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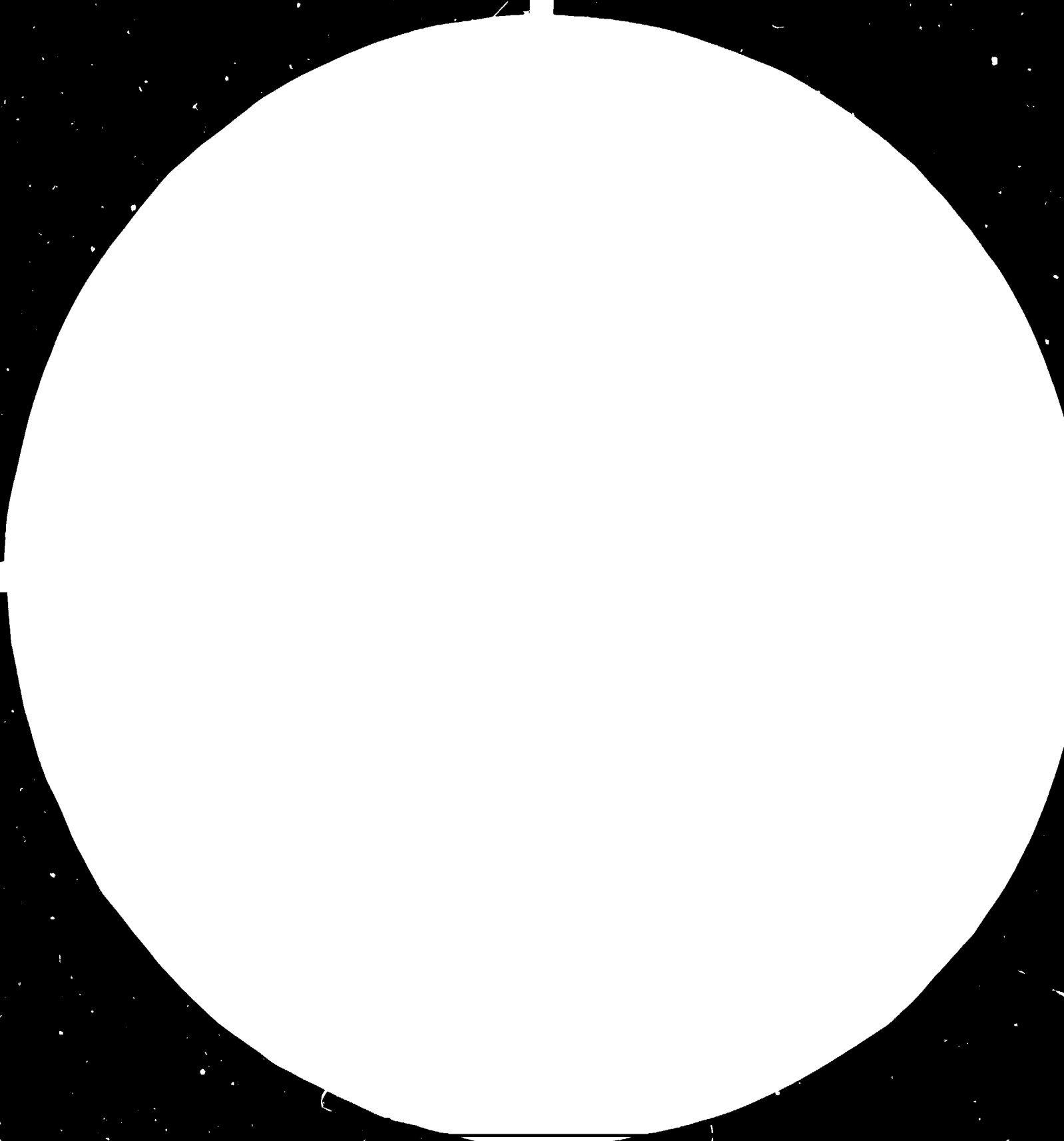


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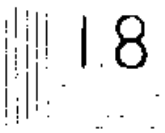
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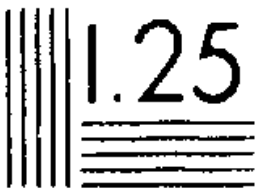
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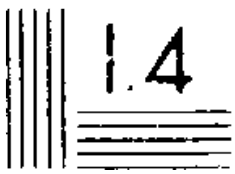
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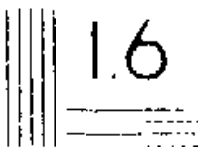
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DP/ID/SER.B/465
25 June 1984
English

Bulgaria.

STRENGTHENING OF THE INSTITUTE FOR INDUSTRIAL CYBERNETICS AND ROBOTICS

DP/BUL/81/002

BULGARIA

Terminal report*

Prepared for the Government of Bulgaria
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of H. Makino,
expert in robots

United Nations Industrial Development Organization
Vienna

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V.84-87809

1. ABSTRACT

The mission of expert on robots was made under the Special Service Agreement between United Nations Industrial Development Organization (UNIDO) and the Subscriber, Dr.Hiroshi Makino, Professor, Yamanashi University, Japan. The purpose of the project is to assist the Institute for Industrial Cybernetics and Robotics (IICR), Sofia, Bulgaria, in the formulation of its technological policy for the development of mechanical systems for industrial robots for welding, assembling and handling operations.

The job had been done in three weeks at the Institute. In the first week basic lectures on the development and control of robots were presented by the expert, and in the following weeks continuing discussions about the IICR's robots had been made. The expert is convinced of that these lectures and discussions are useful and valid to assist the IICR in working out its technolcgical policy for the next ten years on the creation of industrial robcts of the third generation.

A robot is a synthesized system of many components of mechanical, electrical and computer hardware and software. In order to develop the system, development of each component is necessary. By the expert's opinion, a little unbalance of each developed level is observed. By correcting this, a better system will be produced.

CONTENTS

2. KEYWORDS

ASSEMBLY AUTOMATION,
DEVELOPMENT,
FLEXIBLE MANUFACTURING SYSTEMS (FMS),
MECHANICAL STRUCTURE,
ROBOT,
SENSORY FEEDBACK.

3. INTRODUCTION

3A. The Expert

The expert, Professor Hiroshi Makino was born in 1933 in Tokyo. He graduated Precision Engineering Course, Faculty of Engineering, Tokyo University in 1956, and worked for Matsushita Electrical Industrial Co., Ltd. for ten years, and in 1966 he was invited to Yamanashi University as an Associate Professor. In 1976 he was doctorated from Tokyo University and promoted to Professor.

He is the Professor of Precision Engineering and makes several lectures on Kinematics, Machine Design, and Manufacturing Automation. The major subject of his research is on the mechanisms of the assembly machines and robots. He is known as the developer of the SCARA robot.

He was the chairman of the Organizing Committee of the 4th International Conference on Assembly Automation (ICAA), held in Tokyo, on Oct.11-13, 1983, where Mr.Rossen Ivanov, IICR, attended and made the first discussion with him about the assistance to the Institute.

The 5th ICAA was held in Paris, on May 22-24, 1984, where the expert made a keynote speech on "the state-of-the-art of automatic assembly in Japan". In this occasion, after the Conference, he came to Bulgaria for three weeks to accomplish the job.

3B. Schedule

The itinerary and time schedule of the mission was as follows:

25.05.1984

15.35 Meeting at Sofia Airport. Accomodation.

26.05.1984

09.30-10.30 Meeting with the IICR Management Staff.
10.30-12.30 Survey and final specification of the work-programme.
13.30-17.00 Visit to the Pilot Workshop and the IICR sections and laboratories.

27.05.1984 (Sunday) - Free time.

From 28.05 to 01.06.1984

09.00-12.30 Lectures by the expert.(See Annex A2). A detailed explanation was made on the present status of assembly robot in Japan and why and how the SCARA robot was developed. References (See Annex A4) were introduced.

14.00-17.00 Review and consideration of the developments of the Mechanical Structure Department of IICR.

02.06.1984 (Saturday) - Excursion.

03.06.1984 (Sunday) - Excursion

From 04.06. to 05.06.1984

09.30-12.30 Discussions on the future development of Mechanics and Robots.

14.00-17.00 Continuation of the above discussions.
Review and discussions on "ROBCO 03" with the specialized team for Adaptive Systems.

06.06.1984

09.30-12.30 Review and preparation at the middle stage of the mission.

14.30-16.30 Visit to Professor Michael S.Konstantinov, Technical High School for Mechanical and Electrical Engineering.

16.30-18.00 Meeting and discussion with the top managements of IICR, Dr.Vassil Zgurev, Mr.Nedko Shivarov, Mr.Bogdan Stoyanov and Mr.Rossen Ivanov.

19.00 Official Dinner held by Dr.V.Zgurev, Director of IICR.

07.06.1984

09.00-12.30 Elaboration of the project on the Development of Mechanics and Robots at the IICR.

14.00-17.00 A special lecture for the wider audience titled:"State-of-the-art of automatic assembly in Japan both with robots and hard automation" was made by the expert. After the presentation seven films (See Annex A3) were demonstrated.

08.06.1984 Visit to the State's Robot Production Company"BEROE" in Stara Zagora.

09.06.1984 (Saturday) - Excursion.

10.06.1984 (Sunday) - Free time.

11.06.1984

09.00-12.30 Preparation for the report.
14.00-17.00 Discussion and preparation for the report.

12.06.1984

09.00-12.30 Preparation for the report.
14.00-16.00 Discussion with the members of Robot Control Department.

13.06.1984

10.00-12.30 Final discussion on the contents of the report.
12.30-14.00 Official lunch.
14.00-17.00 Free time.

14.06.1984

13.10 Departure from Sofia.
13.35 Arrival in Vienna.

15.06.1984

10.00-17.00 Debriefing at UNIDO Headquarters.

16.06.1984

11.30 Departure from Vienna.

4. SUMMERY OF FINDINGS AND RECOMMENDATIONS

1. The Institute IICR has powerful human resources and a fair capability on developing robotic systems.

2. The developed robots are in fair level in its performance, although a little problem is left in the assembly robot.

3. It is recommended to pour more effort on the development of SCARA (Selective Compliance Assembly Robot Arm) type robot, because it is regarded as to have large market in future.

4. Harmonic Drive reducers is one of the most important component of robot and it is recommended to take some co-operation with the Japanese company, Harmonic Drive Systems Co., Ltd.

5. Sensory feedback systems should be researched powerfully for the third generation robots.

6. Control software is another important problem and there is expected some co-operation between Japanese and Bulgarian researchers.

7. Settling a model plant is recommended and there many surrounding problems will be found and solved.

5. OPINION ON THE PRESENT STATUS

The expert sees the present status as follows:

Bulgaria

Bulgaria is a rather small country in the population of 9,000,000. It is regarded as an agricultural country but now is very eager to introduce modern advanced technology and the Government has the positive policy for the modernization. It is appreciable.

The Institute

The Institute of Industrial Cybernetics and Robotics (IICR) has nine years' experience on developing robots. First, the gantry type transport robot was developed by their own technology, and then some cylindrical co-ordinates handling robots were developed under the license of American (Prab) and Japanese (FANUC) company. Then some types of arc welding robots and spraying robots were developed by themselves, and now many types of assembly robots are being developed. So many developments were done in so short years. It is appreciable.

The Site

The site of the Institute building is now devided into two areas. However, new buildings are now under construction at the site where the pilot plant exists and in a few years the Institute will be united. It is desirable.

Top Managements

The top managements of the Institute are all engineers and very acquainted with the engineering of their specialty and general knowledge. They are all eager to develop advanced robotic systems. It is appreciated.

Laboratory

Research sessions of mechanical, control and systems are all functioning well. It is appreciable. However, the co-operation between these groups seemed to be somewhat imperfect. For instance,

mechanical construction of the prototype model is finished but electrical control is not. The designer of the new robot does not know about the control software, because it is a responsibility of another man.

In Japan, usually, these kinds of developments are done by the "task-force" system. Specialists from each division are gathered in a room, and they co-operate until the job is finished. They know what their colleagues are doing.

Pilot Workshop

The Pilot Workshop of the Institute is now producing patented wire feeders, educational robots, and some electronic circuits. However, the production volume is not so high as compared with the number of workers. It is often a common fault in Japan also, institute workshops are not so busy. More jobs should be given, and more drawings should flow in the workshop. There are a lot of conventional machine tools but there were not seen precision machinery and measuring instruments.

By the opinion of the expert, pilot workshop should be capable of producing precise robots. The machine tools and measuring instruments should be much better than the productive factories' (BEROE's). Prototype of the robot should be more precise and better in performance than the mass-produced ones.

Production Company BEROE

The production company BEROE is well equipped with many machine tools and supported by the well trained workers. It is appreciable.

A problem on the factory is in the low productivity. About 1,500 workers (including officers and research engineers) are producing 150 to 200 robots a month. In Japan the same number of robots are seemed to be produced by 500 persons. But the condition is a little different. In Japan most parts are made by the other manufacturers and bought, while here most parts are produced inside the company. So there should be more value added process and a simple comparison is not seemed to be appropriate.

Comparing BEROE with Japanese machine tool manufacturers, it seems that precision and special purpose machine tools are less

installed. Such machines as jig borer, jig grinder, precise surface and cylindrical grinder, electric discharge machine, electrical wire-cutting machine, gear hobbing machine, gear grinder, etc., are needed. Advanced heat treatment apparatus and precise measurement instruments such as three-dimensional measurement instrument should be more.

Some of the above processes are now made in the other companies. I do not know it is the custom of the socialist countries or planned economics that each function is devived into individual organizations, but it seems better to have more inside power.

Transport, Handling and Welding Robots

Gantry type transport robot, Versatran and Fanuc type handling robot, and gantry type welding robot are seemed to be in the standard level of the worldwide development. Especially the arc welding robot is well supported by the advanced software. It is appreciable.

The movement of the robots in the test running seemed to be a little slower than the Japanese robots. Without measurement it is not sure but it seemed to be 70-80 %. Probably the rating speed is more, and if so the test running should be made in the speed.

Spray Robot

There were seen two types of spraying robot at BEROE Factory. One type is under development and not finished. Some new ideas were observed but to overcome European robot more efforts should be made.

Assembly Robot, Pneumatic

Pneumatic type assembly robots were already developed and saled. They have a fair market for low-cost automation. But the expert believes that this kind of robot will be replaced by the electric driven one because of the reliability, productivity or speed, and of easiness of adjustment and maintenance, Howe er, of course the selection depends upon the customer's preference.

Assembly Robots, Rectangular, Cylindrical and Jointed Type

Prototype modular co structed rectangular and cylindrical

robots were designed in the Institute and now being built. A jointed type versatile robot for assembly, handling and arc welding processes was also designed and being built.

The mechanical construction of these robots seemed to be good except the problem of reduction gears. To avoid the use of Harmonic Drive reducers, they use multi-stage spur and helical gear reducers. For eliminating backlash, they use eccentric bushings. But these techniques need a high precision machining of the gears. Gears should be ground. If the accuracy of the gears is not sufficiently good, then backlash occurs and it causes vibration and noise.

Another problem supposed to be in the controls. The schedule of development of the robot controller delayed, perhaps because of the reliability of the electronic components.

A robot is a synthesized system and the performance of the robot depends upon the performance of the component parts. Development of robot is not only assembling components but also developing the components used.

Assembly Robot, SCARA Type

A SCARA type robot was designed and built in the Institute. The mechanical design of this robot is a little complex and it seems to be able to simplify it if they change the arrangement of the Harmonic Drive component.

For the sake of cost, I suppose, stepping motors are used instead of DC servo motors. But the problem is in the software of the servo controller because it is not established by now.

As the developer of the SCARA robot, the expert hopes to use the best components for the first prototype to accomplish the performance of the robot. It is not denied that the SCARA is one of the most cheapest robots, but at the same time, the robot is the most useful and reliable robot between existing ones. Please check the performance before the cost.

In the case of the development of SCARA at the laboratory of the expert, two major components are used: the Harmonic Drive reducer and Yaskawa's DC motor with their servo units. I relied on the engineering level of these two components. I bought the experience of about ten years of these companies. It may seem curious for a University Professor to use these established elements instead of researching about them. But the problem was not in the component

but to establish a new system. It was needed to develop an assembly robot as soon as possible. Unless, The SCARA robot could not be developed in a short time of three years. The development of the components would follow later. It was the key to success of SCARA.

So the problem is whether they would like to develop: systems or components? If they would like to develop a new system as soon as possible, then they should use the well established and most reliable components at that time in spite of the price.

Harmonic Drive Reducer

The Harmonic Drive is the name of gear reducer which is made by the same name company in Japan. The company bought the license and territory from an American company. Now it is seemed that the quality of the Drives of the Japanese company are better than the mother company's.

In designing the SCARA robot, the Drive is the key element of the robot. The quality of the Drive governs the performance of the robot.

In case of the Institute's prototype, two sets of Harmonic Drives were bought from Japan. The problem is in the cost of these units and also in the foreign currency problem. The payment for the import of the Drive should be done in dollars, while the major customer of the finished robot are the COMECON countries.

It is tried to develop Harmonic Drive in Bulgaria by their own technology. Prof.Konstantinov is one of the most famous professors in the field of machine elements and Kinematics and assisting the project. So in a long term there is a possibility of development of the superior unit. The problem is whether they can wait or not.

Software

There were little discussion about the controlling software of the robot, but the importance of the software is not too much emphasized. The software or controlling programme by the computer relates to the mechanical and electronical hardware of the robot. To develop a good software is a continuous problem of robotic technology.

6. RECOMMENDATIONS FOR THE FUTURE DEVELOPMENTS

Recommendations for the future developments of robot made by the expert are as follows:

SCARA Type Robot

First of all, the finishing of the experimental apparatus should be made as soon as possible. The controller with its software should be finished in the shortest time and experiments on the following items hoped to be done.

(1) Experiment and measurement on the compliance.
It is recommended to prepare some tools and fixtures for the sake of experiments on the insertion phenomena. (for instance, peg-and-hole, and screwdrivers and chamfered tapped hole, etc.).

(2) Experiments and measurements on the motion characteristics.
Displacement, velocity and acceleration of the tool point should be measured. Repeatability or repeatable positional accuracy and the amplitude of vibration should be observed. Standard values for the above are suggested as follows:

Peak velocity at maximum stroke	- 1.5 m/s
Positioning time at stroke of 100mm	- 0.5 s
200mm	- 0.7 s
Repeatability	- ± 0.05 mm
Vibration amplitude	- less than 0.5 mm

The expert is anxious of the speed being low because of the too high resolution. If the resolution (a moving distance caused by a single pulse) is too small, then a high frequency of pulse is needed at a high speed, while the maximum frequency of the stepping motor driver is limited e.g. in 50 kHz and sometimes trouble occurs at the higher frequency.

(3) The virtual cam curve control method (See Ref.5) is preferable. If it is possible, it should be tested.

The expert is convinced that this technique well matches to the stepping motor control.

After the experiments had been done, if it became clear that stepping motor was not suited for this kind of application, another method using DC motor should be tried. But the expert hopes the stepping motor also works well.

It is curious why the SCARA robot is regarded to belong to a different group from other modular assembly robots. It is desirable to treat the robot with the other industrial robots and to apply the same controlling method and apparatus, Or if they are thinking to replace the PUMA-like educational robot by SCARA-like one, then there is another approach.

Harmonic Drive Reducer

The key component of the SCARA robot is the Harmonic Drive reducer. By using this the structure of the machine is much simplified. Because it is the single component between the driving motor and driven arm, the quality of the component directly affects to the performance of the robot. Backlash should be minimum and compliance should be in the moderate value.

As mentioned already, there are several attempts to develop this component inside the COMECON countries. They are the same in function as the Japanese's. But is it same in performance also? For instance, the window glasses at the Institute room are waved. In Japan all glasses are flat. If ever waved the functions are the same. It can shut rain or wind, outside scene can be looked through the glass. However, in performance it is different. A beauty is not a beauty through the waved window glass.

So the expert should like to recommend to tie-up technically to the Japanese company and get know-how on manufacturing. Or it may be better to introduce the factory of the Japanese company in Bulgaria. The expert is responsible for the contact, if necessary.

The easier way is to buy the Japanese component. Because it is the component, they can buy 100 sets by the money corresponding to buy a single complete robot.

Sensory Feedback

After the mechanical structure and the control method

were developed, the next problem is sensory feedback.

Arc welding robots need many sensors. Tactile and sonor sensors are desired to be developed. And for the assembly robot, visual and force sensors are necessary.

In the case of SCARA type robot, by the selective compliance effect there is no need for sensory feedback in an insertion process, so far as the peg is sufficiently strong to bear the insertion force. However, when the pin is thin and easy to bend, then a very sensitive force sensor is needed. And if there were assumed a fair amount of tilting of the peg then sometimes another wrist compliance e.g. RCC may be used. Anyway, to develop a force sensor is valuable to know the state of assembling process.

Visual feedback system is regarded as more significant problem. There are roughly two objectives: one is to find the parts position and orientation at the feeding stage, and the other is to find the exact position of the work when mounting. The former is gross positioning while the latter is fine. For the former application, a versatile pattern recognition method should be developed. It is possible that the cycle time of the assembly process is less than one second, the recognition time should be less than 0.5 second.

For the latter application, a little difference between the expected position and the existing position should be detected, and there often utilized a specified technique for each application. For instance, wire bonder applies a dedicated software for finding the position and where recognition of the error is made in less than 0.2 second.

It is said that at least for the former application 16-bit microprocessor is needed. And it is better to use special IC's developed for the sake of visual processing.

In Japan, visual feedback control is the most active problem between the robot researchers or robot manufacturers. In a few years remarkable progress seems to be done.

Control Software

Control software for the robot is also a big problem. In this point we, the Japanese university professors and research engineers can assist or co-operate with the Institute.

Changing research engineers between Bulgaria and Japan, or possibly changing produced software between the two countries seems to be very effective to develop the robotic systems.

Tooling or Installation

A robot is a standard or versatile unit but for each industrial application the tooling is needed. There needed a variety of mechanical hand and various assembly tools such as screw driver, nut runner, "O" ring adapter, staking head, ultrasonic welder, grease or bonder applicator, etc.

In this field, some Japanese robot suppliers can assist the Institute or BEROE, if necessary. For instance, Nitto Seiko Co., Ltd. is one of the biggest suppliers of SCARA type robot and already has the experience of installation of the robot up to 500 or more. They have some standard working tools and hands. There is a possibility of co-operation with such companies.

Peripherals of Robot

Parts feeders and conveyors are regarded as the peripherals of the robot. So called "Factory automation (FA)", it means a big scaled automation in a factory size, is now being in progress in Japan. There needed many kinds of parts feeders; such as vibratory bowl feeder, swivelling feeder, magazine, parts tray feeder, etc., and many kinds of transfer systems; such as rotary indexing table, intermittent or continuous flow conveyor, automatic guided vehicle (AGV), etc.

Sometimes computerized warehouse is also needed.

The development of these peripherals is as important as the development of robot itself when one should like to automate the manufacturing process. It is desired to have a team for developing such automation facility inside or outside of the Institute.

Model Plant

To clarify the target of robot development , it is recommended to co-operate with some mass production company and make a model plant of automation in it.

As to metal cutting process, BEROE itself is a model plant and already it is well equipped by the robots. While on assembly, there is not yet any model plant. Because assembly is the most fruitful target for automation, it is desired to settle a model plant as early as possible. The following products are suggested as candidates:

(1) Micro switch and relay.
(2) Printed circuit board insertion.
(3) Small motors.
(4) Telephone receiver.
(5) Computer peripherals such as floppy disc driver.
(6) Home electronics appliance.
(7) Small car parts. (It is regretted that there is no car industry in Bulgaria).
(8) Small valves and cocks.

The robots suitable for each application are a little different by the products. That is why settling target is recommended.

The general view of automation may be obtained from the factory sized automation, and of course, computer control for the process should be necessary, where industrial cybernetics and robotics are combined, and it matches to the objective of the Institute of Industrial Cybernetics and Robotics.

7. CONCLUSIONS AND ACKNOWLEDGEMENTS

By the mission, the expert could have general understandings and detailed findings on the present status of development of robotics in Bulgaria. According to the findings the expert made some recommendations and is hoping these recommendations will assist to make future policy of development in the Institute of Industrial Cybernetics and Robotics.

The expert, Prof.Makino, should like to express his gratitude to the related persons who gave the chance of this mission. Mr.N.Shivarov, Director R & D, IICR, and representative of UNIDO in Bulgaria, arranged the whole schedule for me, Dr.V.Zgurev, Director a.i., made useful discussions, Mr.R.Ivanov, Head of Mechanical Design Section, Mr.H.Hristov and Mr.S.Jorev, members of the Mechanical Design Section assisted for the work and guided me for excursions, Mr.V.Ivanov, member of Mechanical Design Section acted as interpreter, Mrs N.Ogorelkova and Mrs.E.Vodenicharova, Administrative Officers for the project, made kind assistance on administrative problems and typed the report.

And I should like to acknowledge to UNIDO for supporting this work and especially to Mr.Aguilar-Bolanos, Project Manager, UNIDO Headquarters, for arranging my visit to Bulgaria.

ANNEX A1

JOB DESCRIPTION
DP/BUL/81/002/11-01/31.9.C

Post title:	Expert on Robots (Design of Mechanical Structure for Industrial Manipulators and Robots)
Duration:	One month
Date required:	As soon as possible
Duty Station:	Sofia
Purpose of project:	To assist the Institute for Industrial Cybernetics and Robotics (IICR) in the formulation of its technological policy for the development of mechanical systems for industrial robots for welding operations, mounting operations and transport operations. To assist the IICR in working out its technological policy for the next ten years on the problems for the creation of industrial robots of the third generation (including elements of artificial intelligence).
Duties:	The expert will be attached to the IICR and will specifically be expected to:

1. Prepare a detailed analysis of the developments leading up to the mechanical constructions carried out by the specialists of the IICR and give recommendations on their future qualifications;
2. Organize seminars with the leading mechanical designers of IICR in order to give a view of the latest achievements in the construction of mechanical systems for industrial robots;
3. Take into consideration the latest achievements of the mechanics of the industrial

robots and assist in working out a new concept of scientific research, as well as the application of the development in the field of mechanics of industrial robots for the next five to ten years;

4. Elaborate, with the help of the above-mentioned specialists on measurements and testing of industrial robots, a project for the selection of equipment for a measuring laboratory for dynamic and static parameters of the industrial robots.

The expert will also be expected to prepare a final report, setting out the findings of the mission and recommendations to the Government on further action which might be taken.

Qualifications: Mechanical Engineer, with extensive experience in the design of a mechanical structure for industrial manipulators and robots.

Language: English

Background Information: Robotics is one of the latest achievements of the scientific and technological revolution. Being a sophisticated complex of the scientific and technological branch, it will bring "life and intelligence" to the direct substitutes of man in production.

The basic task of the IICR is the design, development and implementation of the following:

a) welding robots;

b) application of robots in different fields;

c) training in the field of robot application.

The importance of the Institute is realised by the Government of Bulgaria. The Institute is being equipped with new machines and devices, and the specialists are trained regularly.

ANNEX A2

LIST OF LECTURES

The following lectures were presented by Prof.Makino:

MON. 28.05.1984

09.00-10.40 Lec.1. Philosophy of Assembly Automation.

10.50-12.30 Lec.2. Basic Concept of Selective Compliance.
With Movie No.1 and No.2.

TUE. 29.05.1984

09.00-10.40 Lec.3. Mechanical Structure of the SCARA Robot.

10.50-12.30 Lec.4. Important Components.

WED. 30.05.1984

09.00-10.40 Lec.5. Motion Control Method in the SCARA Prototype.

10.50-12.30 Lec.6. Servo Systems and Elements.

THU. 31.05.1984

09.00-10.40 Lec.7. Kinematic Analysis on the SCARA.

10.50-12.30 Lec.8. Language and Software.

FRI. 01.06.1984

09.00-10.40 Lec.9. Application.

10.50-12.30 Lec.10.Movie Presentation (Nos.4, 5, and 6).

SPECIAL LECTURE

THU. 07.06.1984

14.00-17.00 State-on-the-Art of Automatic Assembly in Japan
Both with Robots and Hard Automation.
With seven 16 mm Movie Demonstration (No.1 - No.7).

ANNEX A3

LIST OF 16 mm MOVIE FILMS

The 16 mm movie films brought by Prof.Makino are as follows:

No.1. "Automatic Assembly Line for Video-Tape-Recorder Mechanisms".
Hitachi Seisakusho Tokai Plant.
In English. 11 min.

No.2. "Precision Assembly Robot - SSR-H Series".
Suwa Seikosha Co., Ltd.
In Englisn. 15 min.

No.3. "High Speed Reflector Lamp Production Line".
CKD Co., Ltd.
In Japanese. 21 min.

No.4. "Cassette Tape Recorder Assembling Line Using SKILAM Robot".
Sankyo Seiki Seisakusho Co., Ltd.
In Japanese. 22 min.

No.5. "Pentel Precision Assembly Robot - PUHA".
Pentel Co., Ltd.
In Japanese. 18 min.

No.6. "Water Colour Packing Line with Robot".
Pentel Co., Ltd.
In Japanese. 9 min.

No.7. "Flexible Insertion Machine with Visual Control".
Hitachi Production Engineering Laboratory.
With no sourd. 3 min.

ANNEX A4

REFERENCES

(1) H.Makino and K.Yamafuji; "State-of-the-art of Automatic Assembly in Japan", Proc. of 5th International Conference on Assembly Automation (ICAA), Paris, May 22-24, (1984), pp 1-22.

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