished. Due to this problem a percentage of plates are polished incorrectly resulting in damaging the plate edges.

In these conditions a solution based on artificial vision has been considered (see Fig. 1). Each station

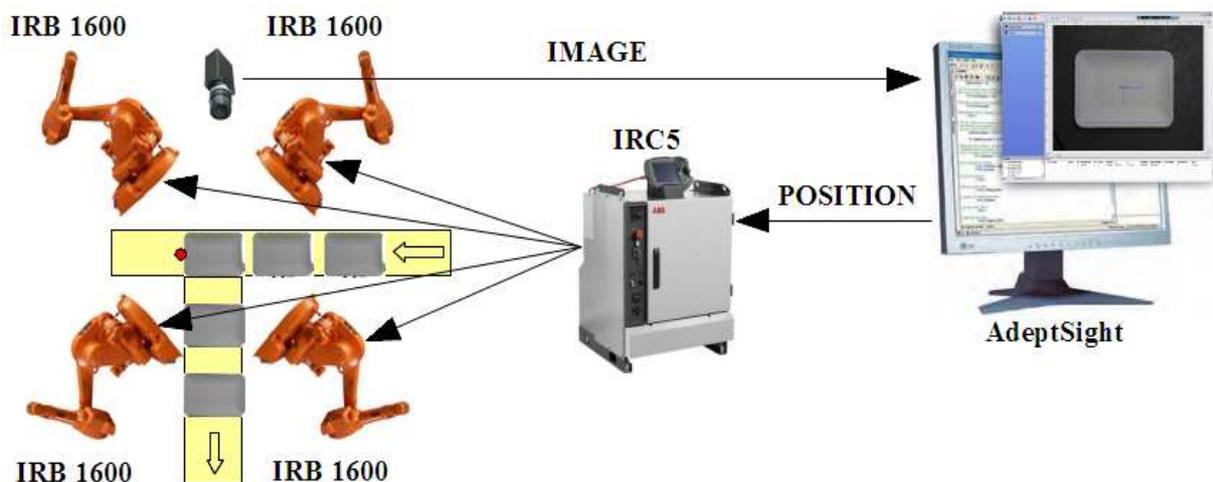


Fig. 1. Vision integration in the robotized production line

must have a vision system which has the role to locate with precision the plate and send the coordinates to the robots. The task is more difficult than implementing the robot-vision (RV) solution from the start because, now the production must be interrupted, and this time must be as short as it can be.

Also the vision task is very difficult due to the environment conditions; first the inspected object has a shape which cannot be viewed entirely due to the fact that the shape is based on the interior shadows of small canals included in the plate, also the environment is heavy loaded with dust which comes from the plate polishing operations.

2. The Vision System

For the vision solution, few systems have been considered, in the end the chosen system was AdeptSight from multiple reasons:

- The vision system have high performances in object localisation: 1/40 of a pixel in position, and 0.01 degree in rotation
- The system has the possibility to train and edit object models based on non connected contours
- The programming interface is based on visual tools (visual programming) for rapid development, and has also the possibility to be integrated with high level programming languages (C#) for complex applications.
- The system can be easily integrated with any robotic system (see Fig. 2).

In Fig. 2 is presented the integration diagram for the AdeptSight vision system in robotic applications. AdeptSight uses up to four FireWire cameras connected directly to the PC where the AdeptSight software is installed.

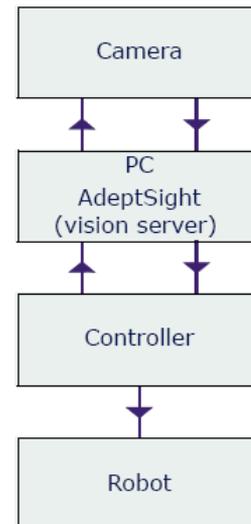


Fig. 2. Robot-Vision Integration

The development of vision applications is based on vision projects which have the following structure (see Fig. 3): The vision project is separated in two main parts, the first part handles the hardware and the communication environment and is composed by communication routines and configuration of system devices like cameras (Basler, Direct Show or Emulation – virtual camera), robot controllers (native communication support with Adept CX and AIB controllers) and conveyor belts. The second part is represented by the vision sequences, which compose the principal part of the project. The sequences are composed by vision tools connected together and which are executed step by step in a sequence defined by the programmer. In addition the user can develop C# programs which interact with the AdeptSight project and extend his functions regarding the communication with other robot systems and other functions which are not implemented in AdeptSight.

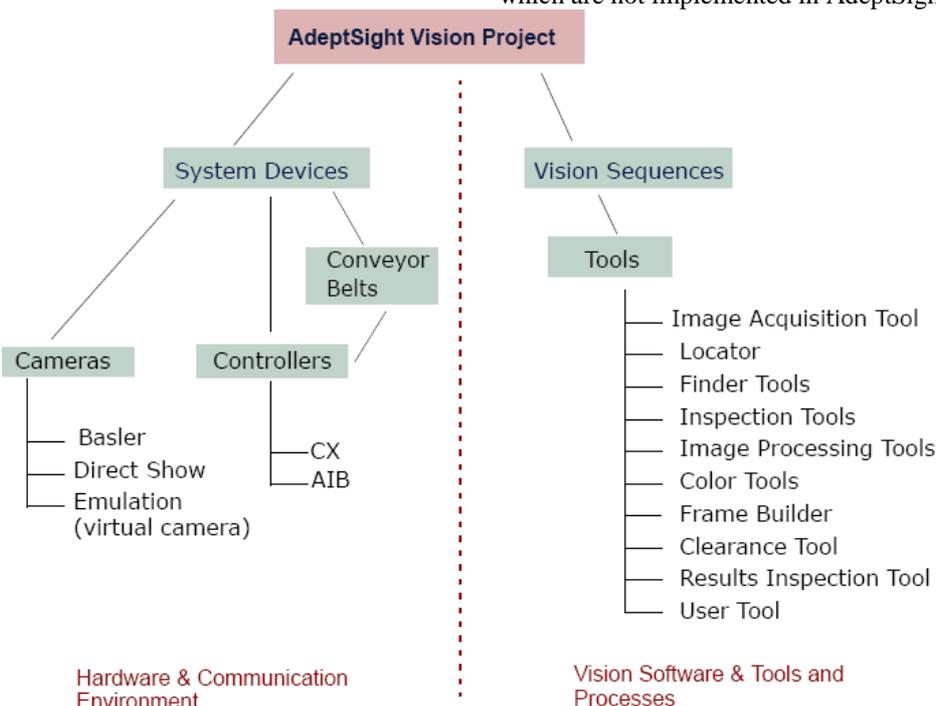


Fig. 3. The vision project structure

3. Vision Project Implementation

The vision is calibrated using a dotted pattern which is placed in front of the camera on the working surface. The calibration is executed using a 2D camera calibration wizard which guides the user step by step through the calibration process. The single information which the user must supply is the Dot Pitch of the calibration pattern, the rest of the process is handled by the wizard. After the 2D camera calibration the following information's are obtained:

- Average Pixel Width/Height (Fig. 4)
- The lens distortions are corrected
- The perspective distortion is also corrected

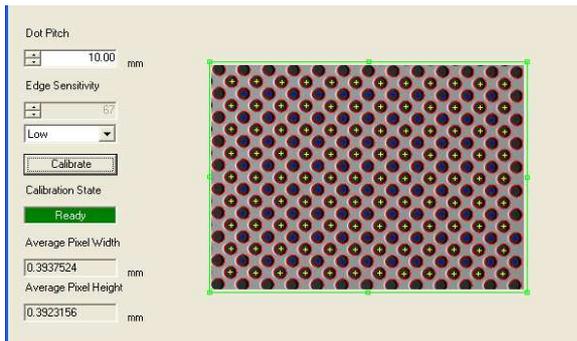


Fig. 4. The result obtained after calibration

After the 2D camera calibration, the sequence can be loaded into the project, and for this application which requires only object recognition, the sequence is very simple and consists on only two vision tools, an acquisition tool which obtain the image from the

Basler (640x480) camera, and a second tool named Locator which has the role to recognize the object.

In this application the difficulty is to detect the correct position of the plate disregarding the outer irregularities which are generated by the fabrication process.

Due to the fact that the contour features are contained in the interior of the object, and in this case it is very difficult to create a lighting setup in such way that the image of the object to contain the complete internal contours. AdeptSight allow the user to generate the object model using open contours, and also the user has the possibility to edit (remove/add) parts of the contours which are of interest.

In Fig. 5 is presented the interface for model editing. The system, based on the contrast threshold, and the outline and detail levels detect the contours and proposes the user a set of contours for model building. The outline level provides a coarser level of contours than the detail level. The location process uses outline level contours to rapidly identify and roughly locate potential instances of the object, then, the location process uses the detail level contours to confirm the identification of an object instance and refine its location within image.

The user can modify the selected contours by deleting/adding contours, or select only parts of the proposed contours (Adept, 2001, Adept, 2007). In the Fig. 5 the red line is selected for deletion, the blue contours are marked as deleted (will not be used for model building) and the green contours are valid contours. After all contours have been selected, the model can be build and used for recognition.

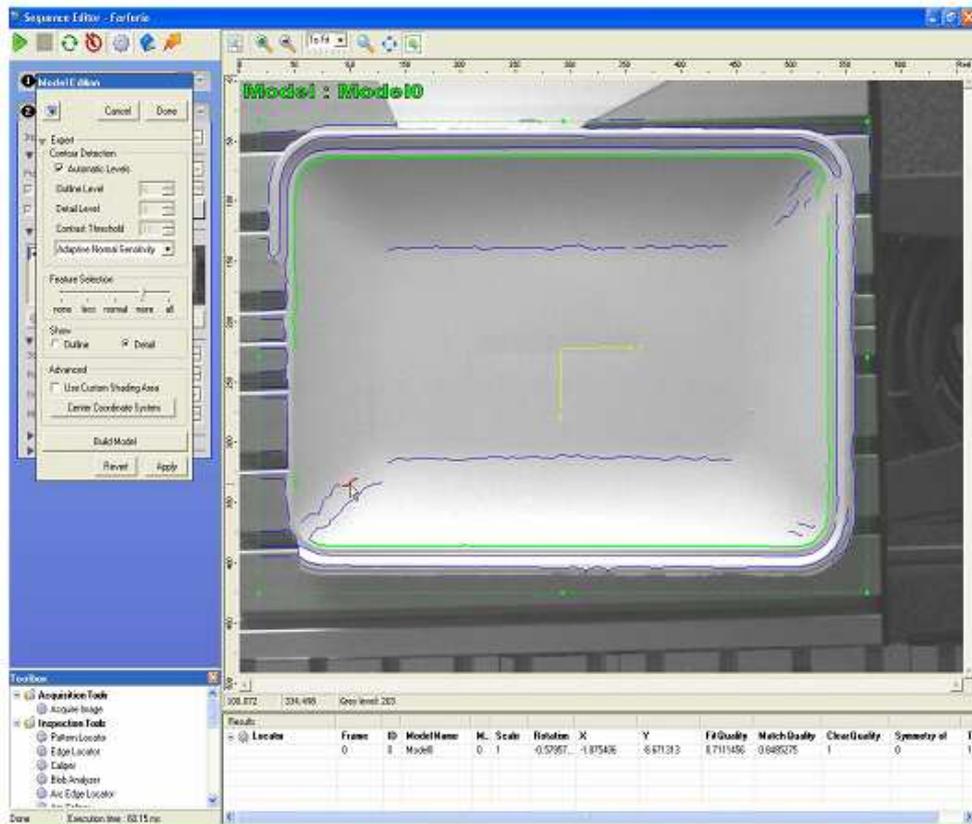


Fig. 5. The plate model, using internal, open contours

4. Robot-Vision Integration

In order to integrate the vision system with the robot two tasks must be achieved (Anton, 2008):

1. A robot-vision calibration procedure must be created and executed
2. A robot-vision server communication mechanism must be implemented.

4.1. Robot-Vision calibration

The robot-vision calibration process and the training of the object grasping model have been integrated in a single procedure. The procedure consists in four steps where the robot grasps the object and places in different positions in the workspace for image acquisition and processing (Borangui, 2004):

1. The calibration object is placed in the workspace and grasped by the robot and then released (position P1), after the robot clears the vision plane the position of the object in the vision plane is computed by AdeptSight.

The position of the object in point P1 is also computed in the vision plane, having the coordinates $P1_x, P1_y$ (the position of the coordinate system attached to the object model).

2. In the second step the robot grasps the object and place him in the same position, but rotated with 180° point P1', and in the vision coordinates $P1'_x, P1'_y$. By comparing the position of the coordinate system of the object in these positions the system can compute the position of the centre of the object which in this case is the centre of mass of the model relative to the grasping point. In this case the grasping point is located in the image on the middle of the segment $[P1, P1']$ (see Fig. 6)

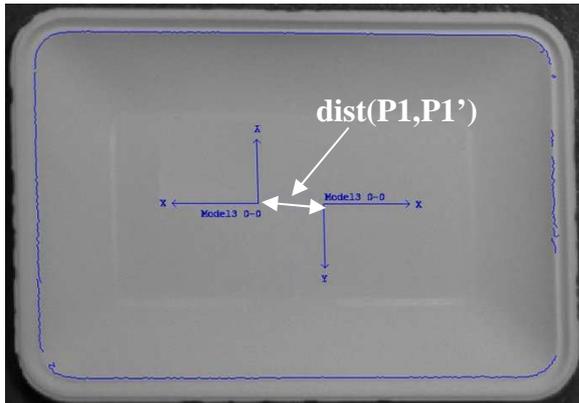


Fig. 6. The relationship Robot point – vision point

In this case the grasping point coordinates in the vision space is given by:

$$P_{gvis} \begin{cases} P_{gvisx} = \min(P1_x, P1'_x) + |P1_x - P1'_x| \\ P_{gvisy} = \min(P1_y, P1'_y) + |P1_y - P1'_y| \end{cases} \quad (1)$$

where P_{gvis} is the grasping point in the vision workspace.

3. Next the object is placed in the position P2 which is trained relative to the position P1 shifted with 100 mm on X axis of the base coordinate system of the robot.
4. In the final step the robot places the object in the position P3 which is trained relative to the position P1 shifted with 100 mm on Y axis of the base coordinate system of the robot. By knowing the correspondence robot-point – image-point, the system can compute now the orientation of the vision plane relative to the robot base coordinate system, and also can compute the distance which the robot must cover to reach an object which is placed at a certain distance from the initial point P1 in the image plane.

This can be expressed as:

For 100mm travelling length on the X coordinate system (base coordinate system) the object moves in the image $P2_x - P1_x$ on X_{vis} axis, and $P2_y - P1_y$ on Y_{vis} , the same travelling length on Y coordinate system generates $P3_x - P1_x$ on X_{vis} axis, and $P3_y - P1_y$ on Y_{vis} , on the vision workspace. Also from here results that the vision system is rotated with the angle:

$$\alpha = a \tan 2(P2_y - P1_y, P2_x - P1_x) \quad (2)$$

toward the base coordinate system. From here results that for an object which is recognized in the image at the location P_v , in the world coordinate system the object will be grasped at the coordinates:

$$\begin{aligned} P_x &= P_{G_x} + \sqrt{(P1_x - P_{v_x})^2 + (P1_y - P_{v_y})^2} \\ &\cdot \cos(\alpha + a \tan 2(P_{v_y} - P1_y, P_{v_x} - P1_x)) \\ P_y &= P_{G_y} + \sqrt{(P1_x - P_{v_x})^2 + (P1_y - P_{v_y})^2} \\ &\cdot \sin(\alpha + a \tan 2(P_{v_y} - P1_y, P_{v_x} - P1_x)) \\ P_{rot} &= P_{G_{rot}} + (P_{v_{rot}} - P1_{rot}) \end{aligned} \quad (3)$$

where P_x, P_y, P_{rot} are the coordinates and the rotation of the grasping point of the object which was located in the vision workspace at the location P_v ($P_{v_x}, P_{v_y}, P_{v_{rot}}$), P_G ($P_{G_x}, P_{G_y}, P_{G_{rot}}$) is the grasping point (in the centre of the mass of the object in the base coordinates system) for the object located in the image in P1 ($P1_x, P1_y, P1_{rot}$).

4.2. Robot – Vision server communication

The application runs two communications threads a TCP/IP server and has also a serial communication thread. Both threads have the same role, they are listening and if they receive an acquisition request, they initialize the execution of the AdeptSight sequence, returning three numbers specifying the position and orientation of the plate (X, Y in mm, and the angle in degrees). The position and orientation is specified relative to the calibration object.

The requests are sent as ASCII characters, and they are of two types (i – information for debugging, or r – real requests), when the vision server receive a request the vision sequence is executed, the object is recognized based on the internal contours, and the values (X, Y and rotation) relative to the initial grasping point (from the calibration procedure) are computed and sent to the robot. In Fig. 7 it can be seen the output in a telnet window.

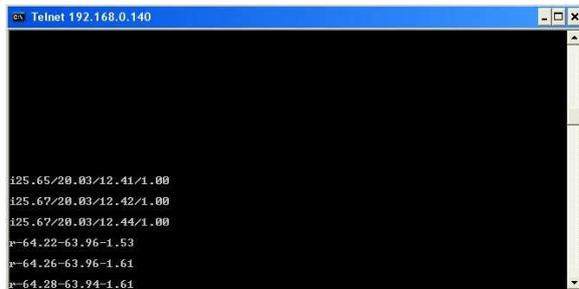


Fig. 7. Communication streams between RV

When the robot receives the three values, shift the initial grasping position (from the calibration) and grasps the plate.

The following code must be part of the main program in order to integrate the communication with the vision server (ABB, 2004):

```
!Open the communication channel (Serial line)
Open "COM1:", COM1 \Bin;
ClearIOBuff COM1;
WaitTime\InPos, 0.5;

!Make a request
WriteStrBin COM1,"r";

!Read the data streams
XData:= ReadStr (COM1 \Delim:="/");
YData:= ReadStr (COM1 \Delim:="/");
AngleData:= ReadStr (COM1 \Delim:="/");
x1:=nXOffs;
y1:=nYOffs;
r1:=nAngle;

!Parsing the data streams
bOK:=StrToVal(XData,nXOffs);
bOK:=StrToVal(YData,nYOffs);
bOK:=StrToVal(AngleData,nAngle);

IF (x1 = nXOffs) AND (y1 = nYOffs) AND (r1 =
nAngle) THEN

!Computing the grasping position
pos:=RelTool (Offs(p1,nXOffs,nYOffs,0), 0, 0, 0
\Rz:= -nAngle);
ENDIF
.....

!Closing the communication
Close COM1;
```

5. Conclusions

The goal with RDA is to reduce the total time, risk, and cost required conceptualizing, designing, engineer, and implementing intelligent automation systems (Dunn, 1996).

The topic approached in this paper was the RDA concept, implemented in a robotized manufacturing plant.

The main problem which had to be solved was to introduce the vision in an already installed solution (without vision), solution which must be stopped a very small amount of time for the vision upgrade.

Also a problem was choosing the vision system, which hat to be a vision system capable to recognize objects (see Fig. 8) of which models must be editable and based on interior contours.

The selected vision system was AdeptSight which is enough robust and has the requested performances, and also can be easily integrated with other industrial equipments.

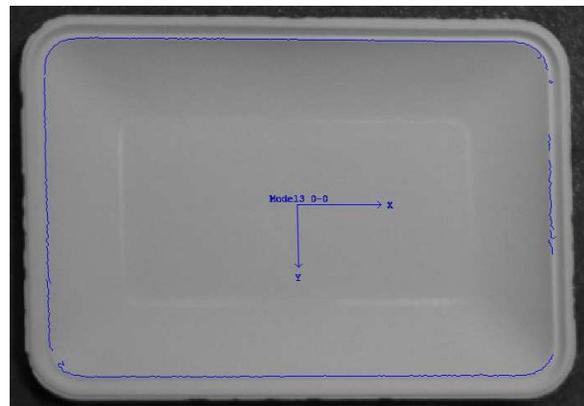


Fig. 8. A recognized plate

The vision system allows a rapid development of the application, based on visual tools which can be combined and configured resulting sequences which can be executed from external C# applications.

Our application was based on C# and managed the robot – vision communication and sequence execution. Also the robot-vision calibration procedure and the grasping model where solved by this application.

The approached solution demonstrates the RDA concept and can be considered as a p.o.f. (proof of concept) in this field.

Using advanced programming tools and the RDA equipments allowed to design build and integrate an elegant, user friendly solution (see Fig. 9) and helped to remove the problems in the production plant and to raise the productivity and the profit in a very short time.

The rate of rejected plates due to bad object grasping and polishing was reduced drastically to almost 0%, the number discarded plates at the polishing stations was not 100% reduced due to others factor such the belt vibrations and due to relatively weak material of the plates (when they are removed from the stencil).

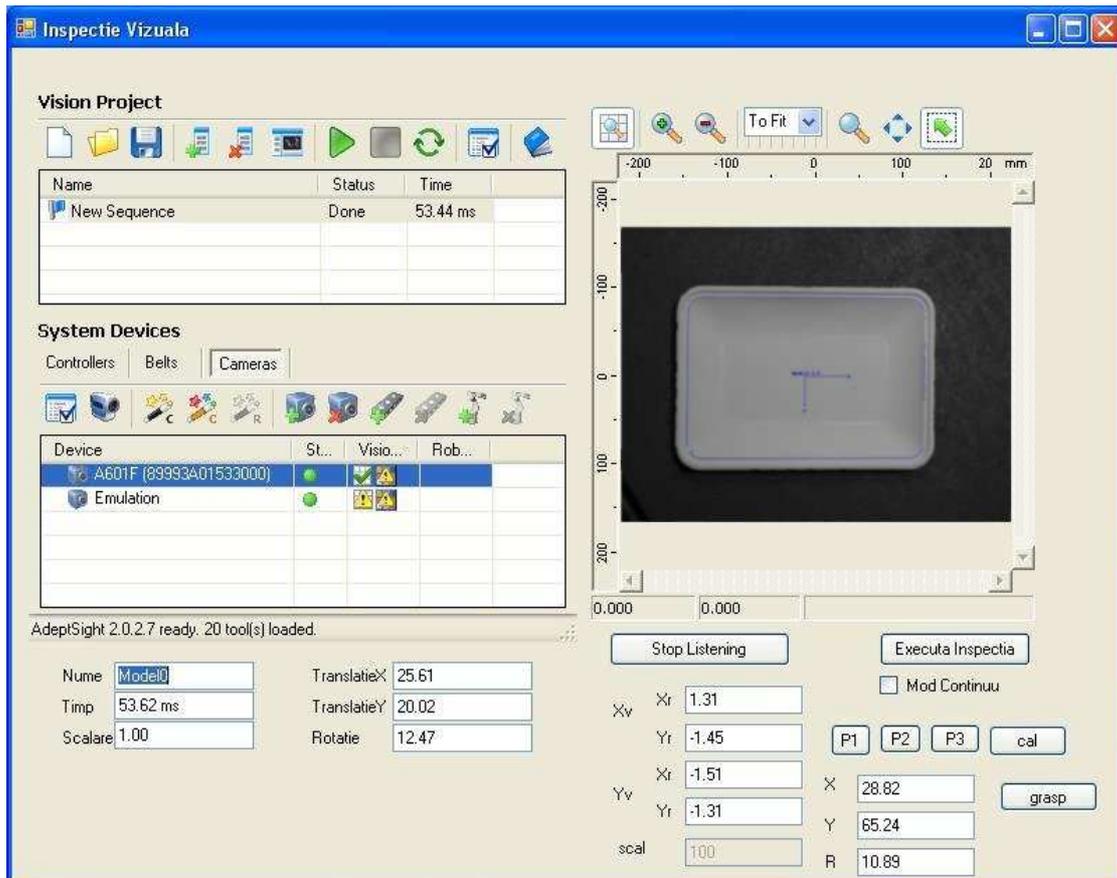


Fig. 9. The application interface

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