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# Using Ultrasound to Determine Part Orientation in a Feeder System for Assembly Operations

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**Introduction**
The practical measurements described in this report were made at IVF (The Swedish Institute of Production Engineering Research) in Stockholm during May 12 to May 13, 1997. The experiments were made as a cooperative work involving M.Sc. Tobias Byron Carlsson from IVF and Ph.D. Gunnar Lindstedt IEA. The original initiative for the experiment was taken at a previous visit by Prof. Gustaf Olsson (IEA) at IVF. During this visit Prof. Olsson discussed the possibilities for a practical experiment with Prof. Anders Arnström ( IVF and the Royal Institute of Technology) and Tech. Lic. Björn Langbäck (IVF).

**The Problem**
Automatic assembly-operations almost always require full control of the position and orientation of the incoming assembly-parts. This is often accomplished by the use of feeder-systems. The basic principle for these feeders may vary a lot. It is preferable if some kind of order can be kept all the way from the manufacturing of the parts. However, this is often not possible since low cost parts often come in a ”barrel-package”. This leads us to the often referred ”picking from a barrel problem”.

To avoid the picking-operation arrangements are often made to make the objects flow from some input-container into a feeder line. Gravity, shaking and conveyor belts can provide forces that keep the flow sufficiently high and constant. Different mechanical guides may often be used to put the parts in the correct position and orientation in the feeder. However, far from all parts can, by the use of such simple mechanical arrangements, be placed correctly with a 100% probability!

This problem has in many cases led to development of an advanced manipulator that often is highly specific for one type of parts. This is an expensive solution to the problem.

The feeder used in the current experiments at IVF can represent a more cost effective and flexible approach to the problem. This type of feeders is based on the fact that each part has a reasonable probability to get an acceptable orientation when it is thrown out in a random way. The actual orientation is then measured and parts with unacceptable orientation are sorted out and fed back to the input container. The feedback mechanism can often be simple and in the current feeder it is implemented simply by a short impulse of pressurized air that blows the part out of the feeder line. This principle makes the mechanical design reasonably simple and flexible but puts the focus on the measurement problem.

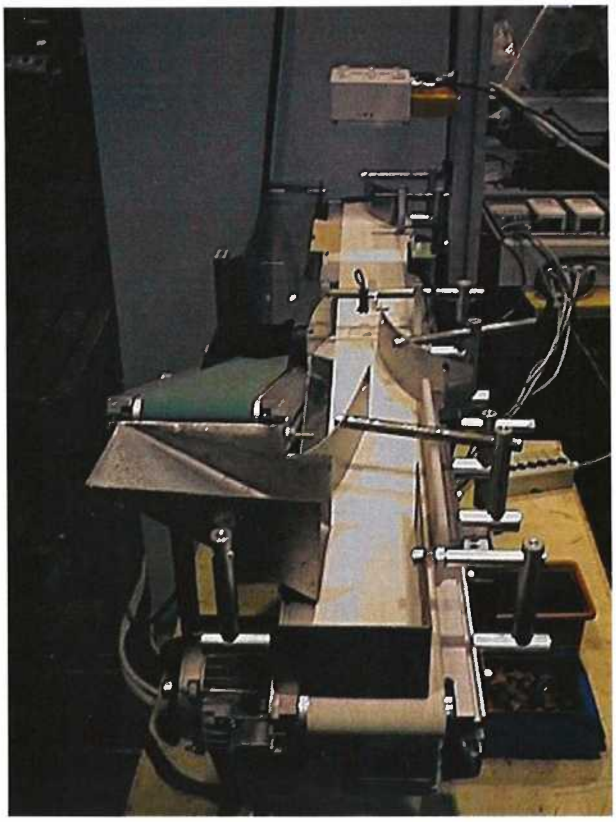


*Figure 1 Overview of the feeder design*

In Figure 1 a picture of the feeder used for the experiments is shown. The used feeder consists of two conveyor belts. The first belt (dark belt to the left) elevates the parts from the input container up to the second positioning belt. At the end of the first belt the objects are tilted over on a slide leaning down to the second belt (white belt in the center). On the second belt the parts are positioned using a few mechanical guides before they go into the measurement position. The pressurized air output is positioned immediately after the measurement position.

The feeder system is built from parts made by the Swiss company Montech. The speeds of the transportation belts can be individually controlled. For the logical control of the system an ordinary PLC from Mitsubishi is used.

In previous experiments with this feeder at IVF binary photosensors have been used to determine object orientation. A number of sensor points (typically two) at different heights along the transportation direction have been used. The dark/light pattern for these sensors related to the belt movement has been the basis for the accept/reject decision. Sometimes a reflection sensor over the transportation belt has been used as well. The current task is to find out whether this measurement problem can be solved using pulsed ultrasound instead of the optical system.

In this experiment are covers for ink-jet printer cartridges used. A cover of the used type can be found in Figure 2. These covers should be placed with their guide pins towards the belt and with their lower part first in the belt moving direction. The mechanical guides make sure that the object always is placed with the largest dimension along the belt. Consequently, the cover can arrive in four different positions. Only one of them is acceptable.

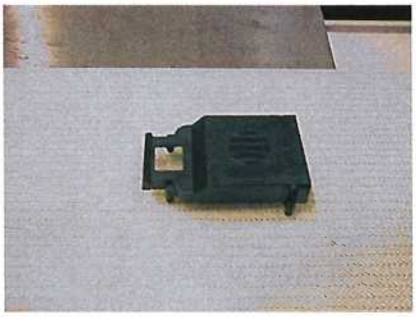


*Figure 2 The mounting detail for the experiment.*

**Purpose and Goal for the measurements**

IVF is currently preparing a report on the feeder system and has an interest in pointing out several possibilities for the detection principle of object orientation. IEA, on the other hand, has for some time developed an ultrasonic measurement unit for automation tasks. This unit is intended to be versatile both by mechanical design and by signal processing capabilities. A task like the current one is thus a real world test on some of the measurement ideas built into the unit.

The goal for the experiment is to find out to what extent the ultrasonic system can replace the optical one in this specific application. Since the systems have quite different natures a direct comparison might be difficult at some points but advantages and/or limitations with the ultrasonic system is of high interest.

**Ultrasonic Measurement Method**

To recognize objects using pulsed ultrasound a method has been suggested in Lindstedt(1996). The basic principle for this measurement is that the received echo is translated from an amplitude function in time to an energy function in time. This energy-function thus forms a "signature" for the reflecting object. Surface changes in the axial direction of the object are easily detected.

When a comparison is made the differences between the current and the reference signatures are computed. Then the sum of the squares of these differences is computed. In this way a simple measure of the matching can be evaluated.

The basic idea for the current measurement is to replace the optical measurement system with a signature based system of this kind. However, a single exposure of an object wouldn't safely detect an error since it only can detect whether the object has got the pins up or down. We also need to know which part of it that comes first.

To solve this we use repeated exposures giving a sequence of signatures. Examples of these signatures can be found in the Figures 4 and 5. The reference will of course be a sequence as well now and the matching is based on the sum of the matching for all signatures in the sequence.

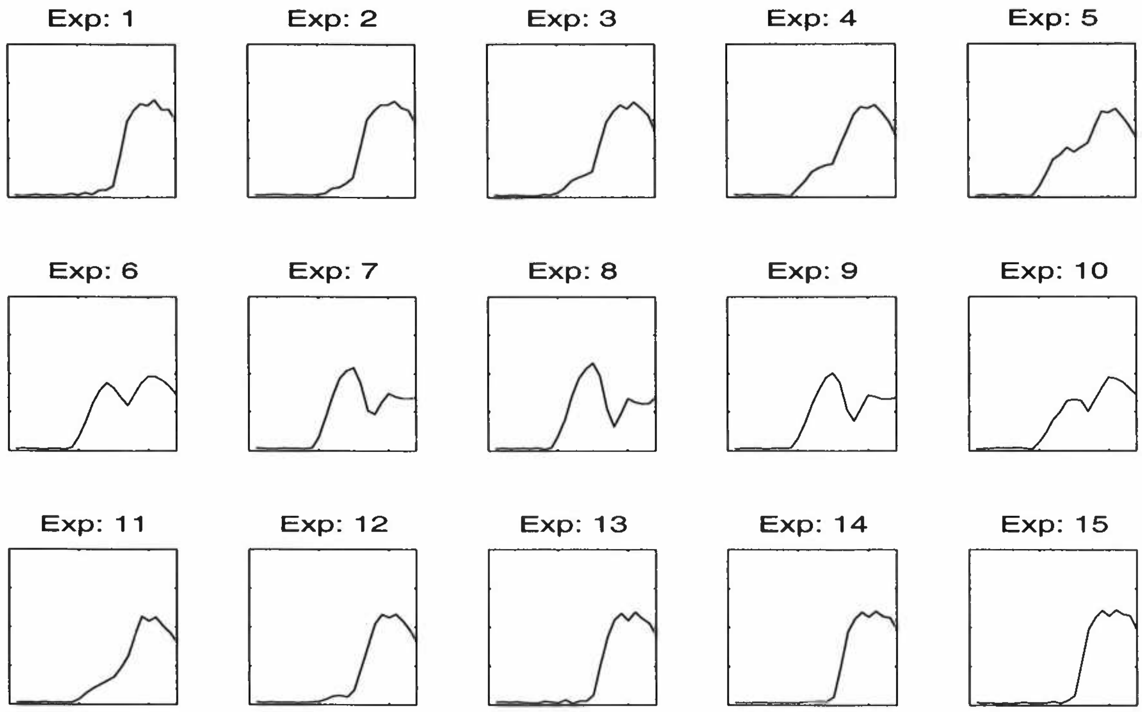



*Figure 3 Signatures from the consecutive exposures as the object passes with the pins down and the high end in front.*

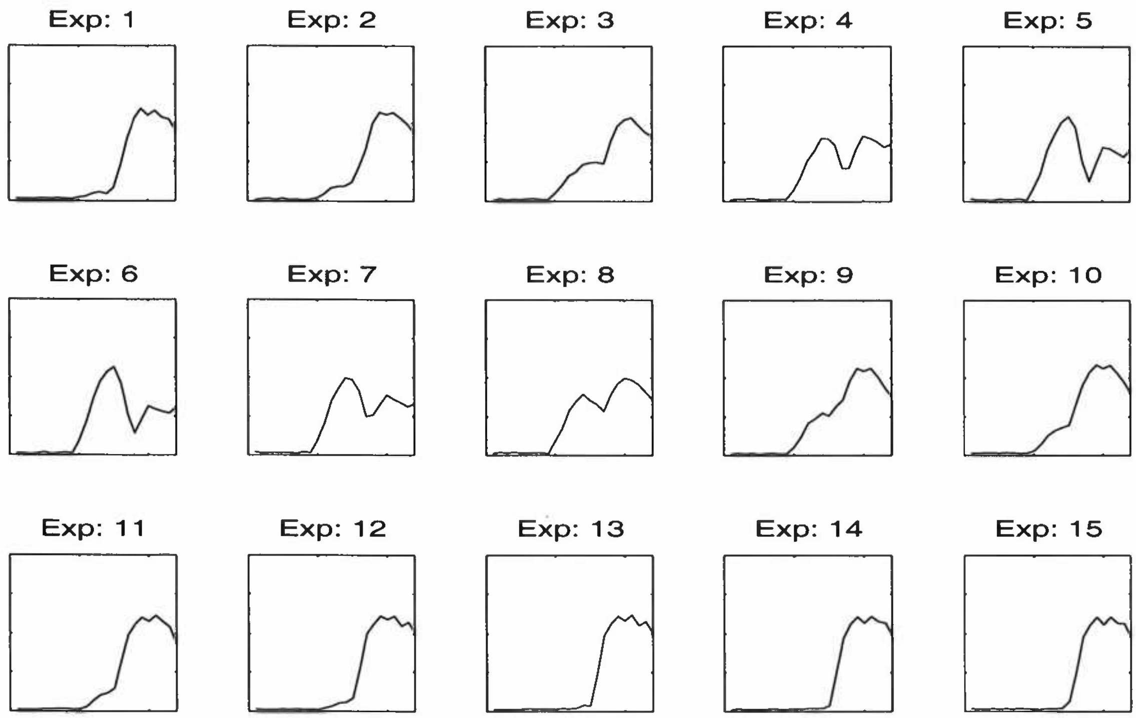
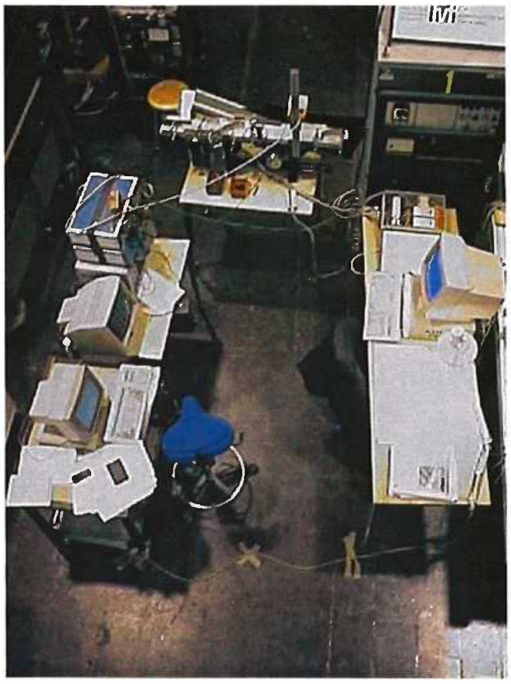



*Figure 4 Signatures from the consecutive exposures as the object passes with the pins down and the low end in front.*

One problem remains to be solved and that is the synchronization of the exposures to the objects movement. An obvious way would be to insert an optical detector that would trigger the ultrasonic system when an object reached a certain position. This is however not necessary since the ultrasonic signal contains a lot of information.

A trigger level in time was set a few millimeters above the conveyor belt i.e. that the echo-signal is only processed during the time from the transmission up to the time when an echo from the belt should have arrived. This means that no echo-signal will arrive unless an object is present on the belt. A trigger level in amplitude was also set to avoid disturbances. In this way the ultrasonic system generated it's own trig-pulse and the measurement principle was ready.

## Experimental Setup



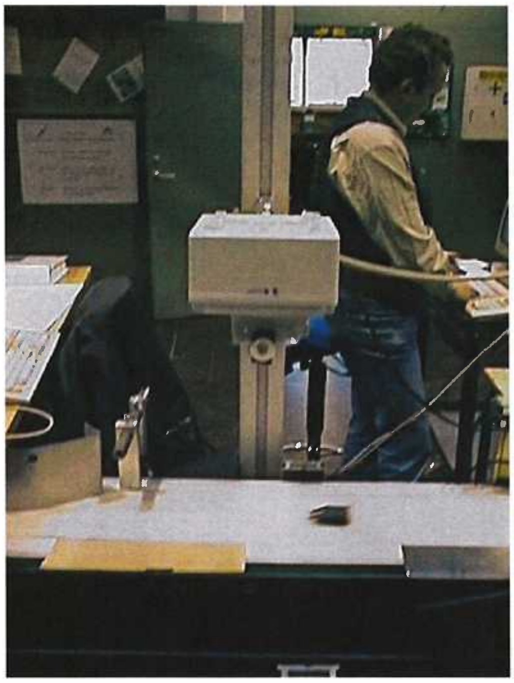


*Figure 5 and 6   To the left an overview of the equipment is shown. To the right an object is passing the ultrasonic sensor. (The box contains five sensor elements but in the measurements described only one transmitting and one receiving element was used.) At the conveyer belt to the left of the ultrasonic unit the outlet for pressurized air can be found.*

In the experimental setup the ultrasonic sensor unit was placed over the conveyer belt. The unit is connected to a VME-bus based computer system. The system is highly oversized for the computation needs of the ultrasonic unit but provides a flexible platform for the programming and the experiments.

The connection of the VME-bus system to the existing PLC-system was very simple. The logical 24V signal from the optical sensors was replaced by a logical 24V signal from the VME-bus computer.

## Results

During the testing we soon got a correct detection frequency of 100%. The system seemed dependable and robust. We soon found out that the system made about five exposures while an object was passing. Probably not all of these were needed for a correct detection. The graphical screen at the VME-bus computer is shown in Figure 7.

However, one phenomenon had been foreseen when the measurement principle was designed. When an object was rejected and thus blown away this pressurized air pulse triggered a new exposure. Since no object was present the recorded echo gave a new impulse to reject and the system continuously rejected objects. This problem can of course be solved by a trigger inhibit while the pressurized air is blowing. However, due to lack of time no such function was implemented. The accuracy of the measurements could be confirmed anyway if the air was not used.

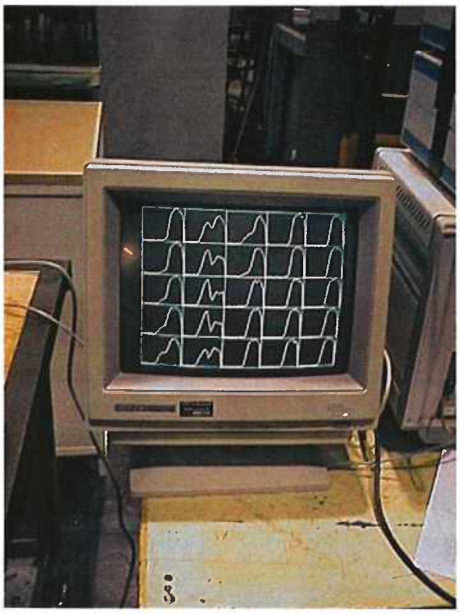


*Figure 7 The graphic screen at the VME-computer showing recorded signatures. The reference and the recorded signals are separated by different colors.*

## Conclusions

The suggested principle works well and has got large industrial potential. The versatility of an ultrasonic echo is emphasized by the fact that the generation of a trigger signal only was a matter of signal interpretation. The sensitivity for pressurized air when working with ultrasonics is well known. In this case however several countermeasures can be suggested.

**Acknowledgments**
I would like to thank M.Sc.Tobias Byron Carlsson at IVF for his enthusiasm and hospitality during the experiments at the IVF lab. I would also like to thank Prof Anders Arnström( IVF and the Royal Institute of Technology), Tech. Lic Björn Langbäck (IVF) and Prof. Gustaf Olsson (IEA) for their initiative that made these experiments possible.

**References**

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