# FLEXIBLE AUTOMATION AS A SPECIAL APPLICATION OF INFORMATION TECHNOLOGY AND DIVISION OF LABOUR

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## PREFACE

This paper by Dr. Schüler was presented at a joint seminar on flexible automation held in Berlin (East) from June 8-11, 1982. The seminar was a collaborative project between IIASA and the Academy of Sciences of the German Democratic Republic.

This paper deals with specific changes brought about by the application of microelectronic components in manufacturing automation.

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## The Issue

Two considerations may serve to explain the chosen topic.

All the world over we meet with unanimous consent that we witness a period of tremendous upheavals in production technology today and in the years ahead. There may also be no doubt about it that these will lead to considerable and intrinsic changes in social relations, structures, and modes of life. Albeit opinions differ extremely what kind of turn these changes will take. There are those who believe that technological progress will cure all our ills, whereas others on the contrary see it doom mankind to disaster. "For better or worse" was the heading of the report submitted to the meeting of the Club of Rome on microelectronics in February 1982 (Friedrichs, Schaff 1982). It is now my first contention that we may analyse and diagnose current experiences on the basis of case studies, but no reliable forecasts will be possible unless we try to find out what is at the root of the process we are watching.

To do this - and this is my second contention - we need a clear concept of a methodological approach. Most of what I have read on the subject confines itself, as it seems, to draw attention to one or more characteristic features of technological progress, sometimes singling out one of them as the outstanding, basic and fundamental force of the scientific-technological revolution. As often as not no attempt has even been made to explain why this should be so. Stress is laid on new sources of energy, new raw materials, techniques and/or instruments of labour. In most cases the decisive role of instruments of labour is emphasised.

The latter point of view, e. g., is most forcibly argued by Ebel (1982)against those who prefer to grant a key position to production techniques. He is surely quite right in condemmning all attempts to isolate techniques from instruments of labour, but quoting Marx in support of his views he forgets that in volume 1 of "Capital" (Marx edn. 1962) the analysis of the labour p r o c e s s precedes the analysis of the development of instruments of labour. Furthermore Marx's analysis of the industrial revolution may serve as a good starting point in the quest for the methodological tool to solve our problem.

Generally speaking every process of labour is a process in which man acquires objects of nature and adapts them to his use. This process is an entity of transformation of matter, energy and information, and at the outset consequently expense of labour is simultaneously expense of physical and intellectual faculties. Benjamin Franklin aptly defined man as a "toolmaking animal", and during the neolithic agrarian revolution he learned not only to pick up or hunt whatever nature would offer freely, but to systematically cultivate, i. e. produce.

As long as simple tools dominated in production, division of labour did not affect the initial unity of physical and intellectual labour in small scale production. Where they indeed were separated in slave-owning modes of production, reducing slaves to be an "instrumentum vocale", this in the long run proved to be inefficient at that stage of development of productive forces.

The second significant revolution of technology was brought about by the industrial revolution. With the advent of machines complex technical equipment could be employed to effect the transformation of matter and energy, releasing man from most of physical (manual) functions of labour, thereby raising the scope, scale, productivity, precision etc. of these actions by more than one order of magnitude. Control as transformation of information remained mainly with the operator of the machine, although as science progressed to mature into an independent and ever more important productive force, higher intellectual functions were separated from the worker in the workshop whose tasks in most cases were not only deprived of scope of physical, but also of mental activity. The industrial revolution swept aside all impediments to the evolution of capitalism, effecting with a new division of labour between man and machine a new social division of labour and a new social structure. The resulting social conditions are too well known as to merit to enlarge upon them.

In analogy it seems fairly evident that modern information technology now enables us to convey intellectual functions of labour to machines on a similar scale as the industrial revolution did for physical operations. And a closer look will reveal further similarities between the two revolutions. The mechanisation of physical operation was made possible when internal division of labour in manufacture as described by Adam Smith (edn. 1937) split up complex jobs into simple elementary operations. Since these implied regular and geometrically uniform movements of tools, it was not any too difficult to attach the tool to a guiding mechanism and to drive this either by hand or any kind of engine. A fairly universal possibility of technical information processing was found by subdividing complex tasks into elementary (binary) logical operations which can be implemented technically by any kind of bistable device. The introduction of electronics and particularly of microelectronics led to a level of performance to make technical computation a feasible proposition on major scale.

I take technical information processing to be the more general concept in relation to automation, a) because its field of application is much more ample than production processes, and b) it enables us to understand the new quality of flexible automation.

## Flexibility, Control and Division of Labour

Automation, of course, is much older than our contemporary information technology which itself has its ancestors. Automata are reported of far back in history. They accompany the history of technology mainly with open loop controls up to the present. Watt's centrifugal governor is the classical example of a feed-back control. If we consider NC-machines to be flexible automation, then the "punch card" controlled Jacquard loom belongs to that class of machinery. In all these cases some sort of control handles and transforms information to some degree.

What then, we may ask, is the new dimension of our contemporaty notion of flexible automation? Evidently a new quality of control is achieved by the quantity of informations processed, or more precisely, the number and kind of process parameters controlled and the speed of computing.

The number of process parameters of a machine tool is fairly limited; their control may with some liberty be compared with the task of steering a rail bound vehicle. Supposing no feed-back to be needed, control may be achieved by punched data carriers in much the same way as Jacquard used for his loom. Quite different a proposition is the control of a robot that is expected to carry out movements similar to those of human limbs. According to our analogy its counterpart would be a trackless vehicle. And the barrier to complexity between the two examples can only be overcome by the universal possibilities and the speed of electronic computing, the microcomputer enabling widespread application.

The possibility of technical information processing required in all sectors of society on a mass production scale leads to far-reaching changes in the division of labour, just as progressing division of labour multiplies the needs for communication and information processing.

The division of labour between man and machine is changed fundamentally: A man-computer-machine system replaces the man-machine system. In this pattern a new component appears, communication between man and technical artifacts as well as communication between such artifacts themselves. This new quality of more or less intelligent machines has not only significant economic and social effects, it also leads to remarkable psychological results. Own observations for instance confirm that operators tend to personify the instrument they have to confer with, they accept it as partner, colleague, "pal" to be nicknamed etc. We must of course bear in mind, that in the GDR social security is granted and their job is not threatened. Under these circumstances and even in such cases where they are relieved from skills and decisions formerly needed, they often do not feel their work to be downgraded and take pride in the fact to be master of such a modern, beautiful and efficient equipment that multiplies their own capabilities. This communication between man and machine may well prove to contribute to an enrichment of personality, as long as it does not alienate the individual worker from his fellows, pushing human intercommunication into the background.

At the same time social division of labour is subject to changes not only within the workshop or bureau, but between sectors of economy and within the whole social structure. Evidently this paper cannot survey the entire problem, lacking not only space but also knowledge to tackle such a task. I must confine myself to regard some few questions prompted by the working paper submitted to our discussion. (Haustein, Maier 1982)

## Flexibility of Automation and the Pattern of Man-Computer-Machine Systems

If we admit the quantity of informations to be processed within a time unit to be the distinctive feature determining the properties of the control system, it logically follows to be uneconomic to overelaborate the control beyond the requirements of the process. On this issue we find ourselves in full agreement with the working paper mentioned. It is just as wasteful to leave unused instrumental skills as it is wasteful to leave human skills unused. However two restrictions have to be introduced. Human education is not only and perhaps not even mainly a capital investment to be exploited in production, but - economically speaking - consumption, enrichment of personality, enjoyment to be employed indeed, but not solely in working life. Under socialism education is not only an individual but a social aim and it must not be curtailed because of imperfections of a technology unable to fully utilize it. The arising contradiction has to be solved the other way round by developing technologies to suit human nature and progress.

Now this does not apply to technical equipment and cannot serve as a justification for unused capacity of controls. But another consideration of quite practical importance arises. When replacing old equipment it is economic good sense to keep in mind not only the requirements of a current production mix, but also future requirements that may arise during the lifetime of the new equipment to be installed. But within this framework the initial assertion will hardly be questioned.

Yet I would not connect the requirements to be met by controls with the innovative properties of the product or the size of production batches as the working paper does. On the one hand it seems hardly justified quasi implicitly to connect batch size and age of products. There are quite traditional products that come in small and smallest batches whereas some products with a very high innovation rate will very quickly grow into mass production scale and must do so just because of their high rate of obsolescence. Moreover there may be many reasons to apply flexible automation in the production of traditional products. Robots find quite ample application in automobile production. In Japan the automobile industry alone had a share of nearly 30 percent of all robots employed in 1980 (Yonemoto 1982), and Ford produced motorcars in mass production early in this century.

Therefore a different approach appears to be indicated. Following our train of thought the logical conclusion leads to an analysis of the process in each individual case, the capacity of the control system depending on the following properties: the number of process parameters to be controlled, the measure of their deterministic or stochastic character, their measurability, the degree to which they are theoretically known and can practically be influenced and controlled.

In Fig. 1 successive structures of automation are modelled in view of information flows between operator, controlled process and control. The material and energetic (production) process consumes a number of inputs $x_i$ (production factors) and effects a certain output $y$ (product). It is influenced by a random vector $z_j$ of environmental factors. This system performing some kind of physical process is controlled by an information-processing system that may include an automatic control system and a human operator. The performance is supposed to meet certain goals, formulated in instructions (G) given to the operator or control system by some external authority. The information-processing system receives informations (M) from the physical process that may be measured values or observations. The physical process is regulated by informations it receives from the control as regulating variables (R) and/or from the operator interfering with actions (A). Finally the automatic control will as a rule transmit signals (S) to the operator to inform him about performance criteria of the physical system. These can vary from simple warning signals in case of deviations exceeding permissible tolerances to already computed results of processed measured values, diagnosing causes or recommending actions. The dashed lines shall indicate information flows occurring at irregular intervals in case of need or for sampling inspections.

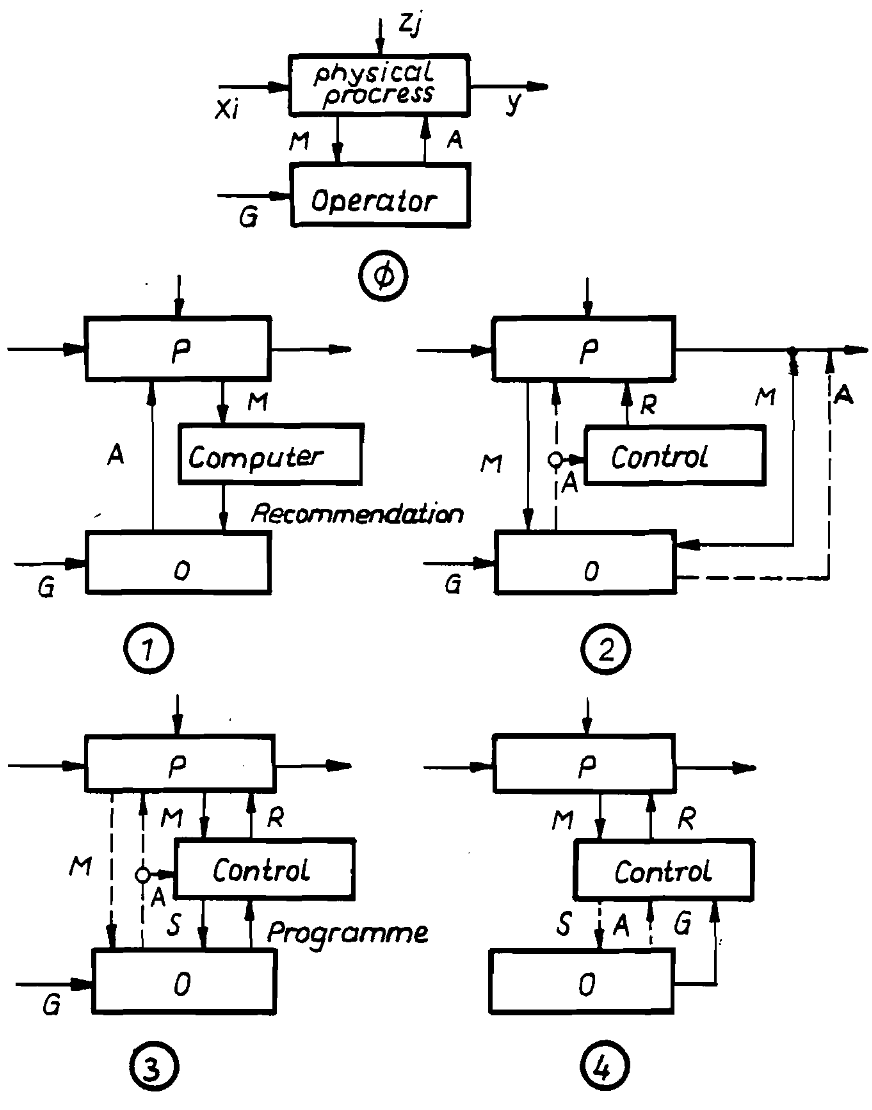


Fig. 1. Stages of automation

Fig. 1 represents five distinctive stages of control. Stage Ø shows the model of a mechanised process in which the operator regulates the physical system without the aid of any technical control system. Stage 1 may be regarded as a first step to automation with very interesting characteristics we shall presently regard more closely. It represents a computer aided control by the operator, a typical instance being computer aided diagnosis in medicine. The following stages 2, 3, and 4 model, in that order, open loop control systems, feed back and adaptive control systems.

The reader will hardly need the aid of verbal explanations to understand the meaning of the graphs. But as previously mentioned, a closer look at stage 1 may be worthwhile. In this case flexibility of control is secured by the operator himself, as decisions and control actions rest with him. But he does not base his decisions on his individual knowledge, skill, and experience alone, he can rely on the memory of the computer, a kind of socialised memory comprehending the experience of a much larger number of preceding processes. The computer is fed with process parameters of a statistically representative number of cases and correlates these with the frequency of good or bad results. Such a procedure has the following advantages: a) It enables the analysis of black-box systems by the use of statistical methods, b) the computer recommends promising strategies under given circumstances to the operator, c) the decisions taken by the operator are made more reliable, d) the final choice of strategy rests with the operator which is very important in the case of unusual conditions not accounted for by the averaging of past experiences. Evidently such a computer aided operative control is best fitted for processes subject to many parameters of complex character not completely known or controllable, such as certain chemical and metallurgic processes, flood prediction, a.o., or, as already mentioned, medical diagnostics. (Mezynski, Seifert 1981)

But there is another point to be made: The responsibility and decision space is not taken away from the human operator, whose skills and functions are not downgraded, although training can be speeded up considerably.

Economic efficiency and technological progress do not allow the unquestionable merits of such a man-computer-machine system to stand in the way of more advanced stages of automation. Yet it is clear that new problems arise we must be aware of.

<u>Computer Integrated Manufacturing Systems and Division of Labour</u>

In the same measure as automatic control systems carry out decisions and do it more efficiently than persons, the human being tends to become dispensable or even a disturbing factor in production. What are we going to do with him?

Temporarily perhaps trade union agreements or other considerations may put a brake on introducing such technology in order to save jobs or skills, but this will not durably solve the problem. Rada (1981) put it like this:

"We have, then, two silmutaneous and contradictory tendencies. On the one hand, fear of unemployment could slow down the diffusion of the technology; on the other, a failure to adopt the technology could create unemployment." (P. 72)

Apparently in competitive market economies a situation arises in which doing and leaving undone cause the identical result: redundancy. Now this does not apply to socialist economies. It is sometimes argued, this was due to lower productivity, but this cannot convince, since low productivity, as Rada argues and experience confirms, is no cure against unemployment under capitalist conditions. So the cause must be sought for rather in economic and social structures than in the labour saving effects of technologies. It is the business of technological progress to save labour, and this aim is invariant to social order. A simple calculation will show, that, other things being equal, unemployment will be caused if the growth of productivity exceeds the growth of production. As long as goods are scarce in relation to wants, the efficiency of an economic order should be judged by its ability to raise production as fast as productivity will allow.

Assuming the worker does not lose his occupation, how will a fully automated system affect his functions, while little or nothing is left for him to do except perhaps some supervising from time to time. In the first place attention has to be drawn to the fact that a man-computer-machine system does not necessarily achieve optimal performance, if **all tasks better done by the computer are left to the computer** to do. A system's performance depends on the performance of all its subsystems, and the gain on one side will not necessarily compensate losses on the other. Optimizing the system in a one-sided manner in the direction of technological possibilities without regard to the human factor must not render the best results. (Rasmussen 1980) This encharges designers with a new quality of responsibility to think not only in terms of technology but beyond them up to social consequences.

We must also in this connection refute all opinions claiming a certain technology to lead inevitably to a determined division of labour. On the basis of case studies a trade union investigation in the FRG concludes that there is no clear answer, "Yes" or "No", to the question, if adoption of robots will favour the interests of employees. It is reasoned, that apart from labour-saving effects robot technology has no strictly defined positive or negative effects on jobs, it all depends on how technology is applied. (Kasiske et al. 1981)

However, what is going to happen to our operator if production cannot grow as fast as productivity? Two conditions could cause such a situation. The growth of production can be impeded by limitations of a market unable to absorb the products, i.e. demand falling short of supply; or hypothetically production could exceed not only demand, but human wants. The first case is a very real problem facing capitalist market economies with the very real threat of growing mass unemployment. Sometimes the hope is expressed, this might only be due to a transition period of adaption to new technologies. These would eventually develop new products opening new markets and creating employment. Such an argument forgets that a market can only be established if supply is matched by demand. Surely a new product may create a new demand for this specific commodity, but unless buying power will grow in proportion, demand will only shift from one commodity to another.

There is no need to stress that a situation in which some are condemned to idleness while others must work hard for their living is intolerable. Yet here again it is argued that this state of affairs is only due to maladjustment of society to modern technologies, sticking to outdated patterns instead of admitting that distribution of incomes should no longer be tied up with participation in social labour. Actually such an admission would not mean anything but a social acceptance of unemployment. The division between labour and enforced idleness could be altered by shortening working hours and dividing leisure time more humanely. Even this will require adjustments of modes of life, learning to use leisure to advantage. Modern technologies including automation invading consumption will inevitably confront society with such tasks.

The vision of a future society of abundance in excess of wants may seem far-fetched in a world where three quarters of its population can only secure survival, if at all, at a bare minimum. It cannot be denied however, there seems to be logic in the conclusion that automation will eventually dispense of human labour. Schaff, among others, at least, thinks so, stating that work will then be replaced by other human activities, such as social services, sciences, arts, games, etc. According to his vision "homo laborans" will be replaced by "homo studiosus", remaining "homo ludens" as well. (Friedrichs, Schaff 1982)

To me a society of playboys - with whatever earnest endeavours to kill their "spare" time - seems highly unlikely and moreover undesirable. Of course, it all depends on what we want labour, work and leisure to mean. In the same measure as work can take on humane properties the boundaries between working time and leisure time will recede. Undeniably automation will shift occupation from direct production to phases preceding production such as research and development, etc. as well as to phases following it such as service sectors, also to education, culture, etc. But no matter how, man will not cease to act upon and fashion his natural and social environment according to his goals, and if we want mankind to survive, all technologies will have to serve this end.

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