PRELIMINARY ASSESSMENT OF THE PROFITABILITY OF INDUSTRIAL ROBOT APPLICATION

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PREFACE

A joint seminar on flexible automation organized by IIASA and the Academy of Sciences of the German Democratic Republic took place in Berlin (East) in June 1982. B.B. Katzarov and Tch.M. Christov from the Bulgarian Academy of Sciences presented a paper dealing with an economic assessment of robotization. Their approach can be compared with the procedures recommended in other countries.

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Summary

Innovation is assumed to be a process of linking the capabilities of scientific and technical achievements to satisfy some social needs with the particular contemporary necessities of goods and processes for a certain industry or country. It is reasonable to treat industrial robots as an example of such achievement, and one of the first steps to the mentioned above linking process may be a preliminary technical and economic assessment of the industrial robot application. A way of performing such an assessment is proposed in the paper.

A microcomputer based interactive information management system with a proper data structure suggests some (or no) robots which are appropriate for robotizing a certain workplace.

The appreciation of the robot suitability is made by a technologist and the approved robots are evaluated in a dialogue with the program which shows whether and how far a particular robot would be effective.

The information management system and the program for efficiency evaluation are parts of the consultative system based on PET COMMODORE 3001, experimentally used in IICR - BAS.

Robotization as an Example of Technical Innovation

Various definitions of innovation include two obligatory components: a change of social practice, and the effect of that change. Technical innovation differs from others types of innovations (organizational, administrative, commercial etc.) in the specific way of the caused change in social practice. That is why technical innovation may be treated as a conversion of some new technical capabilities into the means of production, as well as into the consumer goods, which satisfy some existing or caused by these capabilities new advanced social needs. New technical capabilities are thought to be discoveries, inventions and new technical or technological solutions which have never been used in production and consumption, as well as utilizing some already used capabilities in new application areas.

Therefore, technical innovation may be considered as a process of performing some changes which include the satisfaction of proper social needs. For that reason, the interpretation of a technical innovation as only a new product (or a new process) is not complete. The creation of a new product runs in the frame of a particular process, which alters being influenced by the new product, and the realization of a new process requires a proper new technology or new devices. The exploration of technical innovations must embrace all technical and economic alterations in the chain: "science - technology - production - consumption".

The robotization is a bright example of a technical innovation. It is not reduced to a new product only - a robot, neither to a new process only - a robotized way of production, but covers a set of changes in a technological way of production. The technological way of production expresses, first of all, a technological form of people association into a working process, and their interaction with the means of labour. Robotization, in its turn, is one of the major factors of passing into a new technological way of production - automatic production (unmanned technology and production). In this regard, it would be useful to distinguish technical innovations which make a turn in productive forces (such as robotization, microelectronics, biotechnology, optoelectronics) from those innovations which are performed in the frame of the same technological way of production. Further exploration of this issue is out of limits of this paper.

The information management system described in the paper is a comprehensive and properly structured description of a scientific-technical achievement - some models of robots. Certain social needs exist to robotize work places in some technological sectors of the production. These needs might be best defined by a technologist, who knows the particular production. One of the first steps to satisfying the existing necessities is a preliminary technical and economic assessment of an efficiency, or unefficiency, of a robot introduction at a given work place.

Information Management System Structure

There are five kinds of data files, shown on Fig. 1. Two of them named "Additional data" and "More additional data" are physically separated for convinience, but they are of the same logical kind. The "Additional data" is used rarely and the "More additional data" even more rarely. The most used route of data retrieving is: ②→①→④→③ . It is also often used the follow-

DATA FILES STRUCTURES

Id.No. = Identification number.

FIRMS (3)

- Firm's name
- Id.No., Id.No.,...
  (Identification numbers of models, produced by the firm)
- Firm's address

(2) **TECHNOLOGICAL OPERATIONS**

- Technol.Op.No.
  (Technological operations number)
- Id.No., Id.No.,...
  (Identification numbers of models, which performs the technological operation)

(1) **MODELS DESCRIPTION**

- Id.No.
- Basic characteristics of the model.

ADDITIONAL DATA

- Id.No.
- Additional data:
  type of control, type of motion, sensors, memory, power.

MORE ADDITIONAL DATA

- Id.No.
- Kind of teaching, auxiliary functions, description of robot working.

(4) **PRICES OF ROBOTS**

- Id.No.
- Price of robot
- Supplier's (Dealer's) address

(5) **MODEL NAME - Id.No.**

- Id.No.
- Name of the model
  (according to producer)
- Name of the firm, which produces the model.

Fig. 1.

ing order: ⑤→①→②→④→③ ; or ③→①→④ . When the technologist has some preliminary data about some models, or if he prefers some producers, he could begin with file ③ , through ① and then ④ , or he can start at ⑤ , retrieving the name of a model and using the name he can seek in ① (and eventually in ②), then ④ and ③ .

The process of a proper robot searching may not finish with a choice of any robot because of unsuitable prices or producers, or if certain technological operation couldn't be done, or because of lack of adequate place in the floor, insufficient positioning precision etc.

The information management system and the program for assessment are relatively independent of the particular technological process in which robots have to be used. That is why they were created first. The expert in a certain technology can precisely define a proper model of a robot, but he can not be substituted by any program at this stage. Various interactive programs for choosing of proper robots may be written for various kinds of production and plants. It will allow to computerize the middle link of the chain: robot characteristics - description of the given work place and technological operations performed on it - robots applications efficiency. This process of automation is an iterative one and implies changes in the structures and the range of already written programs, as well as linking them with the new programs into a complete program package.

Two books were used basically to specify sixteen basic, in our opinion, characteristics of known robots: JIRA (1982) and Spur et al. (1979). These characteristics are:
- type (intelligent, NC-robot, playback, variable sequence, fixed sequence, manipulator);
- load capacity;
- number of degrees of freedom;
- repeatability (positioning precision);
- weight of robot itself;
- coordinate system (cartesian, cylindrical, spherical, joint);
- six parameters of arm motion (traverses, rotations);
- three parameters of wrist motion (yaw, pitch, roll);
- gripper type.

Technological operations performed untill now by known robots are divided into several groups, but this separation is not, of course, final and full enough. The technological operations used in the data management system are: handling, loading, grinding, polishing, transferring, palletizing, forging, moulding, die-casting, pressing, assembling, arc welding, spot welding, painting, coating, inspection and measurement, heat treatment. There are also multi-purpose robots.

All Identifying Numbers of robots, which perform certain operation are put into a separate record, or into several adjacent file records.

The personal computer configuration, which is used, includes a microcomputer Commodore 3016, a cassette tape recorder and a printer. As most of data management systems our system (named ROBO-DISCO) has a set of commands, which allow: to create and to add new files and new records (ATTACH-command); to change the contents and erase records (ALTER, ERASE); to display records, or part of records, or whole files (SHOW, WRITE, FPRINT, TOP5); to sort records, to sum any numeric data in fields (parts of records) - commands ARRANGE, SUM; to write files on tape (RECORD), and to load files into memory (LOAD); to find records in files (SEEK); and some others (FIN, SERVE, RUN). Three other commands permit to display, or print any part of records, or to mark records according to a certain content of a particular record fields (EXTRACT, SUBSTRING, DISPERSE).

Efficiency assessment

The interactive program for preliminary assessment of a profitability of the industrial robots using follows a method, which is described by Anguelov et al. (1981). The fundamental profitability condition given by Benedetti (1977) is altered to accord to the purposes of our elaboration, and it is expressed by:

$$T_M \cdot C_{LS} > T_R \cdot C_{RS} + T_O \cdot C'_{LS} + C_{REP} + C_{PLAN} ,$$

where

T_M = human production time per workpiece

C_{LS} = cost of worker's time per second

T_R = work-cycle time for robot per workpiece

C_{RS} = fraction of the robot's cost transferred to each workpiece per second

T_O = operator intervention time (seconds) for each workpiece produced by robot

C'_{LS} = cost of one second of operator time

C_{REP} = cost of reprogramming the robot for a new series per workpiece

C_{PLAN} = cost of planned repairing per workpiece.

In regard to the fact that the assessment is a preliminary one, the following formulae are suggested to calculate some of the variables:

$$T_M = \frac{W . H . S . 3600}{N_M} ,$$

where

W = number of workers in a shift

H = working-hours in a shift

S = number of shifts in a day

N_M = number of workpieces produced by a worker per day,

$$C_{LS} = \frac{B_W + S_a + S_s + S_c}{D \cdot H \cdot 3600} ,$$

where

B_W = basic worker's salary per month

S_a = additions to worker's salary per month

S_s = cost of monthly state and social insurances per worker

S_c = cost of monthly social and cultural actions per worker

D = number of work-days in a month,

$$C_{RS} = \frac{R(1+k)(1+r)^m}{N_h \cdot 3600} ,$$

where

R = price of robot

k = a coefficient in range of 0.3 ÷ 0.7

r = rate of interest on bank borrow (if any)

m = years for paying off the borrow

N_h = total number of hours of the robot working (about 5 to 7 years).

The program asks its questions, computes values of variables and, if it is profitable to apply the robot on the workplace, it continues, calculating the cut of the production costs per workpiece, as well as the single cut of the personnel replaced by the robot. The calculations are doing according to the following expressions:

$$\Delta C = (T_M - T_O) \cdot C_{LS} - (T_R \cdot C_{RS} + C_{REP} + C_{PLAN})$$

and

$$\Delta n = \frac{(T_M - T_O) \cdot V_R}{H \cdot S \cdot 3600} ,$$

where

ΔC = cut of production costs

Δn = single cut of personnel

V_R = robot production quantity per day (V_R is assumed to be greater than N_M - the human production quantity per day).

All calculated results are displayed on the screen and may be printed if desired.

Experimental Exploitation of the System

There are some proper workplaces in bulgarian automobile plant "Chavdar" in Botevgrad town, where arc welding, spot welding, painting and grinding robots are to be applied. Six of the workplaces were examined by means of "ROBO-DISCO". Here are some results.

Robot model	Technological operation	Basic salary of a worker B_W	Additions S_a	Number of workers W	Robot price x1000 (leva) R	Quantity $V_R=N_M$	Cut of production costs (leva) Δc	Single cut of personnel Δn
RB-210	coating	250	50	1	20	245	.05401	.92
RB-210	painting	350	45	2	20	7	7.4727	1.91
ASEA	grinding	220	30	9	50	7	25.0592	8.80
RB-232	spot welding	160	25	4	80	28	.80285	3.98
RB-251	arc welding	280	40	5	60	7	15.2583	4.91
RB-251	arc welding	170	30	15	60	300	.83077	14.73

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