Vision-Guided Fixtureless Assembly of Automotive Components

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Introduction

- Fixtures are used extensively to align and hold parts before joining operations.
- These fixtures must be changed when the product is changed.
- The cost of redesigning, manufacturing and installing them is very expensive!
  - $100 million/plant/year for automotive manufactures.

Introduction (continued)

- The goal of Robotic Fixtureless Assembly (RFA) is to replace the fixtures with sensor-guided robots equipped with programmable grippers.

- The RFA concept was introduced in 1988 by Hoska.

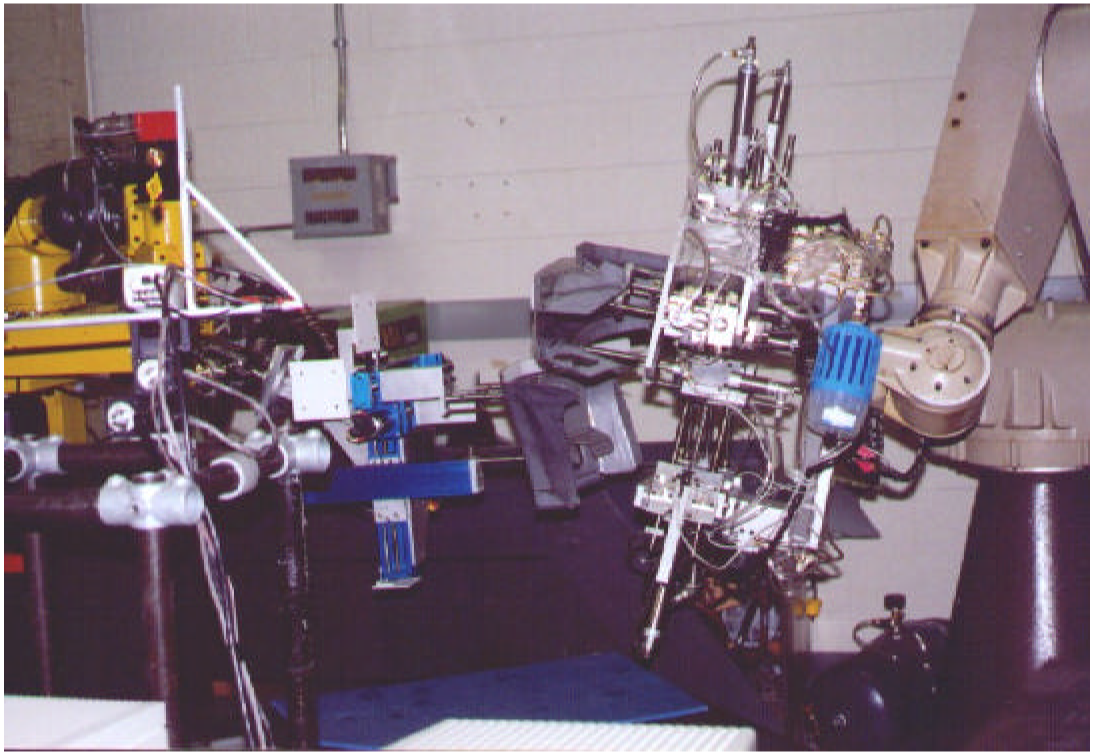
Introduction (continued)

- Advantages of RFA
  - Rapid changeover for new products.
  - Several different products could be produced by the RFA workcell.
  - Substantial cost savings.
- Disadvantages of RFA
  - Technically complex.
  - Software dependent.

Workcell Overview

- Our research group has spent several years developing an RFA workcell.
- The workcell has been designed to be flexible and easily extensible.
- A distributed object-oriented control approach is used to coordinate the actions of the workcell devices.
- We only consider rigid parts.

Workcell Overview (continued)



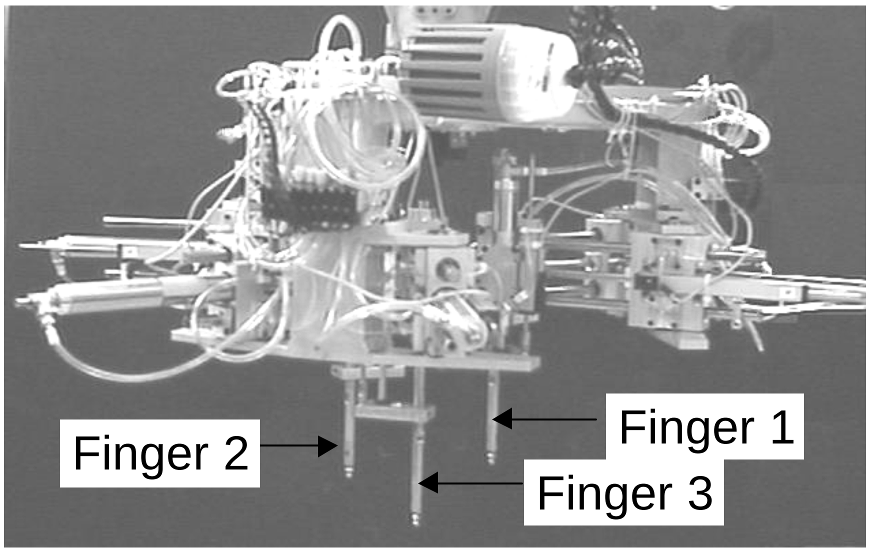
- <u>Workcell devices:</u> PUMA-762 robot, GMF-A1 robot, two programmable grippers, two 2D vision systems, one 3D vision system and four PCs.

Programmable Grippers

- RFA requires a gripper that is:
  - Highly reconfigurable (to handle a wide range of part shapes).
  - Mechanically robust (like a fixture).
- We have developed two such grippers.
- Each has a palm mounted CCD camera used with the 2D vision system.

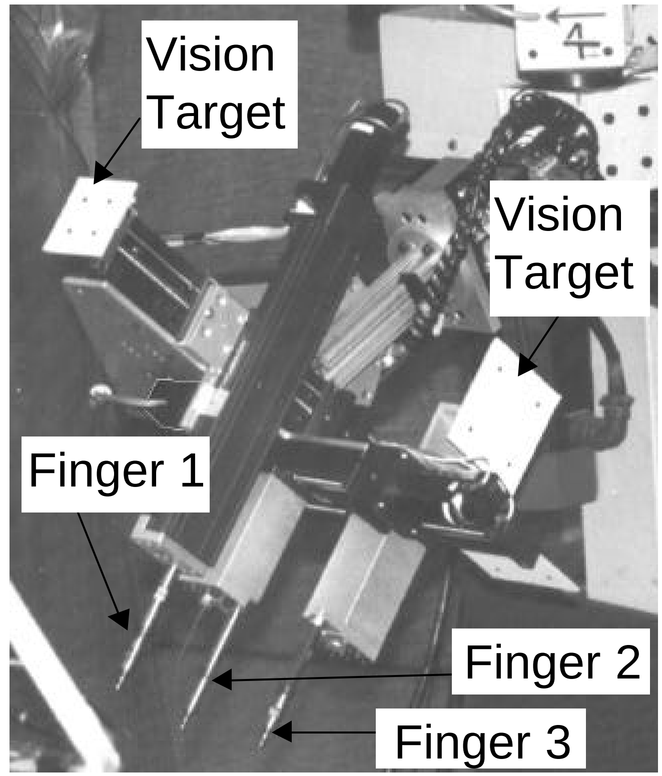
Programmable Grippers (continued)

- Our nine DOF programmable gripper



- Workspace:
  400 mm dia. x 75 mm deep

- Our four DOF programmable gripper



- Workspace:
  200 x 200 x 150 mm

- The fingers are designed to grip sheet metal parts used either holes or outside edges.

Part Locating for Pickup using 2D Vision

- In industry the parts would probably be delivered to the workcell by a pallet conveyor.
- We approximate this by roughly placing the parts on a flat worktable.
- The robot adjusts to the parts' actual position using feedback from 2D computer vision.
- Custom C++ code and the HexSight software package are used to compute the corrections in X, Y, and .

3D Pose Measurement and Correction

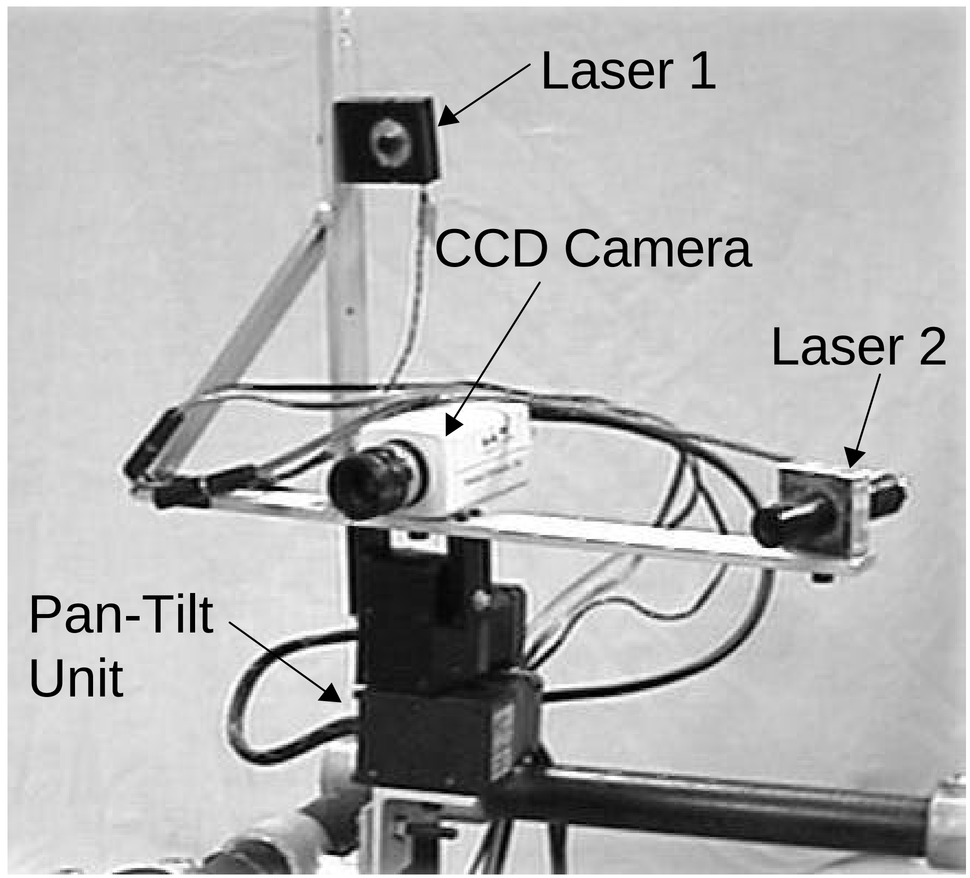
- The desired 3D poses of the parts (i.e. when they are aligned for joining) are taught off-line.

- Errors in gripping and robot positioning cause the parts to be misaligned in practice.

- We measure the actual 3D poses on-line using computer vision and correct them.

3D Pose Measurement and Correction (continued)

- Hardware:



3D Pose Measurement and Correction (continued)

- We have developed two 3D pose measurement methods.
  - Part-Based Pose Measurement: This is the first choice.
  - Target-Based Pose Measurement: This can be used when the part is occluded by another part or by a gripper. It assumes the part has been accurately gripped.

- The pose measurement and correction is performed iteratively on-line.

Distributed Object-Oriented Control

- CORBA, an open-standard for object-level communications, is employed over a 100 Megabit/second ethernet LAN.
- With CORBA, a software object created on one computer can be remotely accessed from any other computer as if it was created locally.
- Physically the objects are distributed over the four PCs on the LAN.

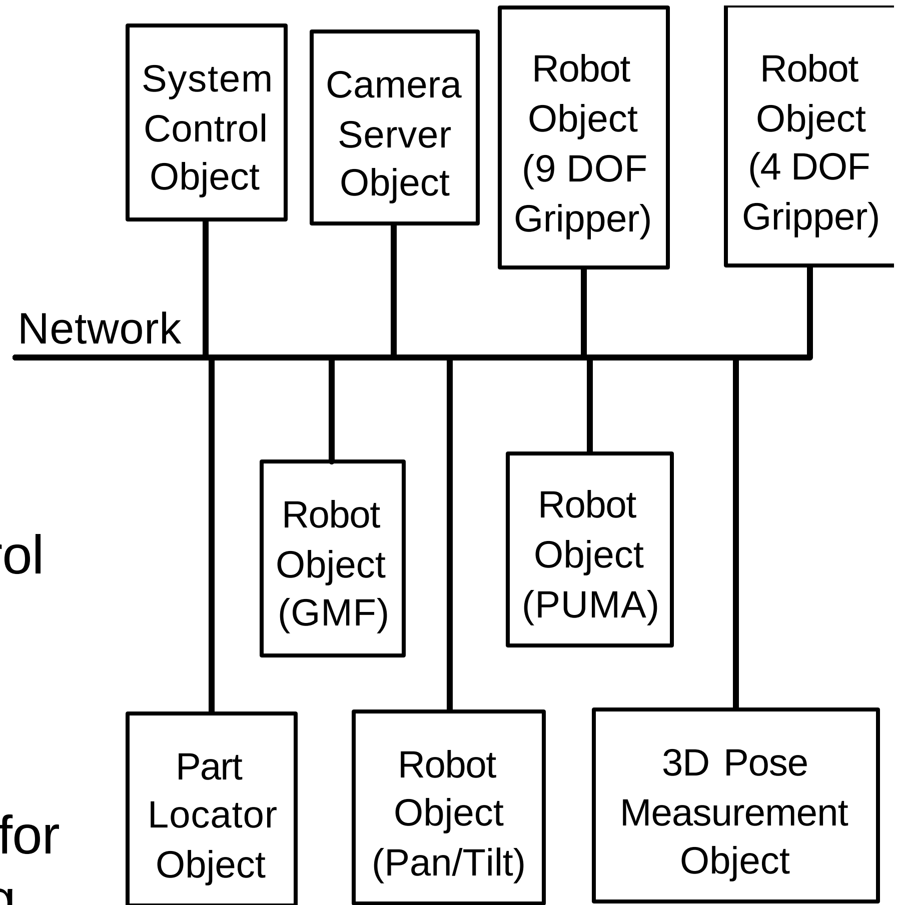
Distributed Object-Oriented Control (continued)

- To simplify the high-level control of the workcell the machine specific syntax of each device is encapsulated within server objects.

- For example, a camera server object hides the specifics of the camera, lens and video capture hardware, and also allows image pre-processing.

Distributed Object-Oriented Control (continued)

- Functional layout ⇒ (Note: two camera server objects are not shown)
- For safety, all robot commands are directed through the System Control Object.
- The sequencing of the workcell actions required for RFA is programmed using CorbaScript.



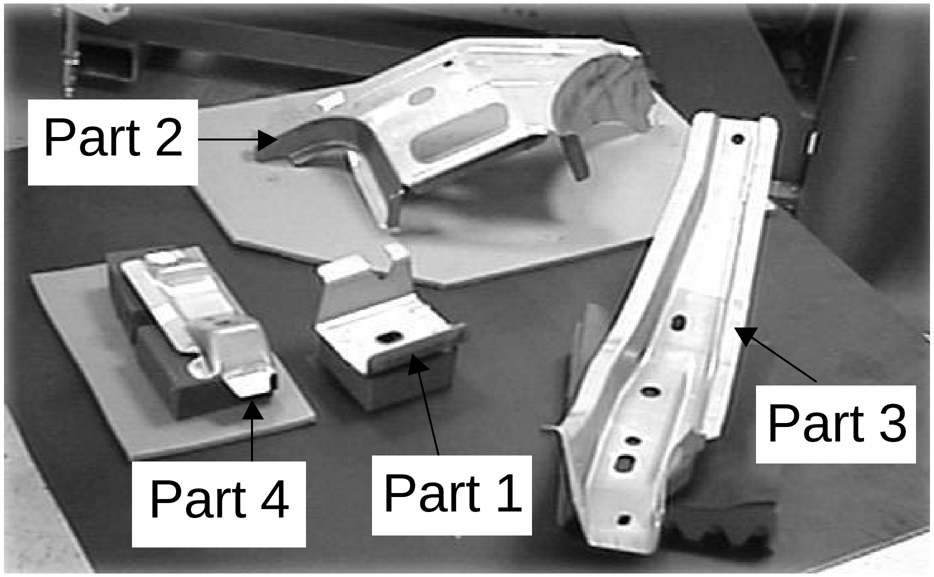
Distributed Object-Oriented Control (continued)

- CorbaScript is a freely available interpreted scripting language that is designed to interact with CORBA objects.

- The use of a interpreted language rather than a compiled one allows much easier program development and debugging.

Experimental Results

- RFA experiments were conducted on a set of four sheet metal automotive body components.
- Each experiment began with the parts roughly placed on a worktable, as shown below.
- The approximate dimensions of parts1-4 in mm are: 150 $\times$ 160 $\times$ 60, 250 $\times$ 640 $\times$ 170, 180 $\times$ 800 $\times$ 200, and 290 $\times$ 110 $\times$ 70.

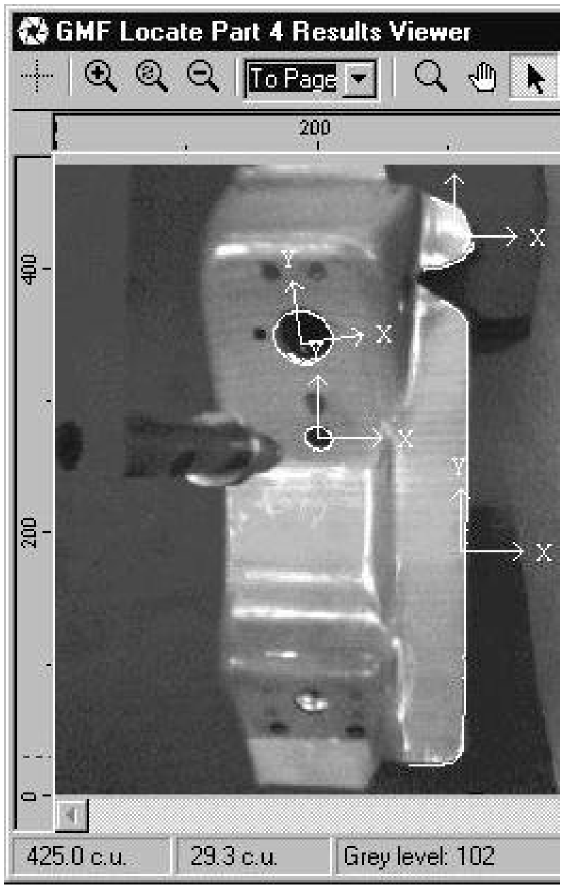


Experimental Results (continued)

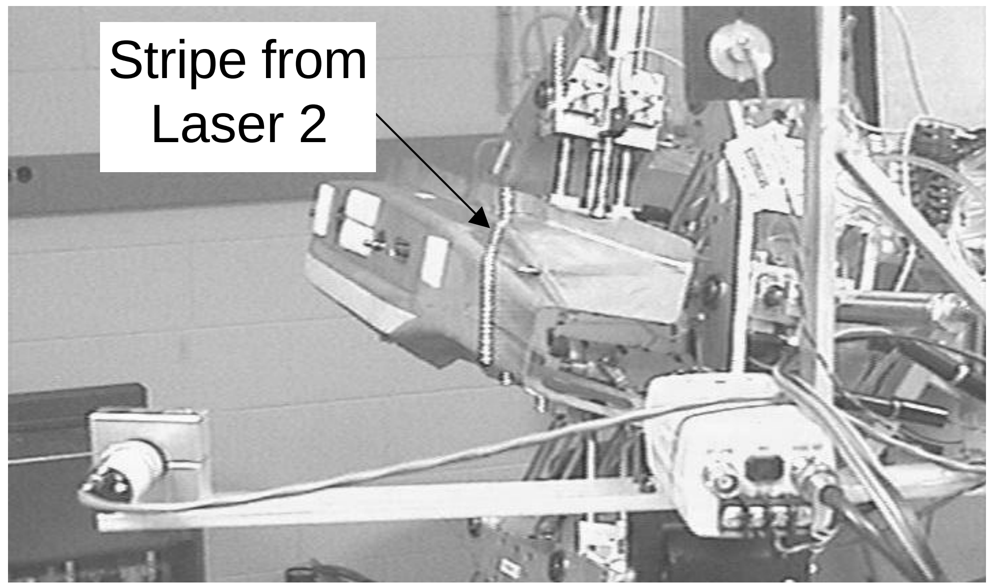
- After they are aligned using 3D pose correction the parts are joined using Velcro. This allowed the parts to be easily re-used.

- The way the parts must be layered in the finished sub-assembly required a non-linear assembly sequence.

Experimental Results (continued)



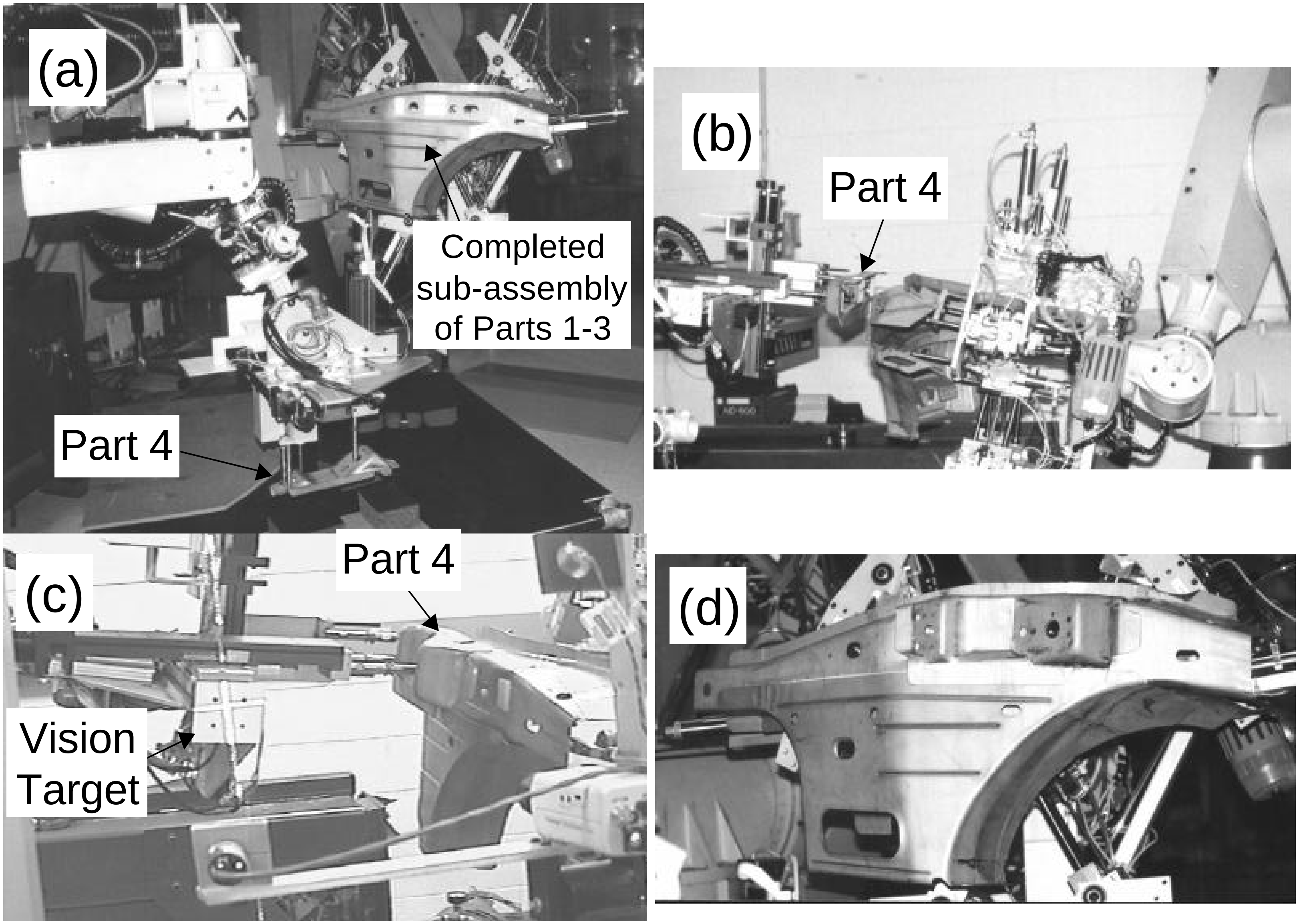
- A 2D vision result for Part 4



- During 3D pose measurement of Part 3

Experimental Results (continued)

- Pickup, alignment and joining of Part 4



Conclusions

- A vision-guided RFA workcell has been developed and experimentally verified.
- The workcell is flexible and easily extensible.
- Work is still required to improve the speed and accuracy of the RFA operation.

Acknowledgements

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