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USE OF PLANT SIMULATION IN AREA OF STORAGE

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Keywords: Tecnomatix Plant Simulation, simulation, distribution process, storage
Abstract: Implementation and use of designing and simulation is currently becoming a standard practice in many undertakings. Simulation enables the company to detect bottlenecks in the production and forecast potential threats. Contribution shows the practical usage of the Tecnomatix Plant Simulation student version in the specific conditions of the industrial company. It deals with the problem of storage and dispatching of the finished products. Plant Simulation is a computer application developed by company Siemens PLM Software for modelling, simulation, analysis, visualisation and optimization of manufacturing systems and processes, flow of material and logistic operations. The application enables comparison of complex manufacturing production alternatives, including the internal processing logic, by help of simulation on computer.

1. Introduction

In the present time are available various information systems which are used by industrial enterprises for removal of problems in production, elimination of losses or decrease of costs.

Plant Simulation is a computer application developed by company Siemens PLM Software for modelling, simulation, analysis, visualisation and optimization of manufacturing systems and processes, flow of material and logistic operations. The application enables comparison of complex manufacturing production alternatives, including the internal processing logic, by help of simulation on computer. Plant Simulation is used by small and also bigger enterprises mainly for strategic planning of layout, check of logic of the process and extent of complex production investment.

2. Use of Tecnomatix Plant Simulation for process of storage

The simulation module Plant Simulation has a wide use mainly in the area of manufacturing and service processes [1]. Its relevant use requires knowledge of basic terms and also understanding of internal logic [5], [7], [8].

The theory of simulation systems usually works with the following terms: [6]

- *Entities* – items which pass through the system (components, documents, clients, statements, reports, etc.).
- *Activities* – activities which are carried out in the system – e.g. loading of truck, turning, check of components, repair of machine, etc.
- *Resources* – means which enable carrying out of activities – personnel, machines, area, tools, energy, financial means, etc.
- *Controls* – rules, which describe how, when and where are carried out the individual activities and under which conditions the individual events may occur in the system.

Overview of basic elements of simulation model of manufacturing system is given in Table 1.

Table 1 Main elements of simulation manufacturing system [6]

Model element	Example		
Components of manufacturing system	static – immobile		machines, stores, ways, conveyors
	mobile	temporary	products, material, tools, cutting fluids, waste, and others.
		permanent	trucks, pallets, workers, etc..
System variables	internal variables		manufacturing performance, number of necessary tools, preparations, etc.
	external variables		number of orders.. failure of machines, and others.
	parameters		number of machines, capacity of containers, number of trucks, and others.

The way of depicting these elements in the model and range of parameters and attributes by which they may be described, is usually given by a specific simulation system [3]. Besides the common objects such as input and output, typical elements for the area of storage are mainly objects existing in the menu of material flow, mobile elements and tools (Table 2) [6].

Table 2 Basic elements for area of storage

	Store	The object serves for storage of components.
	PlaceBuffer	Temporary keeping of parts in row, one behind the other to maximal capacity.
	Buffer	Temporary keeping of parts in row, one behind the other with secured shift.
	Sorter	Temporary keeping of great number of parts and simultaneously their separation according to attributes.
	Line	Modelling of enterprise systems of transport.
	Turntable	Modelling of rotation platform which moves on one of several interconnected material flows or revolves.
	Turnplate	Modelling of rotation platform which revolves after loading of parts.
	Track	Modelling of store or way on which the transporter moves.
	FlowControl	Modelling of strategy of passing and providing total flow of material.
	Display	Presentation of current data and results of simulation process.
	Chart	Presentation of current data and results of simulation process.
	Report	Presentation of current data and results of simulation process.
	Entity	Mobile unit in process represents a component, assembly unit or assembly whole.
	Container	Mobile unit in process represents manipulation units of 1st row.
	Transporter	Mobile unit in process represents motorized and manipulation transport units.
	TransferStation	Control of unloading and loading of entity.

3. Analysis of current state of distribution of finished products

The main task of this part of enterprise is to ensure the put away of manufactured products and their subsequent planned export. The enterprise ensures production of selected models on the basis of orders which are arranged within the shortest time possible so that no overstocks may occur in the store [2].

In the enterprise there exist two inputs of finished products:

1. *TOP LOADER* - serves for separation of products of type T.
2. *FRONT LOADER* - serves for separation of products of type F.

The manufactured, wrapped and marked products are transported on conveyor to the section of physical distribution the main task of which is to distinguish individual models of products and subsequently separate them.

Before the use of simulation program itself it is necessary to analyse the current state of storage and distribution process of finished products. Fig. 1 [4] shows the solution of storage in the enterprise.

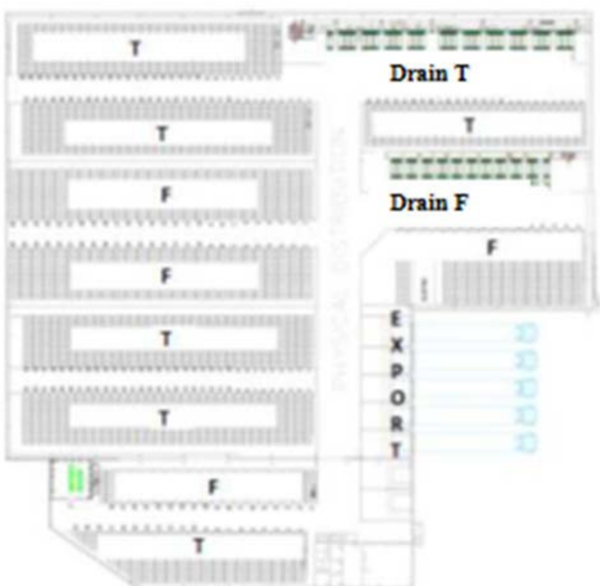

Figure 1 Solution of storage in the enterprise

The products are transported by an input belt to the elevator, which shifts two products into the sorter. In the sorter the operator of the conveyor sets the input requirements under which the device separates them into ten places connected by conveyors. Any such site has three conveyors with a capacity of five pieces per one conveyor. If the sorter requests output into a full destination, the entire belt system is blocked until the conveyors remove the products. For each input are available during the working shift two forklifts while one can transfer twelve pieces of products.

The last part of the followed process in the company is expedition. There are four port ramps for loading of finished products into tandem. For each ramp is provided a forklift and one operator who scans the products according to order and ensures their stability during transport. After preparation of tandem the forklift of respective expedition will start transporting of the required products to the appropriate place where the operator checks the order by scanning. After checking of the order he sequentially stacks the finished products and loads them into the parked tandem. The tandem is filled up until the entire space is filled, respectively until the order is completed.

4. Application of simulation module

For needs and realisation of simulation program Tecnomatix Plant Simulation (TPS) it was necessary to mark the individual types and also transform the real state into the TPS environment. Therefore the products were marked in the program as type A and type B. Their number was adjusted to daily production which represents 5270 pieces for A type and 3300 pieces for B type of products. The transformation into TPS environment itself was realised for input conveyor (Fig. 2), elevator and also sorter.

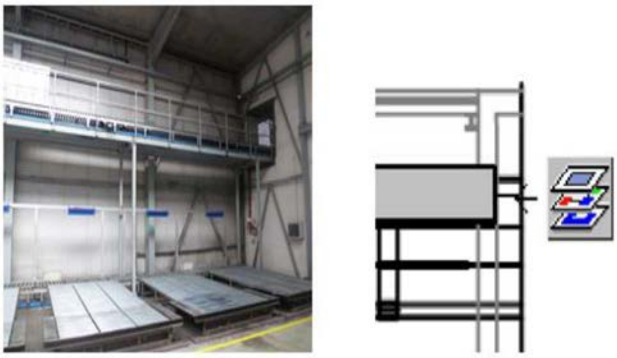

Figure 2 Transformation of real state into the TPS environment – input conveyor

Products entering the conveyor belt individually with the interval of three seconds, due to the safety requirements with respect to the maximum conveyor capacity. The conveyor belt push them to the lift, which ensure transfer on the lower belt, where enters into the sorter. The main task of the sorter is to sort products by planned outputs on a conveyor belt, with a total capacity of 15 units.

Products on the belt are operated with forklift, which is managed by one worker. Overall, in the operation are on the one sorter available two trucks of full condition throughout the work shift. The truck is in this object the moving unit whose main task is to move products from the sorter to the store for the selected product model.

Figure 3 Colour coding of forklifts in the program

At construction of transport in the enterprise the forklifts (Fig. 3) were marked as follows:
- truck A – forklift for put away of the products of type A with maximal capacity 12 pieces,
- truck B – forklift for put away of the products of type B with maximal capacity 12 pieces,
- truck C – forklift for export of products of type A and also B with maximal capacity 12 pieces.

At construction of infrastructure due to programming of crossroads it was necessary to show the movement of all types of trucks after operation. Due to object limitation it was necessary at realisation of the program to point at its versatile use. Therefore are in individual projects included the following basic characteristics of the enterprise's store:

➢ *Loader* – it includes elevator, sorter and conveyors which have a capacity 15 pieces of selected type of product. In figure 4 is shown the 2D and 3D simplified model of the sorter. Its main task is to separate the products according to the code so that separation according to the model may be ensured.

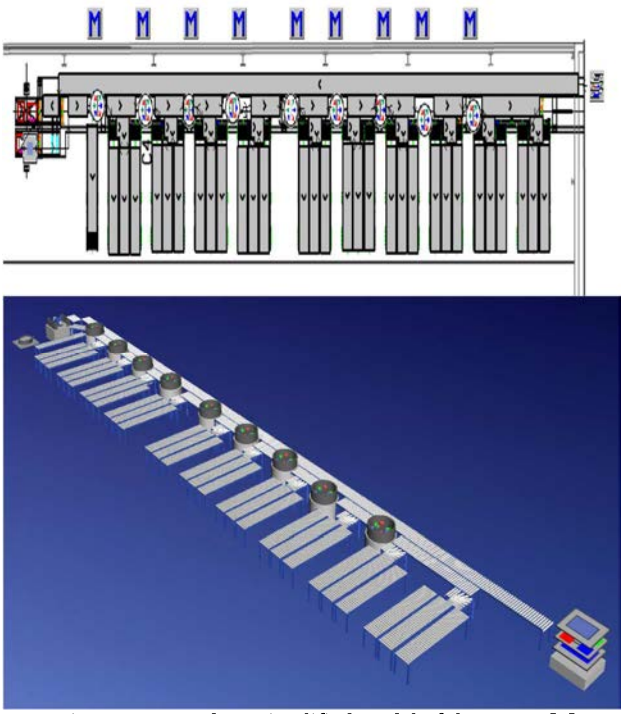

Figure 4 2D and 3D simplified model of the sorter [4]

In the project of simulation were used the following objects: frame, method, control of flow, simple process (serves as elevator) and angular conveyor of the belt.

➢ *Storage and dispatching* – it includes elements as receipt of components, expedition of components from the store, dispatching of components for export and individual ways. In figure 5 is shown the 3D simplified model of storage and dispatching. The main task is to load the finished products from conveyors and transport them into the closest free space designated for storage of selected type of product.

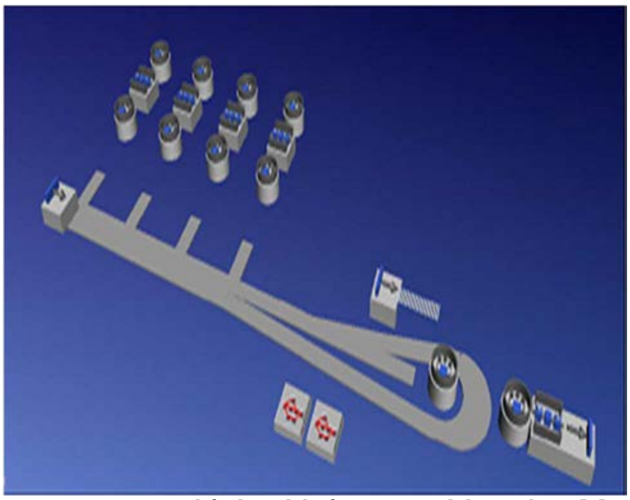

Figure 5 3D simplified model of storage and dispatching [4]

In project of simulation were used the following objects: input, output, letter, way, method, conveyor, display, transforming station and bumper (serves as store).

➢ *Simplified proposal of the process* – within the project was then created a simplified model of total process of storage, shown in figure 6. That includes elements which bear a simplified principled character of the current state. The following objects were used in it: input, output, way, method, simple process, display, Sankey diagram, transforming station, bumper, calendar of changes, work position, worker (operator), work forces, exporter.

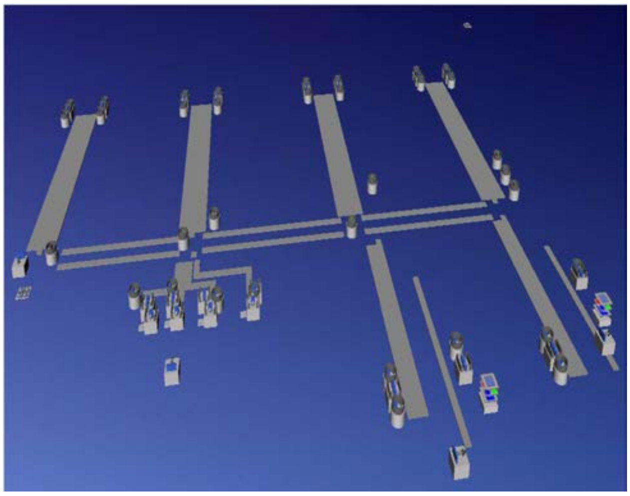

Figure 6 3D simplified model [4]

4.1 *Outputs presented by simulation software*

The report of the company during three day simulation is shown in figure 7.

From the report it is possible to read:

- average time of product from taking over by truck to its export;
- number of pieces which were exported;
- export per hour;
- manufacturing time;
- time of transport; time of storage;
- added value and also graph of total use of time.

Simulation time: 3:00:00:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
export1	Entity	1:03:27:03.3656	3850	57	0.03%	1.19%	98.78%	0.01%	

Figure 7 output of simulation [4]

A further output from the program are graphs of filling up which depict the state after three days of simulation (Fig. 8) and Sankey diagram which after simulation marks the frequency of material flow for selected types of trucks. The program thus provides comprehensible analytic tools for detection of obstacles and also for following the flow of material or products in the manufacturing process.

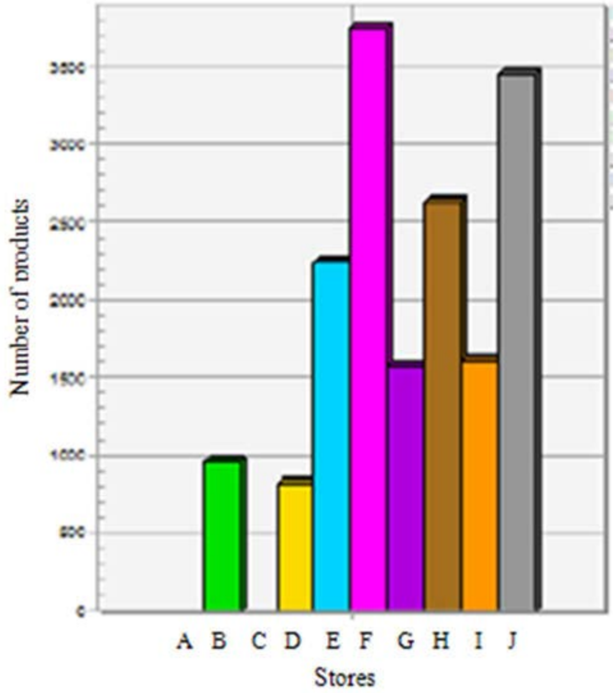

Figure 8 Graph of filling up the stores

At work with simulation program it was necessary to solve several problems and shortages where one of them was the limitation of objects. At full licence which the enterprise would have to buy the problem with limited number of objects would not exist. For work with TPS program it is also necessary to master the basic elements of programming language Simtalk without the knowledge of which the program would be used only to limited extent.

Conclusions

The present era disposes with the whole range of information systems which significantly differ by use in process of proposal, realisation of product and their applications. At use of these systems there is a trend of degradation of complex technological procedures, operational instructions, eliminations of losses and costs of manufacturing.

The use of modern simulation tools brings also a number of necessary analyses and results. With the arrival of newer and newer versions of the Tecnomatix simulation software, wider applications are assumed, which will be more efficient, due to their statistical outputs in the real time, compared to previous versions.

Acknowledgement
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MODERN METHODS OF EVALUATION WORKPLACE FACTORS IN ERGONOMY

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Keywords: musculoskeletal diseases, RULA, REBA, evaluation of ergonomic risks
Abstract: Modern methods of assessment the ergonomic risk serve for early identification and enable complex risk assessment of damage to the musculoskeletal system. These advanced methods include RULA ("Rapid Upper Limb Assessment") and Reba ("Rapid Entire Body Assessment"). The above mentioned methods could serve as prevention of musculoskeletal diseases and could be used in assessing of ergonomic risks in company. Musculoskeletal diseases (MSDs) are the most common diseases in Europe related to work. The implementation of ergonomic principles, i.e. ergonomic risk identification, analysis, proposal, implementation of solutions and evaluation of the effectiveness of measures can significantly reduce the number of MSDs.

1 Introduction

Musculoskeletal diseases (MSDs) are the most common diseases in Europe related to work. The implementation of ergonomic principles, i.e. ergonomic risk identification, analysis, proposal, implementation of solutions and evaluation of the effectiveness of measures can significantly reduce the number of MSDs.

Nowadays, the most used methods enabling the complex ergonomic analysis are methods RULA and REBA.

RULA method ("Rapid Upper Limb Assessment") was developed in University of Nottingham and is used for fast and systematic assessment of the risk in the process of damage the musculoskeletal system with regard to the upper limbs [1]. This method has been used abroad for evaluation disorders of the upper limbs resulting in the evaluation of working positions [3], [4]. REBA method ("Rapid Entire Body Assessment"), systematically evaluate the musculoskeletal apparatus and is based on the methodology RULA [1], [2]. Article deals with the REBA method because the method RULA is freely available on the Internet at: www.rula.co.uk

2 REBA method

The Rapid Entire Body Assessment (REBA) method was developed by Dr. Sue Hignett and Dr. Lynn McAtamney, ergonomists from University of Nottingham in England (Dr. McAtamney is now at Telstra, Australia). REBA is a postural targeting method for estimating the risks of work-related entire body disorders. A REBA assessment gives a quick and systematic assessment of the complete body postural risks to a worker. The analysis can be conducted before and after an intervention to demonstrate that the intervention has worked to lower the risk of injury [5].

The REBA worksheet is divided into two body segment sections on the labelled A and B. Section A (left side) covers the neck, trunk, and leg. Section B (right side) covers the arm and wrist. This segmenting of the worksheet ensures that any awkward or constrained postures of the neck, trunk or legs which might influence the postures of the arms and wrist are included in the assessment [5].

Score Group A. (Trunk, Neck and Legs) postures first, and then score Group B. (Upper Arms, Lower Arms, and Wrists) postures for left and right. For each region, there is a posture scoring scale and additional adjustments which need to be considered and accounted for in the score [1].

2.1 Evaluation of work posture by REBA

Reba assessment is performed in 13 steps. Steps 1-5 value the load of neck, trunk and legs in light of manipulation with loads (group A, score A). Steps 6-10 value the load of upper limbs. Arms, forearms, wrist and graph technique is taken into account (score B). Steps 11-12 determine the final outcome of Reba. It is evaluated according to the table where the values A and B are compared. The score C is assigned in this way and the score activity is added towards it (score C) [1].

Step 13 is an interpretation of the final result Reba.

2.1.1 REBA analysis

REBA analysis A:

Step 1: Locate Neck position:

Choose the picture that matches position of neck at work.

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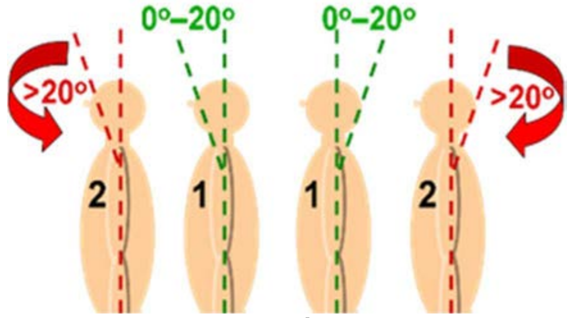

Figure 1 Neck position

If the head is tilted to the side:

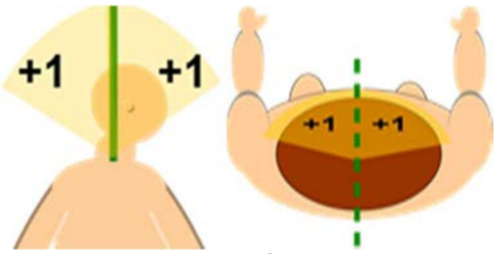

Figure 2 Head position

Enter result to the scheme in item: *neck*:

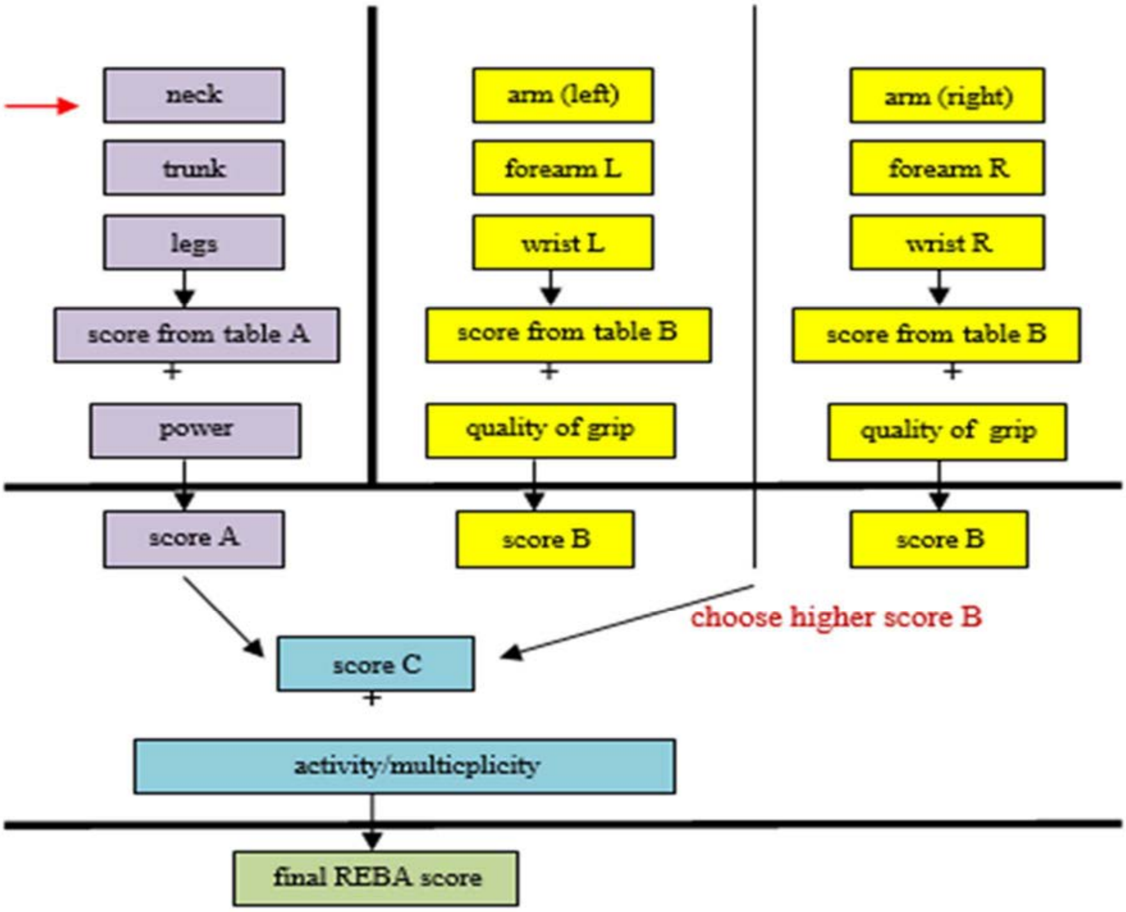

Figure 3 The scheme of REBA results

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Step 2: Locate Trunk position (Figure 4):
Choose the picture that matches position of working posture.

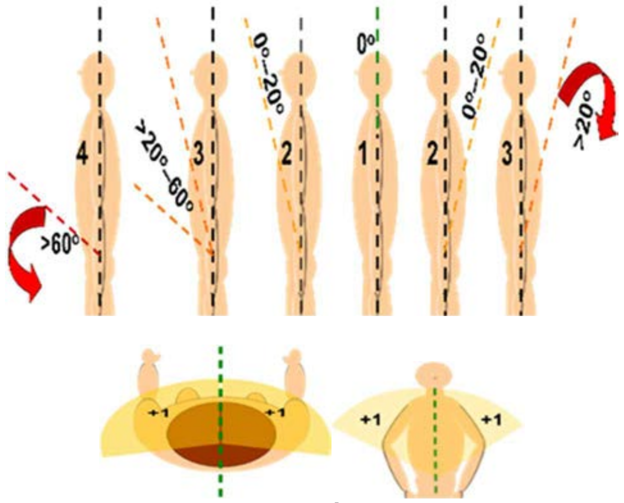

Figure 4 Trunk position

If trunk is twisted: +1
If trunk is side bending: +1
Enter result to the scheme (Figure 3) in item*: trunk*.

Step 3: Location of legs (Figure 5):
Choose the picture that matches position of legs during working process.

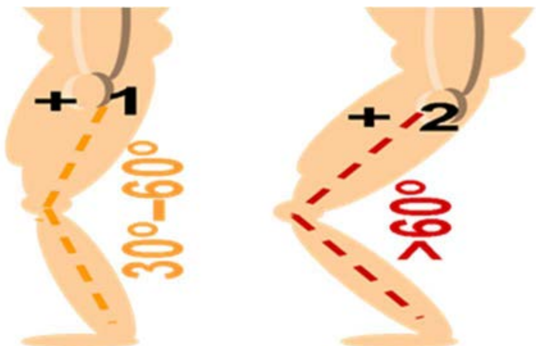

Figure 5 Position of legs

When the knees are bent from 30 ° to 60 °: +1
When the knees are bent more than 60 °: +2
Enter result to the scheme (Figure 3) in item: *legs*.

*Step 4: **REBA analysis A***

Using values from steps 1-3 above, locate posture score in table A (Table 1): According to the table, the posture score is 5.

Table 1 REBA analysis A

tab. A		**trunk**				
		1	2	3	4	5
neck = 1	legs					
	1	1	2	2	3	4
	2	2	3	4	5	6
	3	3	4	5	6	7
	4	4	5	6	7	8
neck =2	legs					
	1	1	3	4	5	6
	2	2	4	5	6	7
	3	3	5	6	7	8
	4	4	6	7	8	9
neck =3	legs					
	1	3	4	5	6	7
	2	3	5	6	7	8
	3	5	6	7	8	9
	4	6	7	8	9	9

Enter result to the scheme (Figure 3) in item: *score from table A* (Table 1).

Step 5: Add force / Load score
If load is < 5 kgs: +0
If load is 5 to 10kgs: +1
If load is > 22 kgs: +2
Enter result to the scheme (Figure 4) in items: *power and score A.*

REBA analysis B:
Step 6: Location of upper arms (Figure 6):
Choose the picture that matches the best position of location the upper arms.

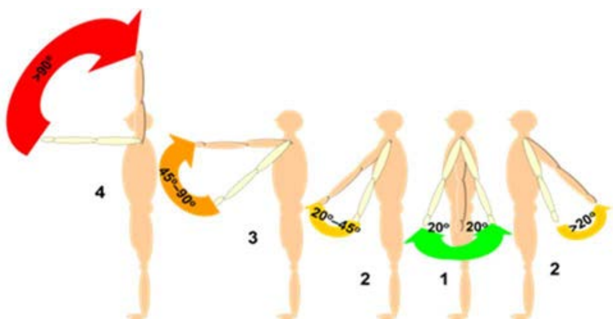

Figure 6 Location of upper arms

If shoulder is raised: +1
If upper arm is abducted: +1

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If arm is supported or leaning: -1
Enter result to the scheme (Figure 3) in items: *left and right arm.*

Step 7: Location of forearms (Figure 7):
Choose the picture that matches the best position of location the forearms.

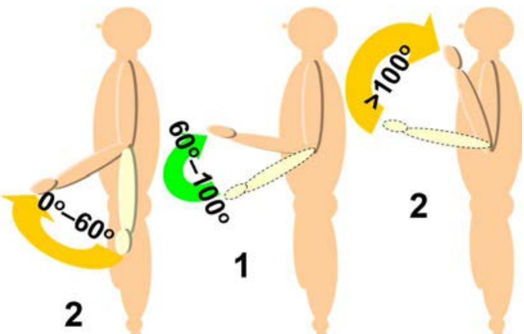

Figure 7 Location of forearms

Enter result to the scheme (Figure 3) in items*: left and right forearm.*

Step 8: Locate wrist position (Figure 8):
Choose the picture that matches the best position of wrist location.

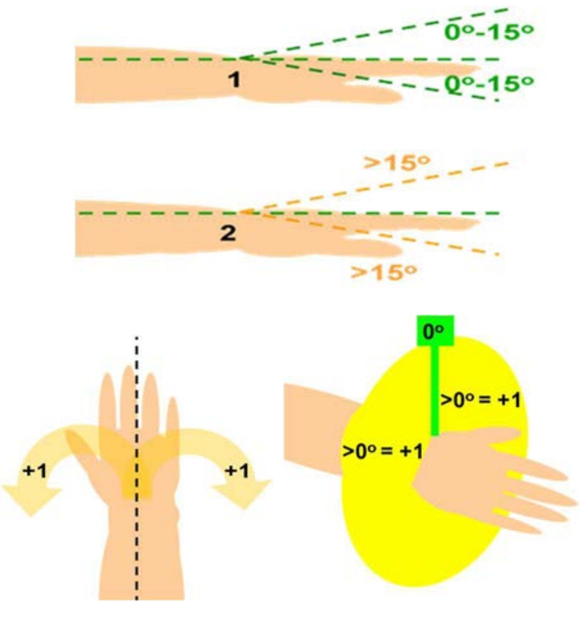

Figure 8 Wrist position

Enter result to the scheme (Figure 3) in items: *left and right wrist.*

Step 9: ***REBA analysis B***
Using values from steps above, locate posture score in table B. According to the table, the posture score is 6.

Table 2 REBA analysis B

tab. B		**arm**					
		1	2	3	4	5	6
forearm = 1	**wrist**						
	1	1	1	3	4	6	7
	2	2	2	4	5	7	8
	3	2	3	5	5	8	8
forearm = 2	**wrist**						
	1	1	2	4	5	7	8
	2	2	3	5	**6**	8	9
	3	3	4	5	7	8	9

Enter result to the scheme (Figure 3) in item: *score from table B (left and right) (Table 2).*

Step 10: Addition of coupling score:
Well fitted handles and mid-range power grip: good: +0
Acceptable but not ideal hold or coupling, acceptable with another body part: fair: +1
Hand hold not acceptable, but possible: poor: +2
No handles, awkward: unacceptable: +3
The higher score is taken into account in final evaluation.

Enter result to the scheme (Figure 3) in items*: quality of grip and score B.*

Step 11: ***REBA analysis C***
Find column in table C.

Table 3 REBA analysis C

tab. C		**final score A**											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Final score B	**1**	1	1	2	3	4	6	7	8	9	10	11	12
	2	1	2	3	4	4	6	7	8	9	10	11	12
	3	1	2	3	4	4	6	7	8	9	10	11	12
	4	2	3	3	4	5	7	8	9	10	11	11	12
	5	3	4	4	5	6	8	8	10	10	11	12	12
	6	3	4	5	6	7	8	9	10	10	11	12	12
	7	4	5	6	7	8	**9**	9	10	11	11	12	12
	8	5	6	7	8	8	9	10	10	11	12	12	12
	9	6	6	7	8	9	10	10	10	11	12	12	12
	10	7	7	8	9	9	10	11	11	12	12	12	12
	11	7	7	8	9	9	10	11	11	12	12	12	12
	12	7	8	8	9	9	10	11	11	12	12	12	12

Enter result to the scheme (Figure 3) in item： *score C (Table 3)*

Step 12: Activity score:
If 1 or more body parts are held longer than a minute (static): +1

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Repeated small range actions (more than 4× per minute): +1
Action causes rapid large range change in postures or unstable base: +1

Enter result to the scheme (Figure 3) in items: *activity/ multiplicity and final Reba score.*

Step 13: Interpretation of Reba result (Table 3):

Table 3 Final REBA result

score	level of risk
1	negligible risk, no action required
2-3	low risk, change may be neede
4-7	medium risk, further investigation, change soon
8-10	high risk, investigate and implemeted change
11+	very high risk, implement change

Conclusion

The aim of the article was to summarize basic knowledge of ergonomic method REBA. Of course there are more methods, approaches and philosophies dealing with ergonomics in workplace. There is developed special software that takes into account the stress of human body during the working process. After these analyses, changes in workplace and working positions are recommended. This software is used in the process of design the workplace. The main goal is to prevent occupational diseases. Each company should focus on its ergonomic side in company. It does not refer to only production workers but also workers who work in offices and spend all day computing, which negatively affects motor system and sight.

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THE CREATING SOFTWARE CONFIGURATIONS MODULAR PRODUCTION ON THE PRINCIPLES OF ERGONOMICS

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Keywords: modular building system, design of workstations, Al-profiles kit systems, planning software, ergonomic factors
Abstract: This article is aimed at problems of designing and ergonomic optimizing of production systems with a modular construction structure made up of building-block principles on the basis of Al components. The modular structure allows an individual and flexible adaption to varying requirements and also the realization of low-cost solutions. Benefits to using the modular profile systems and building elements for creation of new or modernized production base of workstations configuration are mainly: simple fast assembly, short planning time, simple disassembly, easy construction, retrospective modifications, reassembling of all elements.

1 Introduction

This article deals about building principle of ergonomically designing manual workstation focused on modular profile systems.

Production demands can change rapidly, whether they are changing quantities, new product variants, or product generations – the manual production systems from aluminium profile technology can be flexibly adjusted to fit any need. The inventor of aluminium profile technology, in the field of assembly construction, offer alternative to welded steel constructions in the form of the basic mechanical elements and modular profile system.

Profile system is easy to process and quick to assemble- no cutting or welding, no grinding or polishing, no painting. All profiles can be combined in any way imaginable; the accessories provide functional and aesthetic solutions for a wide range of applications: machine bases, enclosures, guarding, work- assembly and inspection stations, transfer and supply trolleys, partitions and protective walls and cabins, special shelves etc.

The software packages (for example MTPro from BoschRexroth) using for computer aided design workstations of aluminium profile system include an up-to-date parts library and parts list information as well as 3-D graphics to help visualize design of production system. In contrast to conventional planning methods, this program helps save time and allows generate planning variants.

2 Modular profiles building block system

The basic elements of the building kit consist of profiles, connecting elements and caps. The extruded aluminium construction profiles are provided with grooves, which can be used in conjunction with connecting elements and can also perform a whole range of additional functions. The aluminium alloy is resistant to weathering and many chemicals and the surface of the profiles has been specially treated to make it permanently scratch- proof and has also been corrosion-protected. All profiles have been designed to deliver maximum strength for the materials used.

System profile technologies offer further modular combination possibilities (e.g. connections with existing constructions, machine frames, protective cabins etc.). With the universally applicable components in modular profile assembly system, it can quickly find a successful solution for all tasks: frames, enclosures, special and series machinery, workstations, supply of materials, etc.

Profit from the benefits of modular profile construction kit system [1]:

- user-friendly screwed connections, perfected, stability-oriented connectors, easy assembly due to standard elements, easily dissembled connections enable flexible modifications during the assembly phase,
- widest system profile range on the market, compatible modular system for all dimensions: 20, 30, 40, 45, 50, 60… mm, all profiles can be combined with each other, the 8 mm and 6 mm groove profiles are used in the construction of simple appliances, partition walls, stands or display cabinets,
- comprehensive range of accessories,
- short planning, design and assembly times, 3-D planning software available,

- high loading capacity with low self-weight, profile technology is fast, stable, and safe.

Profiles of different product lines and sizes can be combined into basic frames with the aid of special connectors. Using connectors with high load-bearing capacities, combined with particularly robust grooves and large central bores allow profile connections even for high static and dynamic loads. All profile connectors have one thing in common: they are screwed into place. Screwed connections can be made quickly and easily. They provide excellent stability, even under heavy loads. And they also have the advantage that can be rebuilt constructions made of basic mechanical elements at any time, or extend them for new requirements. This means you can reuse the same components again and again.

The following advantages are achievable with modular kit [1]:

- Speed: supports during the tender phase, planning and design phase of projects with individual engineering and 3D configuration.
- Risk reduction: by buying in modules at fixed costs the estimating security increases.
- Wide and deep modular system: the whole modular system is so wide and deep that it combines limitless flexibility and compatibility with specific reduction in special parts.
- Degree of assembly: it is possible receive the solutions – as an assembly kit or as a complete module.
- Attractive design of aluminium profiles.
- Combination of stability and function.
- Modern appearance of the whole workstation.
- Minimisation of the risk of injuries.
- No accumulation of dirt.
- No additional covers required.
- Ideal for clean rooms.
- High-quality design.
- No flame cutting and welding - threaded connections instead of welding.
- Profiles and elements can be reused after a system has been dismantled.
- No grinding and polishing - braces and beams can be easily removed or relocated; assembly changes are possible without visible traces and damage.
- No painting - profiles provide a clean surface with good finish; no making good necessary.

The building kit system is a cost-effective and flexible solution for producing a whole range of fixtures and equipment up to and including automated handling systems. The components can be used not only for building laboratory equipment, assembly workstations, electronic manufacturing systems or packaging machinery, but also in highly demanding construction applications such as clean room areas etc.

The products of the building kit system based on aluminium profiles are the perfect solution for everything from simple basic frames and testing stations to complex handling units.

3 Computer aided design of workstations

Computer aided design provides for example tools from Bosch Rexroth – "MTpro" light offers a quick introduction to layout planning software for assembly technology free of cost. MTpro is software for the planning and design of assembly technology systems that supports in selection, configuration and ordering of products from this producer.

Software includes the following functions [2]:

- ✓ Layout Designer for planning and design of complete frames and conveyor systems without a CAD system.
- ✓ Generation of order lists; Upload of order lists to eShop; Sending of requests for quotes to sales contacts.
- ✓ Multilingual content and graphical user interface: switch between 5 different languages at run-time (de/en/fr/it/es).

Advantages:

- Configurable CAD volume models with direct interface to all standard current CAD systems, product configuration.
- Catalog information and assembly instructions at the press of a button, catalog data sheets and assembly instructions.
- Calculating of order lists.
- No limitations to content or functions in the Layout Designer, Layout Designer for planning and constructing complete modules and systems.
- CAD export of layouts created using the Layout Designer.

MTpro is professional software to help plan, design, construct and calculate production systems using building kit components and modules.

Layout Designer functions [2]:

- Combination of catalog components to form assemblies and systems in a virtual 3-D scene with support of a built-in rule engine.
- Drag and drop components directly from the product catalog into the 3-D scene.
- Fast connection and placement of components using the snap function and manipulation handles.
- Hierarchical user library where you can save and reuse your own constructions.
- Consideration of the environment: import floor layouts from 2D-DWG and DXF files; library with room planning elements (walls, windows, doors);

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import custom VRML, DWG and DXF models via drag and drop.
- Intelligent parts list calculation: parts list of all components in the assembly; consideration of additional parts; summary of parts into order units; further processing of the order list via clipboard and integrated report generator.
- Exporting the 3-D layout as a solid into all common CAD systems and save in CAD exchange formats (STEP, SAT, DXF…).
- Extended CAD interface to AutoCAD, Inventor, Solid Works and Pro/Engineer: transfer of CAD models with parts list information; subsequent loading of models from CAD systems into MTpro and reconfiguring them; generation of MTpro order lists from the CAD model.
- Saving the 3-D scene in common graphics and rendering formats, transfer to Office applications using the clipboard (DWG, DXF, 3DS, VRML, PNG).

The sample of planning software to building- block equipments in production system is at fig. 1.

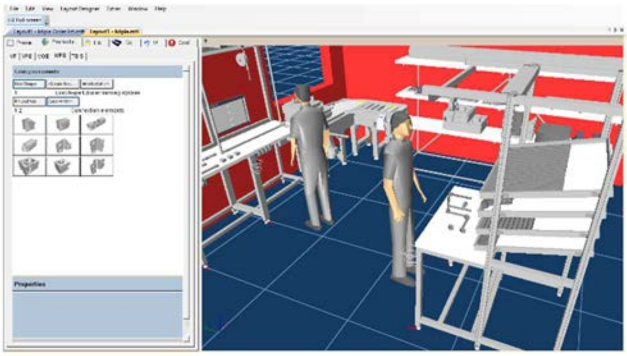

Figure 1 Design software with visualisation tools

Planning software uses icons or menu points and parameter-aided programming techniques so that assemblies, 3D models of humans or individual components of equipment for ergonomic workstations, can be quickly incorporated into a 2D or 3D drawing. The high quality display of the human form is one of the software elements. This enables workstations to be ergonomically planned, tested and optimised to suit every body size.

The example of designing of manual workstation according to customer requirements is presented at fig. 2.

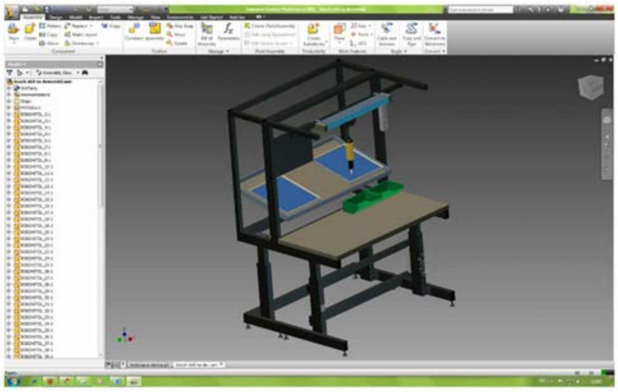

Figure 2 Planning configuration of custom workstation

4 Ergonomic design of modular workstations

An ergonomic workstation facilitates work, maintains health and motivates employees, thereby providing a solid foundation for high productivity and economic success. Ergonomic movements make processes safer, faster and smoother. Ergonomic workstations pay for themselves by facilitating work, reducing downtime, and increasing productivity.

Manual workstations must accommodate a wide range of body heights to ensure that the largest percentage of the population is covered. Country-specific differences and regional requirements must also be taken into account. Design of working systems by ergonomics is described under e.g. DIN ENV 26 385 [2]. Objective of ergonomic design is, among others, adaptation of workplace, working space, environment and lighting to human properties and skills. The modular system for designing individual workplaces enables optimal adaptation to task and individual employee concerned.

Correct workplace design has, to a high degree, positive effects on employees' health, performance, endurance and concentration [3]. The most important factors for designing work equipment are the working height, proper sizing of the reach zones and required legroom, as well as definition of the appropriate range of vision [4]. All of these dimensions are derived from a "standardized" body height.

Further criteria that must be taken into account :
- ✓ Foot and leg room, depth and adjustment range of the footrest;
- ✓ Size and variation of workpiece dimensions;
- ✓ Occurring forces and weights;
- ✓ Changing types of equipment and insert heights;
- ✓ Greatly varying vision distances;
- ✓ Local specifications (deviating body heights, legal requirements, etc.);
- ✓ Aspects related to methods, safety, and efficiency.

By incorporating ergonomic aspects into the design of production equipment in assembly workstations, it will be

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able to optimize working conditions and thus increase the motivation of workers.

Ergonomically and individually designed production systems ensure :

- Work with reduced fatigue;
- Increased productivity;
- Targeted and optimized use of capacities;
- Motivated workers.

An ergonomic workstation design plays a decisive role in reducing waste during production. Thus, for example, the movements for grabbing parts and the distances workers have to walk are directly related to the design of the individual workplace. From an ergonomic aspect, the main focus is on the worker. This is why these workstations are designed to fit each worker and not the other way around.

Designed stand up/moving and sit down/ stand up concepts are the foundation for dynamic, stress-free work. Both concepts are based on individually adaptable workstations with perfectly matched chairs. The building block profile systems provide all the modules that are need to ergonomically design and arrange of workstations. They have developed an ergonomics checklist that assists during workstation planning and design, which will help attain the greatest possible performance, safety, and motivation from workers.

Custom designed workstations offer a wide range of variable dimensions and individual solutions or select from standard products with fixed dimensions. At fig. 3 is example of image manual assembly worktable with accessory equipment.

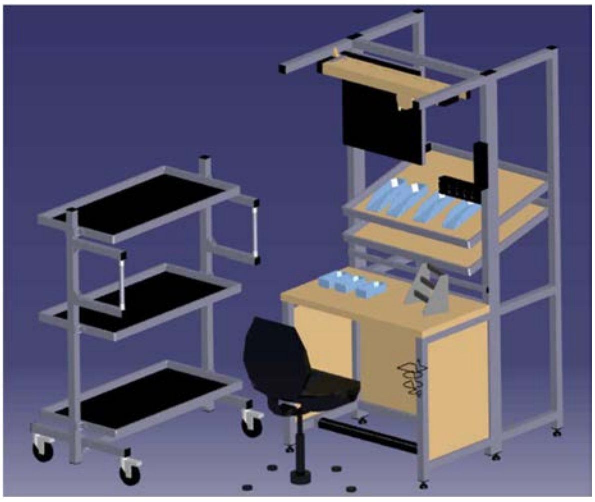

Figure 3 Example of modular workstation and mobile stock rack

The dimensions and position of the table top results from the dimensions selected for the workstation height, width, and depth. Height-adjustable levelling feet make it possible to compensate for floor irregularities and casters can be used to create mobile workstations. Height-adjustable workstations are the most flexible solution for dealing with extremely varied workpiece/component dimensions and large differences in employee heights. Height-adjustable workstations are perfectly suited for visual inspection and manual work (e.g. in wristwatch assembly or jewelry manufacturing).

The sample application of building-block principle equipments, composite to the manual production system structure, on the basis of Al-construction profiles is at fig. 4. Workstation systems and comprehensive accessories from building blocks construction systems can be individually adapted to different production needs.

Figure 4 Examples of a draft concept for workplace work standing up and a ***seated position***

Workstation accessories - these functional workstation components can be used at any station and increase the efficiency of workers. They offer defined storage spaces, support work processes, and ensure optimum transparency and ergonomics. All workstations can be equipped with side panels and footrests, as well as cloth and bottle holders. It is possible equip the workstations with socket strips, system lamps, and compressed air strips. Suitable accessories make it possible to supply grab containers, tools, and information at the workstation. An accessory upright permits, for example, installation of material shelves for parts supply at the workstation.

All reach distances should be as short as possible to avoid redundant, no value- added movements. Grab containers and parts containers that are in direct reach of the employee are ideal. In addition, a comprehensive program of accessories consisting of workstation lighting, power supply, and information provision and positioning of tools, components and swivel work chairs, is available.

To maintain performance and promote productivity, all work equipment near the workstation must be precisely adjusted to the employee and their activity. Correct adjustment of the table, chair, footrest, and grab containers, as well as the position of tools and material shuttles, minimizes movements, thus reducing physical exertion and employee absences.

A few important considerations :

- When adjusting the chair and footrest, make sure that the thighs and calves form a right angle.
- Information boards should be hung at eye level to avoid unnecessary head movements.
- The angle of the shelves for material supply should be adjusted to create short, direct reach distances.
- Use lifting aids to supply heavy parts.
- Monitor brackets and tool shelves can be adjusted to any height via the profile groove.
- With height-adjustable workstations, the optimum working height can be adjusted according to the size of the person or product.
- Information
- on information boards.

It is just small things that often count: handy accessories are necessary addition to perfect design of an optimal workplace. Everything must be on its proper place and instructions or information should be attached properly and clearly visible. Auxiliary equipment helping avoid loads and taking care of workplace overview noticeably support efficiency at reduced employees' stress.

Open system dimensions and numerous components enable individual designs for sit-down and stand-up workstations. It makes an almost unlimited number of designs possible with just a few components. The building kit system can be used to design a whole range of workbenches - from simple standard benches to special ergonomic solutions to meet specific requirements.

Modular assembly workstations have been tried in practice and constantly developed further. The workstation can be constructed from individual components or purchased as a complete and fully assembled system. Profile system contains a broad and highly performed accessory program, which guarantees an optimal adjustment to individual requirements. An adequate modification allows the working table to be integrated easily into existing assembly lines. A future-oriented concept of flexible assembly system compact of workstations is based on standardized structural frame designs, as well as process modules with compact dimensions.

5 Conclusions

The flexibility of modular building blocks profile system in assembly workstations provides a long list of benefits: start-up costs are lower, there is a shorter debug time, reuse reduces later capital investments, they can be reconfigured when production requirements change, simple fast assembly, short planning time, simple disassembly, easy construction, retrospective modifications, reassembling of all elements because offers a comprehensive, harmonised profile system.

The modular, standardized design of all building components means they can be shipped quickly for replacement, resulting in minimum downtime.

All profiles can be combined in any way imaginable; the accessories provide functional and aesthetic solutions for a wide range of applications: machine bases, enclosures, guarding, work- assembly and inspection stations, transfer and supply trolleys, partitions and protective walls and cabins, special shelves etc.

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USAGE OF SIMULATION FOR INTEGRALS CALCULATION

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Keywords: simulation, Monte Carlo method, geometric method, estimation of certain characteristics
Abstract: The article deals with the simulation, more specifically with the method Monte Carlo. The term as a simulation, simulate, a simulator are well known in many scientific disciplines. The simulation model allows performing a number of experiments, analysing them, evaluating, optimizing and afterwards applying the results to the real system. By using the Monte Carlo method it is possible to compute one-dimensional and multi-dimensional integral. Monte Carlo method can be divided according to procedure solutions to geometrical methods and calculation based on the estimation of certain characteristics of random variable.

1 Introduction

Simulation is a method designed to mimic the real system. It is used when an analysis is mathematically difficult or expensive (there is no analytical solution), or in case where is not possible to made a real experiment. In order to simulate the values of the random variables are replaced by generating a large number of the implementation of the random variable and these are statistically processed. One method is Monte Carlo simulation through which it is possible to determine the value of the number π and compute one-dimensional and multi-dimensional integral, it is also applicable in estimating the development of finance and so on. Monte Carlo method can be divided according to procedure solutions to geometrical methods and calculation based on the estimation of certain characteristics of random variable.

2 Monte Carlo method

Geometric algorithm method is based on the fact that we want to calculate the content formation Ω, which lies inside the unit squares (Figure 1). In the square we choose *n* random points evenly distributed and see how many of them fall into the unit, the number denoted *m*. According to the theory of geometric probability it is then content formation Ω is approximately equal ratio m/n. When calculating the area of the process is that it is generated independently from the implementation $(x_i, y_i)\cdots(x_n, y_n)$ of the uniform distribution $(0,1)\,x\,(0,1)$ if true $(x_i, y_i)\in\Omega$ then the random variable $\varphi_i = 1$ otherwise $\varphi_i = 0$. Referred to below $m=\sum_{i=1}^{n}\varphi_i$ in which *m* has the binomial distribution with $n, p \approx Bi(n,p)$, with means $m=\sum_{i=1}^{n}\varphi_i$, $E(m)=np$ and dispersion $D(m)=np(1-p)$. Estimate of the area Ω is then approximately equal ratio m/n.

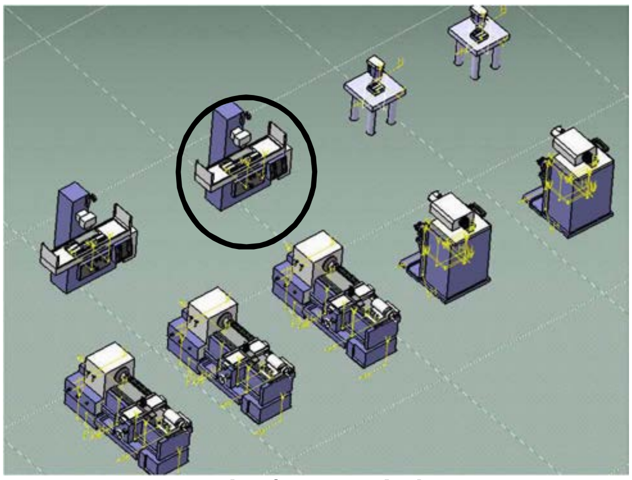

Figure 1 Example of area inside the unit squares

The calculation is based on the estimation of certain characteristics of the random variable is that the need to calculate the value of some unknown *z*. We model such a random variable φ to which is applied $E(\varphi)=z$ (mean random variable is equal to the unknown value). Furthermore, we expect the implementation of *n* independent $x_1, x_2, \ldots x_n$ random variables $\varphi_1, \varphi_2, \ldots \varphi_n$ with the same probability distribution as φ. Unknown value *z* is estimated using the arithmetic average $z=\frac{1}{n}\sum_{i=1}^{n}x_i$. We obtain profit in a suitable transformation of random numbers generated by the search value $x_1, x_2, \ldots x_n$.

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General scheme of Monte Carlo:

- Generating random numbers x_i with uniform distribution on the interval $(0,1)$
- Transformation of random numbers x_i to random numbers z_i to the necessary distribution.
- Calculation of estimates of characteristics of random variables X by random numbers z_i
- Statistical treatment of results.

Monte Carlo calculation method is based on a random process modelling and data-processing statistical methods. To achieve the necessary precision, it is necessary to repeat the simulation many times. At the same time the estimated value of the unknown is important to determine the accuracy of the estimate.

Accuracy of estimates may be determined as follows:

- Searched the unknown value X estimated by the implementation of the random variable $\bar{X}$ while $X \approx \bar{X}$. Unknown value is estimated using the arithmetic average, $\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i$ which $X_1, X_2, \ldots X_n$ are independent random variables with means X and with the dispersion σ^2.
- The accuracy of approximate $X \approx \bar{X}$ has equality ε with the reliability α if the inequality $|X - \bar{X}| < \varepsilon$ is valid: $P(|X - \bar{X}| < \varepsilon) = \alpha$.
- According to the central limit theorems a random variable $\bar{X}$ asymptotically (for $N \to \infty$) a normal distribution with mean $E(\bar{X}) = X$ and variance $D(\bar{X}) = \frac{\sigma^2}{N}$, $P\left(\frac{|X - \bar{X}|}{\sigma^2}\sqrt{N} < u_\alpha\right) = \alpha$ where u_α the critical value of the standard normal distribution ($u_{0,95} = 1{,}644854$).
- For the estimate of the accuracy is valid: $\varepsilon = u_\alpha \sqrt{\frac{\sigma^2}{N}}$ ($N = u^2{}_\alpha \left(\frac{\sigma}{\varepsilon}\right)^2$ - number of attempts needed to achieve the necessary precision ε the level of significance α).
- If a random variable m has a binomial distribution with parameters n and p, with a mean value $E(m) = np$ and dispersion $D(m) = np(1-p)$ so the true size of the error $P\left(\frac{|X - \bar{X}|}{\sigma^2}\sqrt{N} < u_\alpha\right) = \alpha$. The accuracy of the estimate is valid $\varepsilon = u_\alpha \sqrt{\frac{p(1-p)}{n}}$.

2.1 Integral estimate using geometric methods

Estimate of the integral $\int_a^b f(x)dx$ of geometric methods we mean the detection of the equals (1) the area under the curve $f(x)$ in which (a,b), where $f(x)$ the density, to determine the probability that the random value X falls into the range (a,b).

$$P(a < X < b) = p = \int_a^b f(x)dx \qquad (1)$$

Using the Monte Carlo method first generate random numbers x_i from the distribution which has a density $f(x)$ then we determine the number of attempts (m) which are valid $a \le x_i \le b$ According to Bernoulli's sentence for sufficiently large n can take the integral estimate for the relative number m/n.

In calculating the difference whether integrated functions is implemented probability density variable or not.

a) If $f(x)$ is the probability density of a random variable: $\int_{0,3}^{0,7} e^{-x}dx$.

First, they generate random numbers x_i with exponential distribution (e^{-x} - density of a random variable with exponential distribution), and then determine the number of attempts *(m)* which are valid $a \le x_i \le b$. After conversion of attempts n is the approximate value of the integral m/n. The exact value of the integral is 0,244233 the approximate value of the integral depends on the number of attempts and transferred accuracy of the estimate are shown in Table 1. The accuracy of the estimate can be determined from the relation $\varepsilon = u_\alpha \sqrt{\frac{p(1-p)}{n}}$, where p is the exact value of the integral.

Table 1 The approximate value of the integral $\int_{0,3}^{0,7} e^{-x}dx$

n	10	50	100	500	1000
I	0,2	0,21	0,25	0,228	0,235
ε	0,0158	0,00303	0,00152	0,0003	0,00015

b) If $f(x)$ is not the probability density of a random variable $\int_0^1 f(x)dx$ whichever is valid $0 \le f(x) \le 1$

that the value of the integral equals the area under the curve $f(x)$. In this case, a pair generate random numbers (x_i, y_i) from a uniform interval $(0,1)\,x\,(0,1)$ and determine the number of attempts (m) which are valid $y_i < f(x)$. After conversion of attempts n is the approximate value of the integral m/n. The exact value is 0,310268 for the integral $\int_0^1 \sin(x^2)dx$ the approximate value of the depends on the number of attempts and transferred accuracy of the estimate are shown in Table 2.

Table 2 The approximate value of the integral $\int_0^1 \sin(x^2)dx$

n	10	50	100	500	1000
I	0,2	0,3	0,34	0,292	0,306
ε	0,0176	0,003520	0,00176	0,000352	0,000176

If $f(x)$ is not the probability density of a random variable and the limits of the integrals are a,b: $\int_a^b f(x)dx$ is necessary to make the substitution (2):

$x = a + (b-a)z$,

$$\int_a^b f(x)dx = (S-i)(b-a)\int_0^1 g(z)\,dz + (b-a)i \qquad (2)$$

Where S is a supremum and i infimum function $f(x)$ of the interval (a,b), $g(z) = \frac{f[a+(b-a)z]-i}{S-i}$ for the function $g(z)$ valid $0 \le g(z) \le 1$. The exact value is 0,467970 for the integral $\int_1^{1,5} \sin(x^2)dx$ the approximate value of the integral depends on the number of attempts and transferred accuracy of estimates are shown in Table 3.

Table 3 The approximate value of the integral $\int_1^{1,5} \sin(x^2)dx$

n	10	50	100	500	1000
I	0,4556	0,46449	0,464496	0,466271	0,465716
ε	0,0205	0,00409	0,00204	0,00041	0,00020

2.2 Integral calculation based on estimates of the mean value of random variable

The calculation is based on the model of such a random variable φ which is valid $E(\varphi) = z$, (mean of random variable is equal to the unknown value). Unknown value is integral (3):

$$z = I = \int_a^b g(x) f(x) dx \qquad (3)$$

First, we generate random numbers x_i from the distribution which has a density $f(x)$ then calculated $y_i = g(x_i)$. According to the law of large numbers in the form of sentences Khinchin a sufficiently large number of trials n can approximate value for the integral of the arithmetic average $g(x_i)$ (4):

$$I = \int_a^b g(x) f(x) dx \approx \frac{1}{n}\sum_{i=1}^{n} g(x_i) \qquad (4)$$

Accuracy of estimates can be determined by the relationship $\varepsilon = u_\alpha \frac{s}{\sqrt{n}}$.

When calculating the integral $J = \int_a^b h(x)dx$ we choose the distribution with density $f(x)$ $(\int_a^b f(x)dx = 1)$ and integral adjusted as follows (5):

$$J = \int_a^b \frac{h(x)}{f(x)} f(x)dx = \int_a^b g(x) f(x)\,dx \qquad (5).$$

If the final boundary of the interval, so we can $f(x)$ take for uniform distribution and density $f(x) = \frac{1}{b-a}$ of the integral holds: $J = (b-a)\int_a^b h(x)\frac{1}{b-a}dx$. In case of improper integrals for example $\int_0^\infty g(x) f(x)dx$ we take $f(x)$ the density exponential distribution with parameter 1, $f(x) = e^{-x}$.

For integral $\int_1^{1,5} \sin(x^2)dx$ is density for uniform distribution $f(x) = \frac{1}{1,5-1}$, generates a random number x_i from a uniform distribution, since the limits of the integral are 1 and 1.5 will transfer the substitution (6):

$$x_i = (1.5-1)RAND(x) + 1 \qquad (6),$$

calculate values $y_i = h(x_i) = \sin(x_i^2)$ and determine their arithmetic average $\bar{y}$. For the integral value true: $\int_1^{1,5} \sin(x^2)dx \approx (1,5-1)\bar{y}$. The exact value of the integral of 0,467970, the approximate value of the integral depends on the number of attempts and transferred accuracy of estimates is shown in Table 4.

Table 4 The approximate value of the integral $\int_1^{1,5} \sin(x^2)dx$

n	10	50	100	500	1000
$\bar{y}$	0,95271	0,92895	0,94041	0,93721	0,93864
I	0,47635	0,46447	0,47020	0,46860	0,46932
ε	0,05851	0,03016	0,02299	0,01051	0,00736

These methods may also be used in the calculation of multidimensional integral.

Conclusion

The article is an example of using the Monte Carlo, demonstrated the possibility of its usage compute one-dimensional and multi-dimensional integral, it is also applicable in estimating the development of finance and so on. Monte Carlo method can be compute one-dimensional integral, divided according to procedure solutions to geometrical methods and calculation based on the estimation of certain characteristics of random variable. The contributions are calculated integrally both methods and determining the accuracy of the estimate. Both methods have comparatively results. The result is more accurate with a count in simulation.

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