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Analytic Consideration on Real-Time Assembly Line Control for Multi-PCB Models

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The improvement of the production capability of multi PCB assembly line can not be simply done by improving the capacities of each assembly robot cells but must be done by controlling the production line effectively with the line host computer which controls over the whole assembly line. A real time production control, a real time model change and a real time trouble shooting compose the specific concepts of this technique.

In this paper, we present and analyze the definition and application mothod of real time assembly concept. The meanig of real time model change, troubles and error sooting and its algorithm will be introduced. Also, the function of the host computer which is in chgarge of all of many different tasks mentioned above and the method are presented. The improvement of the productivity is mainly focused on the efficiency of multi-PCB production control. The importance of this aspect is gradually increasing, which we have presented the analysis and the solution.

1. Introduction

In order to satify various customer's interest in modern markets, it is certainly necessary to change the production style for various kinds of goods to meet the short life cycle. In this point of view, the efforts to increase the production rate by means of multi-PCB assembly line are nowadays remarkable with the help of FMS. In this thesis, we propose a real time control system for a CIM oriented PCB assembly line and the system construction from the point of view of multi PCB production system. Also the structured development process for the real time control system will be described.

2. System specification for the real time line control

A PCB assembly line is constructed by several cells in which robot, feeder and conveyor are included. These cells should be connected by a line integration controller in order to achieve one integrated job. An organic integration methodology of each cells doing independent job will be pointed out in the following sections with the help of a line integration computer. The multi-PCB production capability with analytical diagnosis plays an important role in our concept of system construction.

In these days, CIM oriented production information monitoring and database handling for hiararchical approach from the higher level, recognition of customer's interest to lower manufacturing level are necessary for more efficient factory management system. We bulid , therefore, a database management system for remote moritoring of the production information and the production scheduling from the host computer by means of LAN.

3. The concept of a real time multi flow control sytem

The multi flow control makes it possible to produce multi PCB models without time delay for changing the system layout. It's meaningful to compare the production rate by both of multi flow control and manual change of sytem layout. Each production rate per one PCB can be derived as follows:

$$P_{auto} = \frac{24}{(T_{standard} + T_{auto})}$$

$$P_{manual} = \frac{24 - N_{model} \times T_{manual}}{T_{standard}}$$

where

- N_{model} : The number of different PCB model per day
- T_{auto} : Delay time for mulit flow control
- T_{manual} : Delay time for manual change of the system layout
- P_{auto} : Production amount per days by multi flow control
- P_{manual} : Production amount per days by manual change of the system layout
- $T_{standard}$: Averaged standard production time per one cell

Assuming T_{auto} is infinitesimal comparing to T_{manual}, P_{auto} can be smaller than P_{manual} according to the increase of N_{model}. This relationship is pictured in Figure.1. The value N_{model}, will be increased gradually to satisfy the various customer's interest and we can reduce the production tact time by means of multi flow control as depicted in the chart. To accomplish the real time flow control system, the PCB flow control must be done by the assembly line integration computer by which each independent cell is connected. The basic concept of an flow control system is illustrated in Figure.2. In order to apply the real time concept into multi flow control system, it will be helpful to recall the real time concept briefly.

- A system is able to keep up with the real world environment it is controlliong
- When an event occurs, the system must respond to it within a limited time period
- A late answer is a wrong answer

To satisfy the second item among above, we devide flow control task into an independent sub tasks as many as the number of cells. When the time of process modeling, the flow control task is defined as a multiple instances.

The model change for multi-PCB flow proceeds with several changes of manufacturing process as described bellow

- Activate feeders containing the parts according to the new model
- Run a new robot program
- change the conveyor width for the new model

The flow control algrithm depicted in Figure.2. must be changed for multi PCB flow described in Figure.3.

4. Diagnosis and failures treatment

We classify the failures and diagnosis problems in assembly line into two catagories. When there are some mistakes on the system operation or some abnormal conditions occure, the system does not work well but can carry out some other operations. We regarded such states as a system error. On the other hand, a critical system error which causes the paralysis of the system operation can occure and it can be dangerous if quick repairment is not made. We classify such states as a system break-down. Analytic consideration about the system error and break-down is necessay to treat these problems and its consequence is described in table.1 and table.2. Figure.4 shows the bypass algorithm to handle the system failure

5. CIM oriented monitoring of the production information and database construction

We consider the necessary functions which have to be constructed in the lower manufacturing field and the method of database embodiment. In general and also in this system, LAN is used to transmit mess of data to the remote host computer as a basic Hardware. Monitoring datas to constitute the database are as below:

- Operation state of each cell
- Job state of each cell
- Production information data

All of the data mentioned above are regarded as a input to the database management system. Our system build and manage the database located in the remote host computer using the various data. We classify the whole database into four items for managing the mass of data easily as follows

- Job state database
- Production status database
- Loss status database
- Operation status database

Four databases mentioned above can be regarded as a output of the database management system. Figure.5 shows the database handling mechanism from the three kinds of external events.

Now we describe the development process for adapting our basic concept to specific PCB assembly line. At first, we suggest a system model for structured development of real time control system. Next we present detailed hardware and software construction in which our basic concept is implemented.

6. System evolution

(1) Modeling Process

In general, instead of rushing immediately into implementation, it's more effective and necessary to model what is intended first. And then use the model as a plan for implementation. We will make two forms of models. One is an essential model which is an implementation free statement of what needs to be done, and the other is an implemetation model which states what technology will be used to carry out the essential model function. We follow the procedures suggested by Paul. T. Ward & Stephen S. Mellor. to build both two models. As for an essential model, it consists of two parts, an enviromental model and a behavioral model. The environmental model is a description of the environment in which the system operates. And the behavioral model is a description of the required behavior of the system. we will follow the notation of data flow diagram proposed by DeMarco to describe the transformation schema assuming readers have some basic knowledge about it.

1) Essential Modeling

As you know, there are several methods to evolve an essential modeling. It is said that functional decomposition can invites "analysis paralisis" because of the after-the-fact approach. So we choose the environment based modeling which can provide real time concept clearly.

i) System Context

First of all, we build a system context to describe a boundary definition that includes both the interactions between the system and its environment and the things in the environment with which the sytem interacts. The system context of the assembly line integration system is illustrated in Figure.6. There are three terminators on transformation schema which delineates the components constituting the system environment and interactions between the system and environments which describe how many and what type of control and data flow exist. A User can give job start and stop command including several job commands. And also the user gives production plan which can be provided by the host computer using LAN too. So there is an alternative on handling the production plan data storage. Host computer can order special job by preprogramed command storage and can give production plan to the A.L.C.S(Assembly Line Control System). The format of the database file of various production data is compatible with the world widly used CLIPPER DBASE file type. In this section we describe the A.L.C.S only in virtual evironment domain so there is no detailed information about Interface Technology which connects virtual environment to real environment. In this thesis, therefore we consider the system context and its subsystem transformation model in the perception/acton space.

ii) Defining context specifics

Before constructing a behavioral model, we need to explain the purpose and objective of the A.L.C.S.. The purpose of this system is abstracted as follows;

- Real time flow contbrol
- Multi-PCB model production capability
- Analytic handling of system error and break-down
- Real time monitoring of production information
- CIM oriented database handling capability for remote ordering and monitoring
- Maintaining special values of MTBF, MTTR, Tacktime and Line efficiency

iii) Modeling external events

External events elicits a predefined response from the system. As shown in Figure.6 the external events occured by the user and host computer are defined clearly. It's necessary to describe the external events elicited by cell controller in detail. The identification of a complete set of events is a critical point in the requirements definetion process

① External events for flow control

Figure.7 illustrates various external events and reactions between the flow control transformation and the cell controller. There are multiple instances of the flow control transformation. It receives Enable/Disable events from control manager and react to severial events produced by the cell controller switching conveyor motion on and off as shown. We need a lot of flow control instances as many as the number of cells.

② External events for model change to handle the multi-PCB model

Model change control transformation can be regared as a sub function of the flow control transformation. We combine therefor the two transformations as shown in Figure.8. The transformation extract current model codes from its own and former cell controllers to make a decision of the model change. If the two model codes are different "change model" command is sent to the cell controller. And model change completion event is given from the cell controller when the model change procedure is completed.

③ External events for failure handling

Like the model change control transformation, diagnosis control transformation can be also regarded as a sub function of the flow control transformation. Diagnosis control transformation receives failure and error events from the cell controller and anlyze the kind of failure and error, then decide whether the failure can be cured or not. It makes some failure and error information on cell state storage. If it is not a failure of conveyor sytem diagnosis control transformation change the operation mode from normal to bypass. Figure.9 shows the diagnosis control transformation.

iv) Behavioral modeling

In behavioral modeling, we describe the response which should be made by the A.L.C.S. for each event in the external event lists and several functions to execute higher level system behavior. we can make a hierarchical approach to constitute behavioral model which can be devided into following five levels;

- planning
- scheduling
- monitoring
- coordination
- local control

These hierarchical levels can be classified into two groups. Higher two levels(plannig, scheduling) can be regarded as an "off-real-time" group. The others, three lower levels are a real time group with which external events interface. So we establish upper two levels as single independent application treated as a non-time critical system behavior. And lower three levels which have to be treated as a response to the time critical external events can be composed as an another independent application. It is ,therefore, necessary to build several lumps of shared data storage between the two applications for transmission of production information and cell state from assembly line to user and remote host computer. The state transition diagram of upper two levels can be pictured as shown in Figure.10. Job planning and job scheduling states are activated by two planning and scheduling events elicited by user or host computer. The timer interrupt treated as higher priority rather than scheduling or planning events is used to update production information and database in order to offer real time values to the user and remote host computer connected by LAN. So the state activated by the timmer interrupt can be executed while another state is already being activated.

The lower application in which lower three levels are included can have the state transition diagram as shown in Figure.11. AS shown in state transition diagram, there are seven state including idle state. All state can activated independantly by conditional or external events. As you will see later, we use serial communication linked by optical fiver to monitor all of the production and state informations for conforming data reliability in long distance communication and reducing the effort to apply this system to industrial fields. Data acquisiton state is activated by timmer interrupt having very short and constant period. So all of the information collected by this state is treated as external events to system behavior model.

From now on, we establish hardware and software structures to implement our system modeling concretely.

7. Hardware and software implemention

1) Hardware

As we mentioned above interface technology between virtual and real environment was implemented by RS-232C serial communication using the optical fiber linkage. The main reason why we select this technology can be explained once again as follows

- Conforming data reliability in long distance communication
- Reducing the effort to apply into the industrial

field

- Decreasing the cost for building the system

We meet the problem of context definition in a systems engineering environment because of the presence of parallel development situation. As depicted in Figure.7 through Figure.9 all of the detailed control procedures are included in cell controllers and A.L.C.S have the right of motivation about each modularized procedures in cell controllers. So we do not have any serious problem to apply our interface technology to assembly line in the industrial field. Figure.12 shows the developed system hardware layout and its components. Samsung PC(SPC 6000) was used for the integration of each cell to a group of assembly line. And Secnet optical communication link was selected to construct ring shaped communication linkage for establishing computer link by polling method.

2) Software

To make it sure that the response to the external events should be done within a limited time period for the real time control, all the control transfomations must be constructed into stand alone tasks in which seperable independent functions are included. In PC based programming, it is not easy to execute stand alone tasks parallely. So we take a message oriented programming method to handle multitasking system and build our system in the MS-WINDOWS environment which can offer multitasking and message oriented programming. All of the external events are treated as message and we make a priority filter to classify the messages into several priority levels using the hook function. Figure.13 shows the message oriented programming architecture. A message loop is regarded as a idle state in the state transition diagram. The external event service routines are matched to the states. Multitask programming method stretchs the common programming techology as follows;

- Increase the operation capability of single CPU
- Any task can activated whenever external events occur

We show the multitasking environment in Figure.14. Implementation of DDE(Dynamic Data Exchange) capability of MS-WINDOWS can solve the inter application communication problem easily in PC based programming. So mass of data can be transmitted from low to higher application dynamically. We build our own danamic data communication protocol to make it possible that many sorts of data can be transmitted.

8. Conclusion

We build an experimental system model to integrate multi-PCB flow control in the PCB assembly line which is already being built in the industrial field. In order to achieve our purpose, we consider the productivity of our system model compared to the existing assembly line analyticaly. And we induce the conclusion that multi PCB flow control system can take a better position than existing assembly line varieties of models are increasing in the moden market. In other words, Real time multi PCB line control system can increase productivity when the various kinds of goods have to be assembled simultaniously. In this point of view we introduce the system modeling procedure with analytic consideration about the problem of real time control system development.

In the development time, we meet the problem of context definition due to the parallel development situation. It is necesary to make a detailed external events list in the perception/action space to avoid this problem. Finally we describe the concrete system H/W and S/W for implementation of our system model. Several important functions are developed for assembly line in this paper described below;

- Function of real-time model change.
- Function of Diagnosis and treatments
- Function of real-time line control, management and production information analysis

These functions are integrated in our system model for better line efficiency and better productivity.

kinds of error	detection method	cause of error occurance		error treatment
insertion error	proximity sensor	PCB	interference between new parts and existing parts	improvement of insertion method
		robot	variation of teaching positin by infinetesimal distortion of robot body	robot positioning error calibration
		conveyor	infinetesimal distortion of PCB zig&fixture	correction of zig&fixture position
robot gripping job error	tactail sensor	robot	variation of teaching positin by infinetesimal distortion of robot body	robot positioning error calibration
		feeder	inaccurate figure of parts at final supply device	improvement of parts supply mechanism
parts supply error	proximity sensor	feeder	incorrect design of parts supply mechanism no more parts supply with empty feeder	improvement of parts supply mechanism regular survailance of parts by supervisor
conveyor width control error		conveyor	position data loss during the data communication	improvement of encoder accuracy control time guarantee by cutting off the communication dugin the conveyor width control

table 1. Error classifcation and treatment

break down	trouble shooting	trouble indication by the cell controller
robot feeder conveyor cell controller	except for the conveyor breakdown	/ change the state lamp \ ring the bell send a message to line control PC change the job mode to bypass mode

table 2. trouble shooting

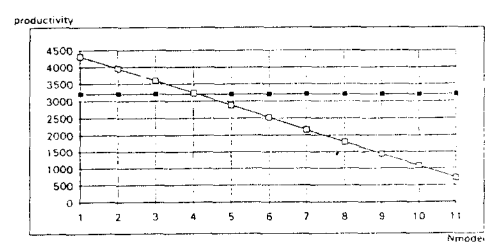

Figure.1. Comparision of two productivies

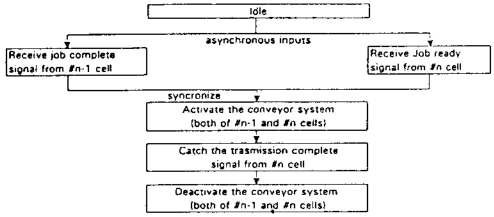

Figure.2. Flow control algorithm

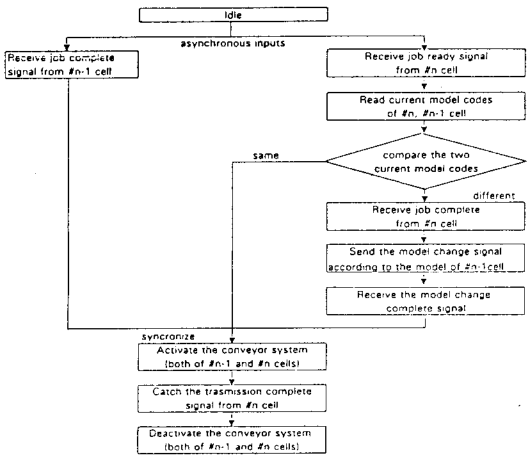

Figure.3 Model change algorithm

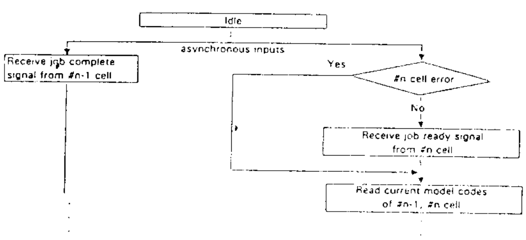

Figure.4. Error treatment algorithm

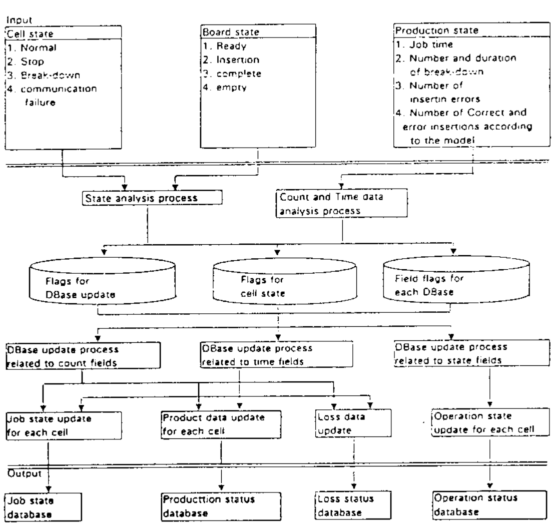

Figure.5. Database handling mechanism

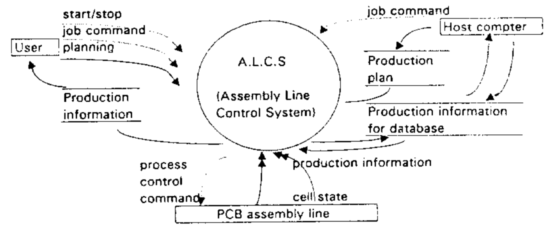

Figure.6. System context

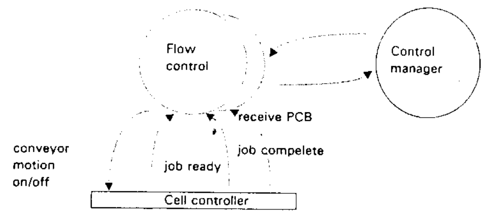

Figure.7. Event flow and flow control transformation

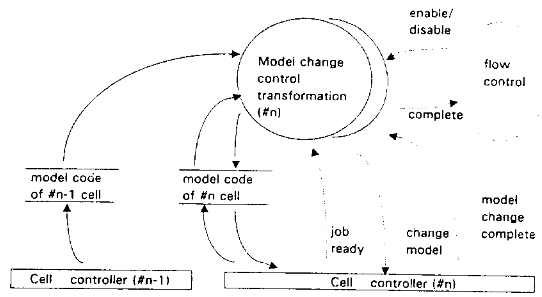

Figure.8. Model change transformation

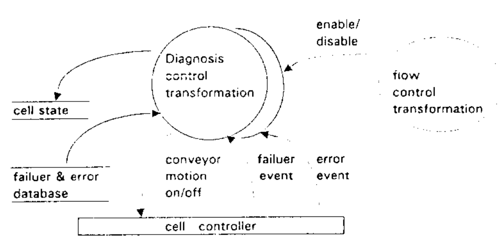

Figure.9. Diagnosis control transformation

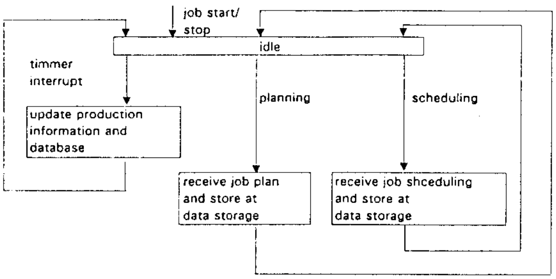

Figure.10. State transition diagram of off-real-time-group

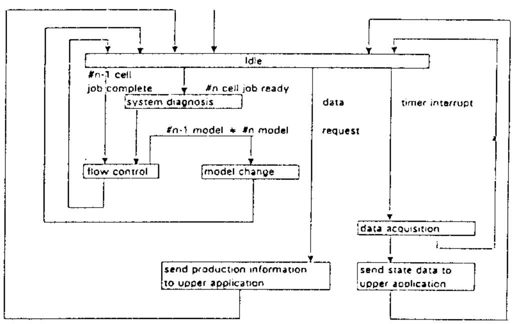

Figure.11. State transition diagram of real-time group

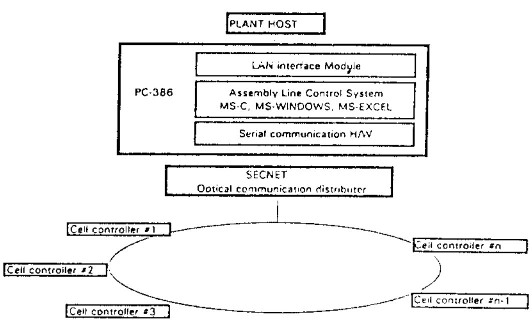

Figure.12 Hardware construction

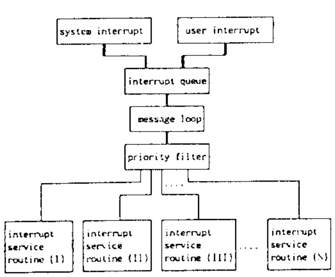

Figure.13. Message oriented programmign architecture

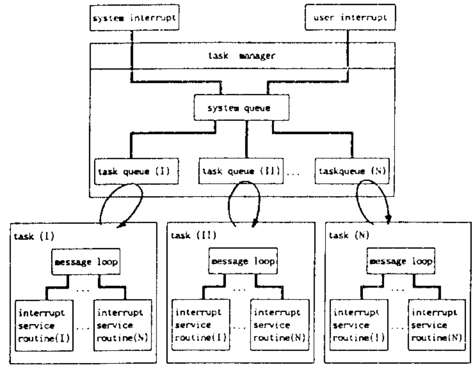

Figure.14 Programming methodology in the multitasking environment