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**Aleksandar Vujovic** [1]
**Zdravko Krivokapic**
**Jelena Jovanovic**
**Gordan Kijanovic**

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# PRODUCTION OPTIMIZATION USING AGENT-BASED SYSTEM

***Abstract:*** *Production systems suffer frequent changes due to the growing demand and need for providing market competitiveness. Therefore, the application of intelligent systems can greatly increase the level of flexibility and efficiency, but also reduce the overall costs. On example of system for the production of irregular and variable shaped parts by cutting the wooden flat surfaces, it is discussed the possibility of applying intelligent agent-based system. In order to implement it in the production process, it was necessary to firstly performed an analysis and assessment of the initial situation. Then, we spotted a weak points and gave some suggestions to improve process by application of agents. The obtained solution has reduced the number of engaged workers, reduced the scope of their duties, made faster flow of materials, improved its utilization and we finally introduced the scheme of the new agent-based manufacturing process that achieves the foregoing benefits.*

***Keywords:*** *intelligent systems, agent-based system, production system*

## 1. Introduction

The process of globalization affects all spheres of social life and creates entirely new conditions of production and socio-economic developments. The global competitiveness on the 21st century markets is feeding a continuous technological progress with new generations of technology and products, with higher capability of intensive productions and with a general raising in buyers' demand and expectation for quality (Fragassa *et al.*, 2014; Matiskova, 2015; Oswald *et al.*, 2015). Such conditions impose to organizations an obligation of constant adaptation and development of their capacities through fostering of approaches that are oriented toward knowledge, quality, competence and continuity, and manufacturing should adapt to strong changing conditions imposed by the markets (Barbosa and Leitão, 2011). Manufacturing has faced significant changes during the last years, namely the move from a local economy towards a global and competitive economy, with markets demanding for highly customized products of high quality at lower costs, and with short life cycles (Leitão, 2009). Rather than dealing with each component individually, it is necessary to have a new paradigm for management of manufacturing systems, so that all the components and their operations can be managed in an integrated fashion (Sikora and Shaw, 1997).

Earlier stages in the development of

[1] Corresponding author: Aleksandar Vujovic
email: aleksv@ac.me

production were characterized by huge series that provided organizations the ability to use their production capacity both in technique and technology, and the development of knowledge to project for a longer period and ensure sustainable development. Today, however, the conditions are quite different and production and all the factors that influence to it are changed and must constantly adapt to new conditions and requirements of the market. That's why is developed a completely new field of intelligent systems that both individually or in combination can provide a high level of flexibility and adaptability of a production process. Some examples of intelligent systems and/or approaches are:

- Agent-based systems,
- Lean conception,
- Genetic algorithms,
- Systems based on socio-biological and mathematical principles,
- Intelligent Management Systems,
- Robots, etc.

For intelligent systems are said to be able to work independently or with a high degree of autonomy in a changeable and unpredictable environment with little supervision and contact by a person. Basically the intelligent machines can be defined as a hierarchical structure with the primary aim of developing intelligence, and subsequently precision. The intelligent manufacturing system takes the intelligent activities in manufacturing and uses them to better harmonise human beings and intelligent machines, integrating the entire corporation from marketing through the design, production and distribution, in a flexible manner, which improves productivity (Deen, 2003). They differ from other hierarchical structures and must have a general control mechanism that allows the realization of properties by which they're distinguished, for example, the comparative use of available memory, adaptation with the surroundings and self-organization, flexibility according to the changing demands of users and the rest. The greatest efforts in the design process and development of intelligent systems are just being dedicated to imitate the human logic, the relationships and aspirations toward study. The following lines of this study point out the development and specifics of intelligent systems with special emphasis on the application of agent-based systems in order to highlight their importance and applicability to the specific conditions of production of wooden objects.

## 2. The development and specifics of the intelligent agent-based systems

The development of intelligent systems and the beginnings of dealing with this theme could be sought in the ancient history. However, in the literature most often as a serious indication of the development of intelligent systems is highlighted 1937 years and Turing's activities described in the paper "On Computable Numbers, with an Application to the Entscheidungsproblem" where he talks about intelligent machine that can "think" as a man does. Alan Mathison Turing (1912-1954) was a British mathematician and cryptographer who is considered the father of modern computers. Later in 1950, the British journal Mind published a Turing's test of intelligence or just "Turing test", which probed the machine to the level of intelligence or possessing artificial intelligence. There are probably accurate indicators which suggest that, apart from man, not a machine so far passed this test. In Artificial Intelligence the goal is often to create autonomous, intelligent behavior, learning capabilities, and adaptation mechanisms in machines used for sophisticated tasks (Frei *et al.*, 2007).

The subsequent development of intelligent systems goes through the process of development and application of genetic algorithms in CAD/CAM concepts. These systems have found immense application in solving the most complex problems of designing. A special place in the development of intelligent systems include the safe programmable CNC system with the programming possibilities of movement of pieces, tools, defining and setting the cooling mode, etc. Later, the space for research and development in the field of intelligent systems can defined through the following three areas: Inclusion of artificial intelligence in CAM systems, Modeling and control of varios parameters of tools by using arificial intelligence, Incorporation of artificial intelligence in CNC units.

In the initial part of the field of application of artificial intelligence in particular were singled out as the most attractive knowledge-based systems (expert systems, decision-making support systems, etc.), Then the neural systems, case-based reasoning systems, genetic algorithms and "fuzzy" logic systems. The main reasons for the effective application of artificial intelligence systems in production can be perceived in the following:

- imprecision and ambiguity are always included in the mindset of the person who makes the decision, and such entities in the business and production systems are a lot, especially in today's circumstances,
- in business and production systems it is necessary to set up information: to formulate models, variables, constraints of certain parameters, and these elements often can not be easily and accurately measured,
- imprecision and ambiguity as a result of personal attitudes and ambiguity or subjective opinions can qualitatively and quantitatively endanger the available information.

Intelligent systems and intelligent control are developed to implement the functions of the hierarchical system and can be considered a fusion between mathematical and linguistic methods and algorithms applied to the system and its processes. Intelligent controls are hierarchically distributed according to the principles of growth and development of intelligence. The generally accepted structure consists of three levels of control as follows (Figure 1): organizational control, coordination control and execution control. The intelligent system is consisted of more segments shown in Figure 2.

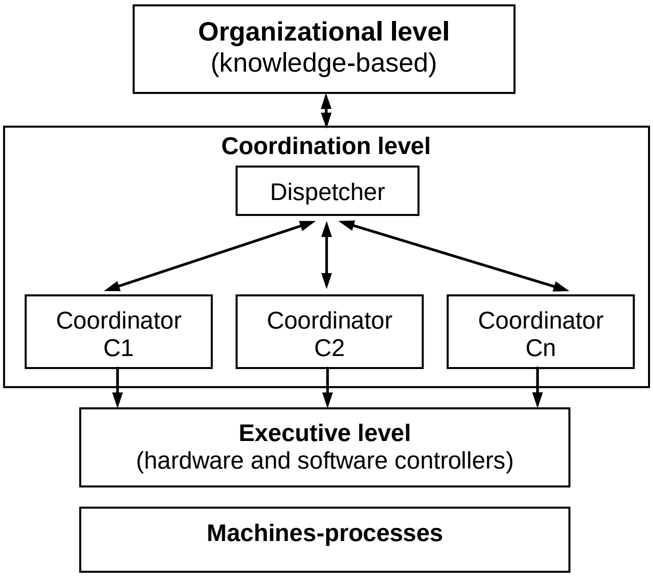


**Figure 1.** The generally accepted structure of intelligent control

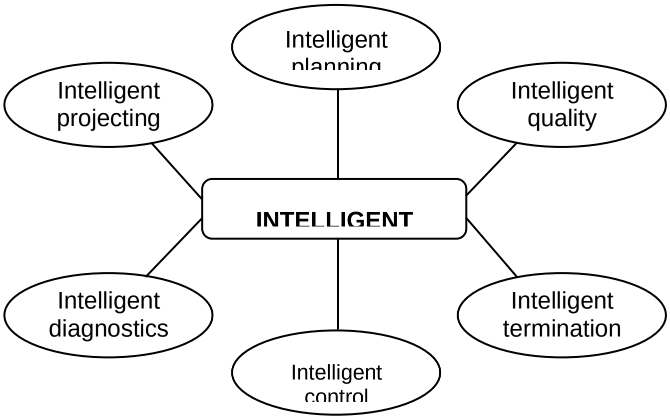


**Figure 2.** The components of intelligent system

*Intelligent projecting and design* – today, the modern business conditions as particularly important element in the process of doing business and manufacturing in general require to dedicate special attention to the design process and projecting. It is a prerequisite to meet the customer's demands and needs, and indirectly the product or service later to be realized in the market. This stage requires absolute multidisciplinary and involvement of a large number of fields and disciplines.

*Intelligent planning* – is a process consisting of a dynamic and complex activity. The planning process involves a series of detailed description of the business and production activities with certain requirements and capabilities that are used for transformation of the input parameters in a range of output parameters or results. Intelligent planning processes include mechanisms such as CAPP (Computer Aided Process Planning) both in business and production in general.

*Intelligent quality management* – the inspection process and statistical process of control, which were applied as a classic mechanisms of quality control on production lines, today are transformed into forms that are more general and include all general business and production processes. This trend reaches the levels of the TQM approach (Total Quality Management) model for the assessment of business excellence to the level of Qom (quality of man/life – quality life).

*Intelligent diagnostics and maintenance* – the basic objective of this approach is that any possible errors in the system to be identified at an early stage to be able to carry out activities to avoid weakening of organizational performance. In addition to the indications on the possible occurrence of errors, considered by many as the most important activities, this approach has to provide information on the type and size of errors, analysis and evaluation of potential risk and its size, as well as defining measures to resolve the problems. Thus, the approach must be rounded up to provide: identification, classification, assessment and measures to address them. In today's business conditions, each of these stages involves modern techniques especially in the field of application of artificial intelligence.

*Intelligent scheduling and termination* – represents a process which involves the optimization in arranging the schedule of equipment and define the terms for its launch and carry out the planned functions. This is a very complex process and requires harmonization and optimization of the huge number of parameters. It often happens that certain parameters and their optima do not agree or are opposite one another and in this case it is necessary to do optimization and decide which values should be assigned to which parameter, but in a way that the system in the current and future state to be maximally effective.

*Intelligent control* – means the process of bringing about a signal that indicates about the case and/or its part thereof on the basis of which the system gives a response or implement certain action in order to achieve pre-defined requirements for the product. Today, these processes are realized on the basis of software application which reacts eg. To the state of the process that has defined objectives that are measurable or example. on the basis of the signals coming from the sensors that affect the movement of machines and thus the realization of the planned measures.

In order to create conditions that in today's economic conditions to create a system that can effectively meet the users' requirements (without reducing quality or increasing the price), was developed the concept and production-based agents. An agent is basically a self-directed software object with its own value system and a means to communicate with other such objects (Baker, 1998). There are several features of this concept which gave it the right to find the adequate implementation as follows:

- agents are autonomous and based on that they control their internal state and behavior in relation to the environment,
- agents are rational in the sense that they can make judgments on the basis of information they receive, on the way of finding the best goal,
- agents are adaptive in the sense that they can learn and modify their behavior according to the environment and a better way of achieving the goal,
- agents are goal-oriented and proactive facilities that generate their capacity control based on internal objectives,
- agents typically always are looking for new information about the environment and they're never satisfied with a set of information that at that time possess,
- agents have expressed sociological characteristics as they can and tend cooperation with other agents achieving multi-agent system that has its joint action and style of behavior.

In order to set an agent-based production, first you have to set the definition of "agent". There is no universally accepted definition for the agent. In practical applications under the agent is considered the only directing program that has its own value system and the ability to solve certain subtasks independently of the others in the system, and then to communicate with others and contribute to their solution process of solving the overall problem. This works on its own initiative or at the request of another agent. To participate in this society of agents, humans require the services of personal assistants in order to enable communication through E-mail, graphical editors, and other standard modalitie, such as beepers, faxes, telephone (Pan & Tenenbaum, 1991). In Figure 3 is shown the agent model with four components.

**Processor of knowledge** is knowledge-based system that stores and processes the necessary knowledge for the agent and the role that is intended in the system,

**Perceptor** is a channel that allows the agent to receive information from the outside world,

**Effector** is the interface of the agent with which it changes or has an impact on its position in the community,

**Communicator** is the mechanism by which the agent exchange attitudes or views with other members of the community,

**Objects** representa a list of rules by which the agent controls.

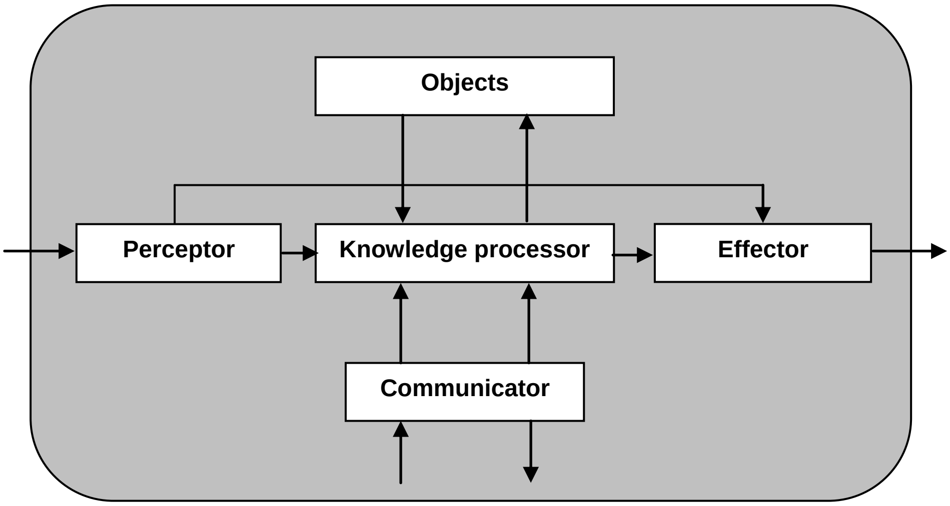


**Figure 3.** Model of agent with four components (Qiao and Zhu, 2002)

Therefore, now the MAS (Multi-Agent System) can be defined as an open and distributed system that is formed by a group of agents that are combined with one another for the purpose of cooperation necessary for troubleshooting. MAS can be applied in many fields. In today's production and business systems that are strictly decentralized application of such a system is very important.

In order to understand the concept of an agent, there may be displayed some characteristics which are a combination of definitions and perceptions of the term of agent by many authors who says that an agent is a software entity which:

- is autonomous,
- may represent physical resurces (eg. Robot, etc.),
- may represent logical resurces (schedules, lines, etc.),
- has the intelligence to make their own decisions in order to achieve the objectives(process planning, scheduling, etc.),
- has the ability to cooperate with other agents (as with humans) in cases where there is not enough knowledge to achieve the defined objectives on its own,
- can react with the environment in places where is placed (for example in a production environment) and to be changed and adapts according to the knowledge they possess,
- can react in the context of stimulation (as stimulator), and to define an action plan according to available knowledge,
- may decide on the basis of its knowledge of whether to accept or reject requests from other agents,
- has the ability to collect and memorize new knowledge.

There are many advantages in using these systems. First, these systems have the information distributed by agents and do not burdensome the centralized form. Second, such a conception can very well implement small or incremental improvement, which have a major impact on improving the whole system. Third, these systems provide the ability to integrate a large number of business or production capacities.

## 3. Intelligent agent-based systems, developmet and specifics

As previously pointed out, as a prerequisite for the successful implementation of an agent-based system, it is necessary to correctly implement the phase of analysis and evaluation of the starting situation and the possibilities for efficient and effective application of intelligent systems (Kijanović, 2014). Agents and similar concepts were welcome in manufacturing because they helped to realize important properties as autonomy, responsiveness, redundancy, distributedness, and openness (Monostori *et al.*, 2006). Miscellaneous parameters related to the wood manufacturing, as machine tools, tools, productivity and many others, have to be taken in count (Lucisano *et al.*, 2016). Here is an example of the production system which examines the possibility of applying agent-based system (Figure 4).

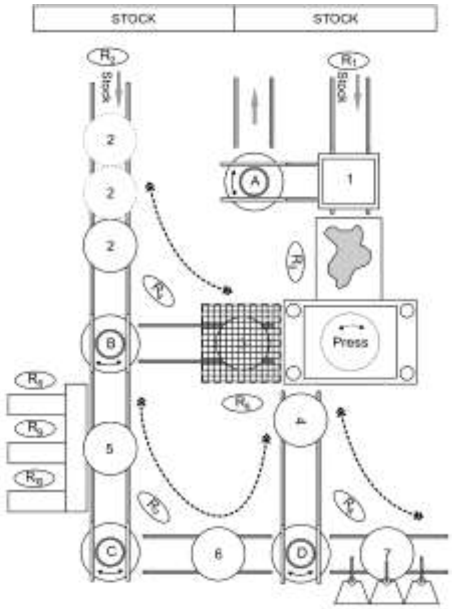


**Figure 4.** The scheme of the current state of the production system

Production refers to cutting of parts by cutting from a wooden flat surface of improper and variable shape. Cutters are arranged on the entire surface of the press, are numbered and can be activated or deactivated individually. In addition to wood production, this may relate to products from natural animal skins, precious metals, etc.

In the manufacturing process are engaged 10 workers ($R_1$, $R_2$, ..., $R_{10}$) positioned at their workplaces. Worker $R_1$ removes an emptied container no.1 on a rotating platform A, and send tracks from stock (storage) a container filled with raw materials no.1 to the workplace of worker $R_3$. From platform A the empty container is taken to a warehouse and of raw materials and fill with the same preparing a new submission. At the same time, also from a stock, worker $R_2$ delivers an empty container to rails no.2 to worker $R_4$. A worker $R_4$ takes over container no.2 and places over B rotating platform in place of container no.3 to worker $R_5$.

Worker $R_3$ takes the workpiece from the delivered container no.1 and puts it on a movable desk, which is at this stage static, corrects any irregularities and according to his subjective conclusion rotates press for a certain angle. In this way he is trying to economically use raw materials. Then activates the press that has the optimum number of profiled knives for provided cut-out parts. After returning the press in the original position the cut-out parts along with surplus material relocate to the grid plate to a position of workers $R_5$. It frees up the cut-out parts with its vibration which are collected in a container no.3 under the grate and the surplus material remains on the grid. Worker $R_5$ takes the surplus material to the container no.4, and orders the maintenance, if necessary, the replacement or sharpening of a particular cutter, whose function is disturbed. When in the container no.3 accumulates a sufficient number of processed pieces worker $R_5$ moves container no.3 on a rotating platform B where it is taken by a worker $R_7$ and moves to working place of workers $R_8$, $R_9$ and $R_{10}$ to rectify or obtain the finished product (upholstery of buttons, stitching of emblems, adding of fashion details, classing...). At the same time worker $R_4$ empties container over no.2 and over the rotation platform B brings to the position no.3 to worker $R_5$.

When is filled the container no.4 worker $R_6$ takes it over and transports to the position of the container no.7 over the rotation platform of D. There can be carried out adding of certain substances (chemicals, metals, water...) for further purposes. In addition to on this position can be set presses, mixers, crushers, chopper... depending on the purpose. From there the container no.7 goes on rails for processing (raw material for further processing, the recycling center, the lager of harmless waste...).

After emptying the container no.5 worker $R_7$ forwards it over the rotating platform C at position no.6. When the container no.4 over the rotating platform D transports to the position no.7, an empty container no.6 is placed into position over the same rotational platform D.

Observing this production system is quite noticeable points on which could be improved production in terms of decrease in the number of workers, increased efficiency, reduced time making finished pieces, the continuity of the process, the timely response of the subsystem maintenance...

The deficiencies observed in the conventional technical system and suggestions for improvement are given in Table 1.

**Table 1.** The perceived negativity and suggestions for improvement in the conventional technical system

| | **The perceived negativities** | **Proposal for improvement and expected results** |
|---|---|---|
| $\mathbf{R_1}$ | – upon receit of goods in the warehouse a worker once manipulated with entire order<br>– the second time puts over his hand while sorting from the shelf in an adapted transport container through plant<br>– physically moves container **no.1** on the rails to the workplace of the worker $\mathbf{R_3}$<br>– from his skills in sorting of raw materials in the container and timely manipulation with it depends efficiency and speed of operation of the worker $\mathbf{R_3}$ | – instead of container with rails to install conveyor belt from stock to worker $\mathbf{R_3}$ whose movement he controls<br>– would reduce the physical effort of worker $\mathbf{R_1}$<br>– would reduce the obligations of worker $\mathbf{R_3}$<br>– there is no returned empty containers |
| $\mathbf{R_2}$ | – required storage space for containers<br>– sufficient physical activities and waiting for action<br>– tension due to delays caused by untimely reactions in manipulation of containers | – with introduction of conveyor belts in the process is lost the workplace of $\mathbf{R_2}$ and containers with rails<br>– enabled continuous process |
| $\mathbf{R_3}$ | – a long period of required training of workers to gain experience in a large number of workpieces due to more efficiency use of materials<br>– workplace requires workers with strong bias toward shape and orientation in space<br>– subjective influence of worker $\mathbf{R_3}$ for what angle will rotate the press in order the raw materials to be optimally used<br>– subjective influence of worker $\mathbf{R_3}$ on selection of the cutter which will be in operation, and which will not for a concrete action<br>– tension of a worker due to the need of | – the worker $\mathbf{R_3}$, according to obtained information from pre-installed scanner on rotation angle of the press and numbering of cutter that is to be blocked, rotates the press and blocks the mentioned cutters, and then activates the belt for delivery of workpieces under the press and activates it<br>– the workpiece is transported to the lattice part automatically with conveyor belt from the press upon its returning to its original position<br>– the worker is not exposed to risk by putting his hands under the press<br>– if the movement of belt was automated |

| | | |
|---|---|---|
| | constant concentration because of danger from work of the press and a great need for coordination of movement | and manipulation with the press, the worker would play a role of controller, and perhaps without it |
| **$R_4$** | – insufficient time of active engagement of the worker **$R_4$**<br>– lack or absence of concentration would lead to a halt of production in its part of the process | – witht the introduction of conveyor belt from the grate section this workplace would be disappeared |
| **$R_5$** | – subjective influence on the determination of the properly cut pieces and when the containers are full<br>– subjective effect on the determination of the cutter's label which improperly performs its function due to replacement or sharpening (maintenance)<br>– besides the correct finished products in the container **no.3** will be found and the cut parts which have no required shape because they were cut from the end of the raw materials<br>– there is no information on the mass of the unused materials due to amount of addition in the workplace **$R_6$** | – cannot be known the number of currectly cut parts, which will lead to the creation of new quantities of suplus materials (waste) in the workplaces **$R_8$**, **$R_9$** i **$R_{10}$**, as well as their transport to the position of the container **$R_7$**<br>– placing the conveyor belts under the grate and in continuation this workplace would be superfluous |
| **$R_6$** | – there is no precise information on the amount of the surplus materials in the container **no.4** and subjectively is concluded how much of which addition should be inserted to the position of the container **no. 7**<br>– required coordination of work to avoid the deadlock in his workplace **no.4**, **no.7** and **D** | – installation of conveyor belt in continuation of the grid, scale and scanner a worker would has a role that on the basis of the obtained results to add the required amount of ingredients (activate shredder, crusher, press...)<br>– if an automat would be set up (robot) which could perform it, then this workplace would be disappeared |
| **$R_7$** | – physical effort of worker **$R_7$**<br>– tension of the worker due to the need to coordinate timely handling of containers | – with the application of previous measures the workplace **$R_7$** would be disappeared |
| **$R_8$**<br>**$R_9$**<br>**$R_{10}$** | – improper taking of cut parts<br>– the possibility of uneven engagement in relation to other workers in the same workplace<br>– real possibility of errors in determination of the processed finished pieces which is transferred to the state of stocks which effects to the determination of the final balance | – less efforts in taking of cut pieces<br>– increase of utilization of the work time due to operation on the conveyor belt<br>– employment possibility of a large number of workers due to continuous delivery of materials on the belt |

The improvment of the considered production system could be achieved by introducing conveyor belts, scanners, vending machines (robots), beam scale, stationary agents with the appropriate software. After introduction of the previously mentioned measures, the manufacturing system has the form shown in the figure 5.

Worker $R_1$ takes the workpiece from stock and puts it on the conveyor belt, if it is free. After activation of belts, workpiece faces sensors (scanner) and comes to the press. The scanner provides information about the contours of the workpiece to the agent $A_1$, which processes them (by appropriate software) in terms of optimizing cutter of press and forwards it to the central agent A.

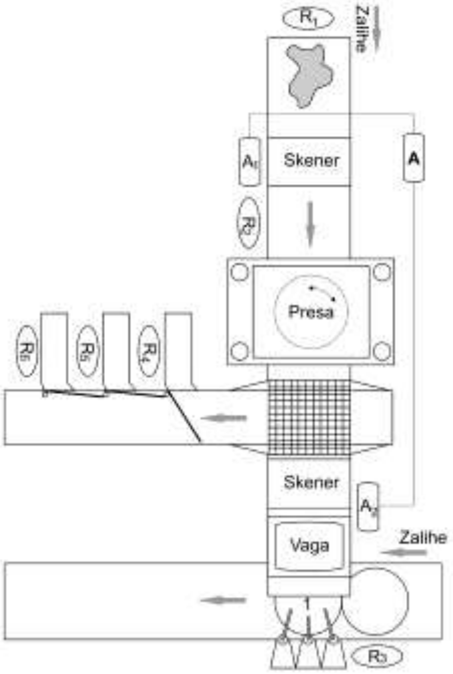


**Figure 5.** The scheme of the production system improved by the application of agents

Central agent A in its database has a maximum number of finished workpieces from a particular cut, and gives instructions to the worker $R_2$ or automatic machines (robots) about the necessary angle to rotate the press and about the chisels necessary to be put in active phase. After that, worker or machine (robot) runs the press. When the press is in its starting position, the belt runs automatically and transfers the workpiece on a lattice-vibration bar (design adapted to separate the cut out pieces) through which the workpiece falls on the lower conveyor belt that transports them to the workers $R_4$, $R_5$ and $R_6$. At the same time next workpiece comes under the press. Excess material is transported away by lattice strip to another track in the same level at which there are sensors (scanner), beam scale, container no.1. Agent $A_2$ takes, processes and forwards information from sensor (number of holes) and beam scale (mass of waste) to the central agent A. In its database, central agent now has a data from both the agents whose processing leads to the desired results.

## 4. Conclusions

Application of intelligent systems is a necessity if we want to realize the preconditions for a permanent improvement of the system and adapting to frequent changes in market demand. As one of the successful and applicable model is the implementation of systems based on the capabilities of agents. Applying this approach can be made improvements in terms of: reduction of subjective feelings, inaccuracies reduction, material savings, reduced production time, workforce reductions and more. As a particularly important stage in the implementation of an agent-based system is the recording phase and analysis of the current production cycle. On the basis of the identified non-conformities or rather critical or non-functional points and production phases can be introduced agent function which optimizes the production process. This paper describes a manufacturing process of cut-out pieces of irregular shape of the wooden board and pointed to certain sites that can be optimized and provides measures for improvement. Further research will go to the application of design solutions and defining a model of production based on intelligent agent based concept.

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**Aleksandar Vujovic**
University of Montenegro,
Faculty of Mechanical
Engineering
Podgorica
Montenegro
aleksv@ac.me

**Zdravko Krivokapic**
University of Montenegro,
Faculty of Mechanical
Engineering
Podgorica
Montenegro
zdravkok@ac.me

**Jelena Jovanovic**
University of Montenegro,
Faculty of Mechanical
Engineering
Podgorica
Montenegro
sjelena@t-com.me

**Gordan Kijanovic**
University of Montenegro,
Faculty of Mechanical
Engineering
Podgorica
Montenegro
stvl@t-com.me