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Increasing of the Efficiency of Flexible Manufacturing System

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Abstract

Management of universal shelf stacker process many varied operations, whose are different in difficulty of solved problems, time of reaction of controller and next parameters. Usually is used one controller with all functions, which have many external input-output modules and have to solve parallel many tasks together. The control application have to be very complicated and blind with risk of collisions control processes and needed of solving control process priority. If the processes are separated to the groups, every group of processes solved with separate control automat. For simple processes, whose needs immediate reaction can be used simple and easy controller, complex control processes have to been solved with controller with sufficient performance, mathematical performance and adequate memory.

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Keywords: universal shelf stacker; control system; layers of control system; positioning, sensors; defragmentation.

1. Introduction

Universal shelf stacker (USS), is device, that store shelves, so the residual space was minimized and the store space in USS is very effectively employed (see Fig. 1).

The device is contained from two towers, between them there is vertically moving device, which is manipulating with shelves (extractor). Extractor puts the shelf into tower on any position and removes the shelf from tower. Extractor can manipulate on time with only one shelf. The shelf can be placed in tower in any position, so don't make collision with other shelf or shelves or other item of mechanical construction of USS [1]. In tower (usually front) is situated dispensing slot, in which operating personal can handle with shelf content or a shelf. When shelf is putting into USS from dispensing slot, the maximum high of shelf is measured. This entry is very important for establishing of space for positioning of shelf. When the shelf is moved on extractor from dispensing space, the weight of shelf content is measured by special method. When weight limit is overrun, the USS does not put shelf into tower, but put it back into dispensing slot. Move of moving parts of USS is performed by actuators – three phase asynchronous motor, of which only one is connected to output of inverter. This solution is sufficient for moving, because from principle of USS results, that it is not possible moving vertical and horizontal direction together.

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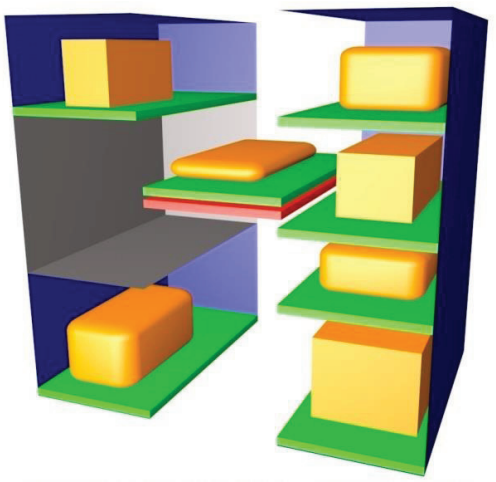

Fig. 1. Scheme of USS.
blue – towers of USS, gray – dispensing slot, green – shelves, red – extractor, yellow – items on the shelve

2. Objectives and methodology

Control system of USS is complicated set of electronic components, sensors, actuators, safety elements and so on. Control system must perform:

- synchronous performing more tasks with various priority of processing
- synchronous performing more tasks with various time of reaction
- performing input data from sensors, measuring components, back-coupling components, etc
- controlling many types of actuators
- communication with outer system
- communication interface for operating personal and servicemen

Process of management of USS must handle many various processes, whose are different their difficulty and time reaction [4]. Usually is done, that the process which need shorter time for reactions is simpler. The simplest processes need the shortest reaction time (e.g. emergency stop) and processes, whose we have to control on base of difficult algorithm, usually don't need immediate reaction (e.g. establish the best position on positioning shelf into tower USS).

The control system for an easy processes needs usually the different hardware as control system for a difficult processes, therefore is control system of USS divided to 4 layers with vertical hierarchy. These layers are linked by communication channels (see Picture 2). Each of control layer can be realized on different hardware platform, but this fact not exclude joining any layers, with the same hardware platform, on one unit.

On hardware design, the layers can be make on next hardware platforms:

8-bit microprocessor (for example from Intel, Atmel, PIC, Fairchild, Motorola and others companies)

32-bit microprocessor from Atmel, ARM, Intel, Motorola or others companies

Many types of PLC (Programmable Logic Controller) from many companies (B&R, Siemens, Unitronics, Panasonic, Rockwell Automation, ...)

Industrial PC, for hard industrial environs.

Layers of control USS are divided by time of reaction and by functioning to 4 independent parts, whose are in vertical hierarchy structure.

2.1. Layer zero of control system of USS

collect data from sensors of position, sensors of end of position, sensors of presence of shelf on extractor and dispensing slot, synchronize and safety sensors. Layer zero too operate with actuators this way, that by its outputs manage connecting elements for enabling move and switch the power from frequency inverter between motors of moving parts. This layer is the quickest and its reaction time is the shortest in control process of moving parts USS. Together the processes whose the layer zero control are

very simple and easy. By this for control system of layer zero be enough simple programmable component, which can prepare data from more digital inputs and can control more digital outputs [7].

2.2. Layer one of control system of USS

sets collection of parameters in actuators, is doing partial control jobs as positioning on increment, harmonization of actuators moving on height measuring and weight measuring of shelves and so on. Layer one communicate with slave systems as: measuring barrier for measuring of height of shelf, frequency inverter for moving of actuators, layer zero and with master system, which is layer two. Layer one has to make quick reaction on change level on inputs, but together have to calculate on positioning and communicate on four different communicating channels.

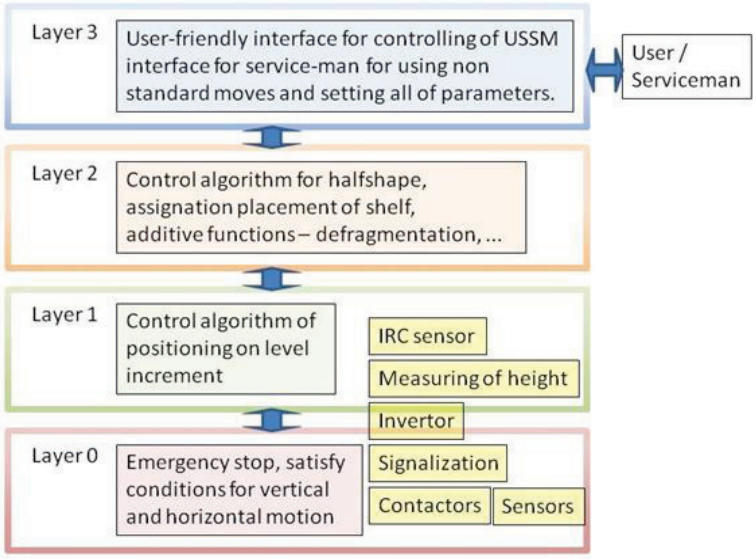

Fig. 2 Hierarchical structure of layers of control system of USSM.

2.3. Layer two of control system of USS

contains the lead control algorithms USS. It decides, if job is executable, that means, that algorithm defines, if is possible the shelf put into USS on base of measured height of shelf, measured weight of shelf and layout of positions of other shelves on USS. In the next step the layer two decide ideal position of shelf for economical using of storing space. The layer two resolve all option functions of USS as defragmentation of storing space, loading new shelves for using into USS and unloading shelves from using, temporary deleting the shelves from using and their return, recovering USS after electrical disaster, after emergency stop of device and so on. Layer two store operational and system data, and on this layer are stored all of parameters of USS (description of position of free zones, mechanical parts USS, packages of parameters for frequency inverter). On layer two are stored operational data as data package for operating USS, database of shelves, data backup, whose are using on recovering machine after non-standard break of operation [2,8].

2.4. Layer three of control system of USS

is graphical, user friendly interface, which is designed for users of USS and servicemen (HMI – Human Machine Interface). Layer three enables managing USS by menu very easy and users can use all of functions USS, whose are designed for level users, e.g. get shelf from USS. The Administrator can read, by HMI, statistical data about activity of USS, frequency of using shelves, can manage users and its user rights for shelves (which shelf user can get from USS), can load and delete shelves into or from device and can temporary load and unload the shelves from using. Servicemen can by HMI completely set all of parameters USS in user-friendly interface, they can define mechanical view of machine, the places, where are located mechanical reinforcements of machine, dispensing slot. They can define positions of free zones, in whose are located shelves. Servicemen can check functions of all sensors of all types, which are located in USS. Servicemen can move independently with actuators by HMI in situations, when the moving is not safety or the moves are in opposite to basic logic of moving parts of USS.

3. Results

Control unit of USS is made on 8-bit microprocessor base from Atmel company (layers zero and layer one) and on platform industrial PC (layers two and layer three).

Layer zero is implemented on microprocessor AtMega 128, which has sufficient memory space for software and has sufficient number inputs and outputs. To microprocessor are connected sensors for synchronizing position, sensor for maximum high and low position of extractor, sensors for scanning shelf on extractor and on dispensing slot. Outputs manage contactors, which are connecting motors of actuators to output frequency inverter and indication components on front panel of USS. Reaction time of control unit is less then 1 ms. This reaction time is sufficient to stopping move of motors in case of disaster or if is needed emergency stop.

Layer one was made on microprocessor AtXmega128A1 because:

- it has sufficient number of communicating interfaces, the four from them is used
- it has technology named “event system”, where function quadrature decoding establish position if IRC sensor without software addition
- it works on high frequency (32 MHz), so the input data are executed immediately and in real time is setting the outputs

On microprocessor is connected positioning sensor for vertical and horizontal move. Positioning controller provide regulation of position extractor (vertical move of shelf). Slave regulation of speed, current and moment of actuator provide frequency inverter.

The layer one communicate with frequency inverter and when this communication is broken, stop the movement of moving parts of USS. Control of move direction is done by digital inputs of frequency inverter, because time of reaction of inverter on data communication is so long so is needed. When the weight is measuring, frequency inverter puts data into communication bus, and there are data about torque current, from which can be empirical derived weight of shelf. The layer one communicate too with measuring barrier. Height of shelf is measured on every time, when the shelf is moving from dispensing slot into USS on extractor. The highest point is sending to the layer two for establish the best position on positioning shelf into tower USS. The layer one communicate with master layer two and slave layer zero.

Layer two is realized on industrial PC, version "all in one" with touch monitor. This layer solve the base algorithms for moving of actuators (vertical and horizontal moving), must provide out of collision move of moving parts of USS. Layer two have to make primarily:

- calculation of position of shelf in USS, so the shelf can't collide with mechanical parts of USS (reinforcements) or other shelves or shelves contents, which are on shelves located
- commands for mechanical move of actuators, so into dispensing slot of USS put the shelf, which is needed.
- commands for mechanical move of actuators, so the shelf from dispensing slot is move into USS on ideal position
- sequence of commands, whose make measuring of height of shelf, when it is moving from dispensing slot into USS on extractor
- sequence of commands for moving actuators for detection of weight of shelf
- working out of algorithm defragmentation of storing space
- working of command automat, which automatic executes the commands with reply about status after executing command
- recovery of device after power failure or emergency stop of USS or disaster or other not planed break of work USS

Layer two use many data collections, whose are stored in external data store. This failsafe data store has internal mechanism for preventing data loss and destroying. On layer two can be connected master system for managing material, which is stored in USS and by its can be assigned the commands for moving the shelves into dispensing slot.

Calculation of position of shelf in USS can be executed with other optional parameters. The basic parameter is economy of using storing space. Procedure of defragmentation of storing space is doing for integration of residual spaces in USS, where isn’t possible put the shelves, to a few free spaces with sufficient height for storage the shelves.

Layer three is by economical reason designed too on industrial PC platform, as independent application, which is executing from application of layer two. A users can only login and logout on the basic screen and after login user can bring in any shelf, on which he has a privileges. By this command the shelf is moving to dispensing slot. The same procedure is using for taking away the shelf into USS. The user can also temporary delete the shelf from using and temporary deleted shelf again add to system and change the percentage of acceleration on moving with the shelf. Administrator can, in addition, manage users, it means create and delete users, manage privileges for using of shelves by users. Administrator can also insert a new shelves into system and remove a shelves from system [4,9].

4. Conclusion

Menu for servicemen can be used after log on and it consist of screens, whose describe the USS setup. On this screens the servicemen can see organization of shelves with the basic data about them, can define shelves positions, parameters, height, all what is needed. Servicemen can manage description of mechanical elements, reinforcements. The servicemen can check the

status of all sensors by logical group and check their functions, independently move with actuators, make backup and restore settings of USS, initialize the module and restore all parameters in module from backup.

Hardware platform of layers of control module for USS is realized as is described by economical reasons and by minimizing the time for developing and programming all of described algorithms on all layers. The complex and difficult algorithm of calculating positioning of the shelf on optimal position and defragmentation of store space on layer two can be solved on platform PLC, but this solution is disproportional more expensive. The layer two can be realized too on platform 32-bit microprocessors or 8-bits microprocessors (for example AtXmega), but possibility of debugging on PC platform expressively shorts the time needed for developing control software.

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