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NEURAL NETWORK APPLICATION FOR TIME STANDARDS SETTING IN ASSEMBLY AND DISASSEMBLY

Time standards belong to the key indicators of production process effectiveness. The paper discusses time standard setting in the production process. One of the important stages of the production process is assembly, which is a crucial stage in case of manufacturing customized products. The aim of the article is to show the methods of time standard setting which facilitate assembly planning. Specific goals of the article are focused on finding common attributes useful in assembly tasks characteristics and changeover, as well as finding value intervals helpful in assembly description. Shortening the product lifecycle, new product development and product customization bring about the development of a modular reconfigurable assembly line. The development of flexible assembly lines requires standards related to typical assembly tasks and tools. Reconfiguration and balancing assembly lines require a knowledge base related to time standards. This article presents examples of typical tasks, tools and time standards for planning product assembly and changeover which use the assembly and disassembly processes.

1 INTRODUCTION

One of the most important strategies aimed at reducing lead times and cutting costs is standardization which is focused on defining and implementing standard processes for core activities in manufacturing [1].

One of the main stages of the production process is assembly, which is a crucial stage in customized product production process where products are assembled according to customer needs. In the presented approach, a product and production process data model will be created with the use of an object-attribute-value (OAV) framework and the neural network NN. The aim of the article is to present a neural network NN method of time standard setting for a given assembly process.

2. LITERATURE ANALYSIS

Researchers have discussed different aspects of the assembly system. Schedin et.al. [2] discusses assembly system design, whereas Gorski et al. [3] deals with mass customization

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assumption. The idea supporting the customised assembly process is reconfigurable modular assembly system, whose design principles have been discussed by Müller at al. [4]. The assembly-oriented method for reconfigurable assembly process and equipment according to Muller et al. included product and process analysis, identification of change drivers and responsibilities, modelling the assembly system, technical design of the modules, composition and design of the overall assembly system. According to Kang et al [5], product assembly consists of several components and fasteners which mechanically join or affix two or more components together, such as a screw. In the assembly model used in the presented approach, a product is divided into several major subassemblies which consist of components and fasteners.

According to Müller et al. [4] the tasks of operation in assembly can be classified into handling (included: feeding, transport, locking), joining (included: pressing, welding, screwing, etc.), commissioning (included: adjustment, parameter set-up, function test), support processes (included: storing, change quantity, checking, etc.) and special operations (included: cleaning, reworking, packaging, etc.).

Mital et al. [6] presents various assembly methods: manual assembly, automatic (fixed) assembly, hard automation, robotic assembly (soft automation).

Manual assembly time estimation was discussed by Chan et al. [7] who assembly times obtained by the MODAPTS predetermined time system. Cohen et al [8] apply for assembly time standard setting a Predetermined Time and Motion Study (PMTS) method such as MTM or MOST.

Ritchie et al [9] analysed assembly activity-related actions. Liu at al. [10] proposes an assembly process modelling mechanism based on the product hierarchy, and the assembly-by-disassembly approach is used for constructing the assembly process model.

Disassembly was discussed by Li et al. [11] who analysing the disassembly knowledge and experiences of connectors. Disassembly is a function of several design parameters that directly or indirectly affect the process of product disassembly. The following parameters have been addressed by Mital et.al. [6]: degree of accessibility of components and fasteners; amount of force (or torque) required for disengaging components (in case of snap fits); design factors such as the weight, shape, and size of components being disassembled.

Researchers use NN to approximate multi-dimensional influencing variables or combinations of the influencing variables [12]. According to Vosniakos et al a manufacturing cell can be modelled using cell performance estimation through NNs [13].

3. TIME STANDARD SETTING IN ASSEMBLY AND DISASSEMBLY WITH THE USE OF NEURAL NETWORK

Time standard setting with the use of NN can be based on the following stages (Fig. 1):

- Assembly and disassembly process analysis – characteristic of the attributes affecting time standard, time data collection.
- NN model development of the assembly process - development of training and testing sets, finding the best NN structure which is a model of the assembly process.

- Time standard prediction with the use of NN assembly process model – new assembly or disassembly task characteristic, time prediction.

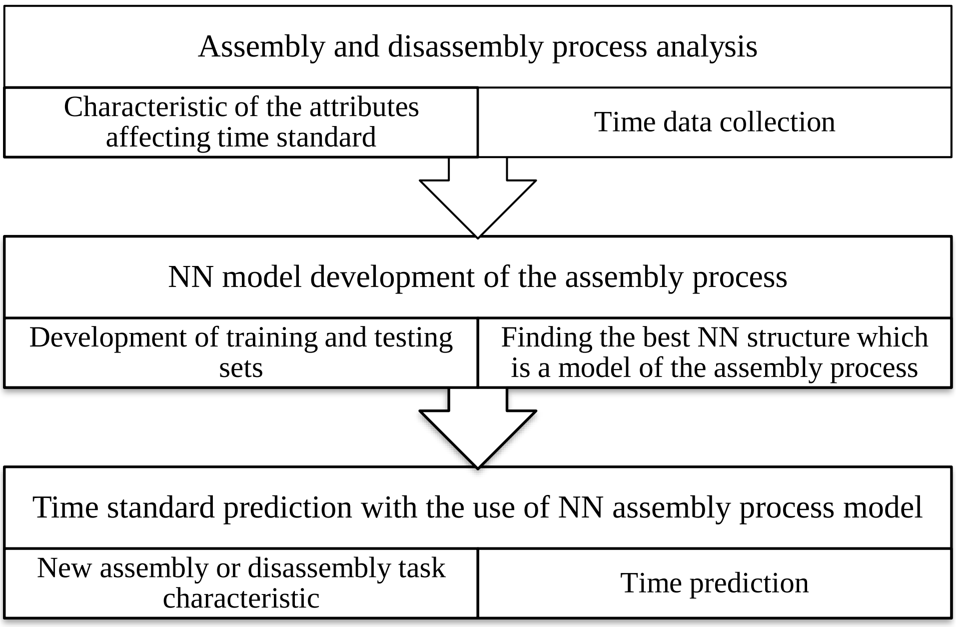

Fig. 1. Time standard setting with the use of NN

3.1. ASSEMBLY AND DISASSEMBLY PROCESS ANALYSIS

3.1.1. CHARACTERISTIC OF THE ATTRIBUTES AFFECTING TIME STANDARD

Assembly and disassembly process analysis can use factors affecting time standards which were presented in Fig. 2. The idea is to create time standards regarding standard manual and machine-manual operations, taking into consideration product characteristic and typical tools, equipment and layout.

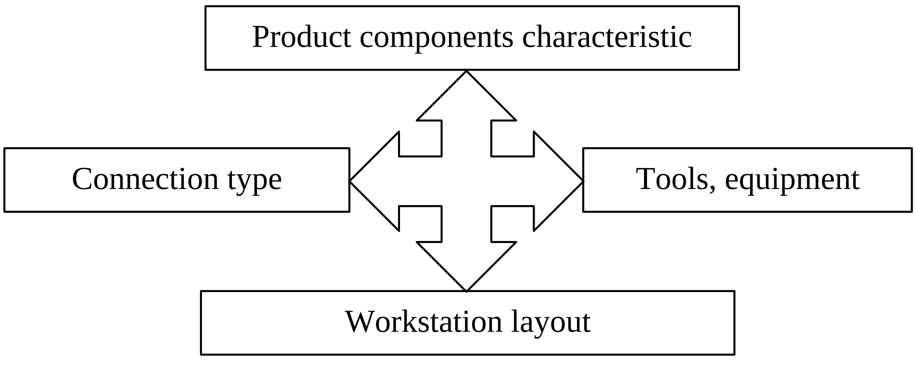

Fig. 2. Factors affecting time standard of the assembly and disassembly process

The analysed features include:

- Information determined during product development (e.g. from CAD software)
  - product structure, part characteristic (e.g. weight, size),
  - connection type.
- Information determined during assembly planning
  - Tools (hand screw driver, power screw driver, pliers)
  - Equipment (press, heater),
  - Workstation layout (distances, way of feeding.)

Collecting data is focused on time consumption analysis and the factors affecting time standard. The factors can be analysed according to the object-attribute-value (OAV) framework, in which an object is understood as an entity being described, an attribute is a feature characterizing a given object, and value is a measure of a given attribute.

Eppinger et. al. [14] created a model in which process planning know-how is described with the use of product assembly information classified into the following categories: information to be saved and automatically detected in CAD, information to be selected by product development, information to be added by assembly planning.

The proposed OAV framework uses information to be saved in CAD, such as component type and characteristic, and information to be added in assembly planning, like workstation layout, tools and equipment (Fig. 3).

Product assembly information (two components assembly)			
Attribute	Value		
		Information to be saved in CAD	Components characteristic
			Connection type
		Information to be added in assembly planning	Workstation layout
			Tools, equipment

Fig. 3. Product assembly information model based on [14]

The connecting elements belong to the crucial data affecting time standard of the assembly and disassembly process. A connecting element can by classified [14, 15] into the following categories:

- Detachable (without destruction of the connecting elements): screw, pin, bolt, cone connection, press connection, profile.
- Detachable (with destruction of the connecting elements): rivets, clip connection.
- Non detachable: soldering, sticking, welding.

In production, fastening tools include, among others:

- Hand fastening tools (manually operated assembly tools): hand wrenches, hammers, pliers, a woodruff key, an Allan key, screw drivers.
- Power fastening tools (Electrically-powered, Air-driven): power drills, electric screw drivers, electric nut runners.

Types of connections included e.g.: screwing, pressing, sticking. The assembly process can be analysed with the following movements:

- Picking up a component.
- Assembly – connection of two components, or disassembly – disconnection of the components.
- Putting down a component.

The detailed characteristic of the assembly and disassembly process was presented in Fig 4.

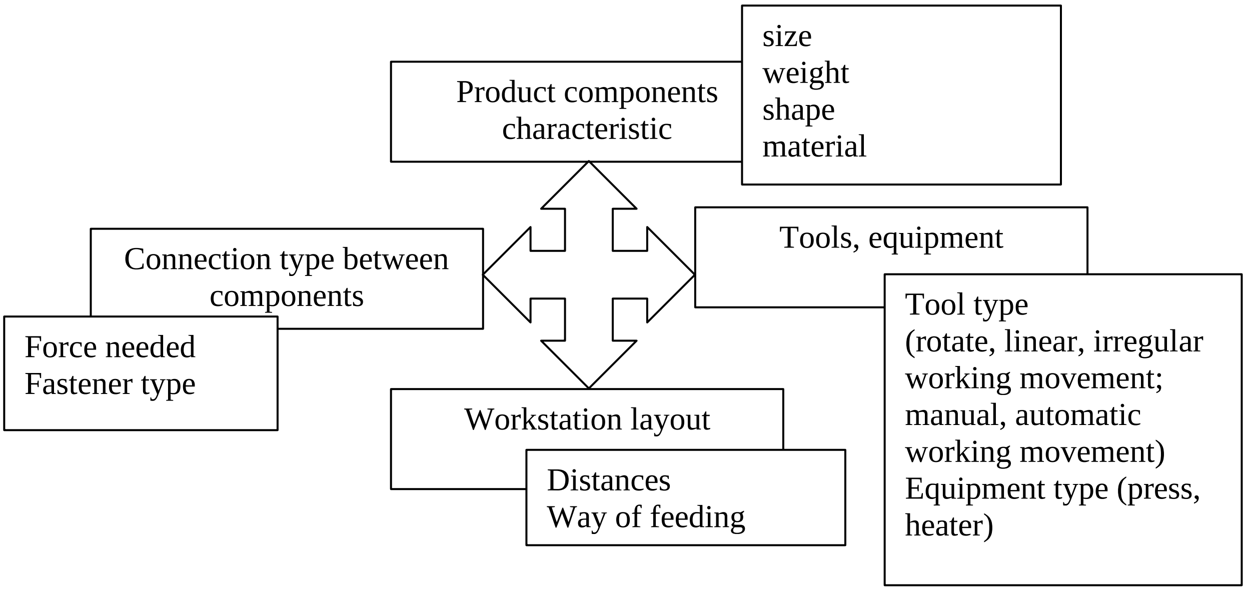

Fig. 4. Factors (attributes) affecting time standard of two components assembly or disassembly

3.1.2. TIME DATA COLLECTION

Standard time which is understand as the amount of time that should be allowed for an average worker to process one work unit using the standard method and working at a normal pace [19, 20] can be set with methods such as e.g.: Predetermined Time and Motion Study (PMTS) method such as MTM or MOST as well as time measurement method or subjective estimates of times [19, 20].

Predetermined Time and Motion Study (PMTS) methods are typically used to estimate the standard times of operations before their execution [8].

In time measurement method the Standard Time is the product of the following factors [19, 20]: observed time (the time is measured to complete the task) and performance rating factor (the pace the person is working at. 70–95% is working slower than normal, 105–120% is working faster than normal, 100% is normal, the pace lower than 70 and higher than 120% is out of analysis, this factor is estimated by an experienced worker who is trained to observe and determine the rating).

Subjective estimates of times is focused on time setting with an experienced worker. Research by Chan and Hoffmann [21, 22] showed that people can estimate task times with reasonable accuracy [8].

3.2. NEURAL NETWORK MODEL DEVELOPMENT OF THE ASSEMBLY PROCESS

NN model development of the assembly process can based on the following steps:
- Development of training and testing sets.
- Finding the best NN structure which is a model of the assembly process.

3.2.1. DEVELOPMENT OF TRAINING AND TESTING SETS

Training and testing set development applies the OAV framework and assembly analysis, in which each assembly movement consists of the following phases:
- Picking up a component, fastener or tool.
- Assembly or disassembly of the components and fasteners.
- Putting down a component, fastener or tool.

The relation between attributes and assembly movement which can be used in training set development was presented in Table 1.

Table 1. Attributes used for assembly movements characteristic

Product, tool, layout		Movement type		
Attribute	Value	Picking up	Connection, disconnection	Putting down
Distance	Small (less than 20 cm) Medium (20-80 cm) Large (over 80 cm)	x		x
Way of feeding	Singly Many	x		x
Weight	Light (less than 1 kg) Medium (over 1 kg less than 8 kg) Heavy (over 8 kg)	x	x	x
Size	Small (less than 2 cm) Medium (2-80 cm) Large (over 80 cm)	x	x	x
Shape	Simple - regular shape, small number of surfaces used in assembly Complicated - irregularly shaped, many number of surfaces used in assembly	x	x	x
Material	Flexible, fragile Inflexible		x	
Force needed	Low force High force		x	
Fastener type	Detachable (without destruction of the connecting elements) Detachable (with destruction of the connecting elements) Non detachable		x	
Movement type	Rotational Linear Irregular	x	x	x

Tool	Manual		x	
	Automatic			
	No		x	
Additional treatment	Heating		x	
	Cooling			
	Other			

Attributes can be classified as constant or variable. Constant attributes can be used for product, tool and layout description, whereas variable attributes can be applied for a given assembly process description. Constant attributes examples are shown in Table 2, and examples of variable attributes were presented in Table 3.

Table 2. Examples of constant attributes

Product, tool, layout		Constant attributes
Attribute	Value	
Distance	Small (less than 20 cm)	x
	Medium (20-80 cm)	
	Large (over 80 cm)	
Material	Flexible, fragile	
	Inflexible	x
Force needed	Low force	x
	High force	
Tool	No	x
	Manual	x
	Automatic	
Additional treatment	No	x
	Yes	

Table 3. Examples of variable attributes

Product, tool, layout		Variable attributes
Attribute	Value	
Number of connecting elements	1	x
	2	x
Length of connecting elements	0.5	x
	1	x
	6	x

3.2.2. FINDING THE BEST NN STRUCTURE AS A MODEL OF THE ASSEMBLY PROCESS

One of the most commonly used neural networks is multilayer perceptrons network (MLP) [16]. In the MLP structure, neurons are grouped into layers. The first layer is called the input layer, the last layer is called the output layer, and the remaining layers are called hidden layers. The number of layers and neurons is MLP NN structure determines its learning capability. NN should be trained to represent any given problem behaviour. During the training process, the weighed connections between neurons are changing and finally a model of the given problem is created. The NN structure depends on the modelled problem. Too many hidden neurons may lead to overlearning of the neural network. Experience can help determine the number of hidden neurons, or the optimal size of the network can be obtained through the trial and error process [16].

4. AN EXAMPLE OF TIME STANDARD SETTING FOR SCREW CONNECTIONS

The screw-fastening assembly process is one of the most widely used fastening methods in industrial assembly [17]. One of the laboratory examples of components for which a time analysis of disassembly of the screw connection of two components was carried out is shown in Fig. 5. The time consumption for this example was calculated by MTM (Table 4) and measured.

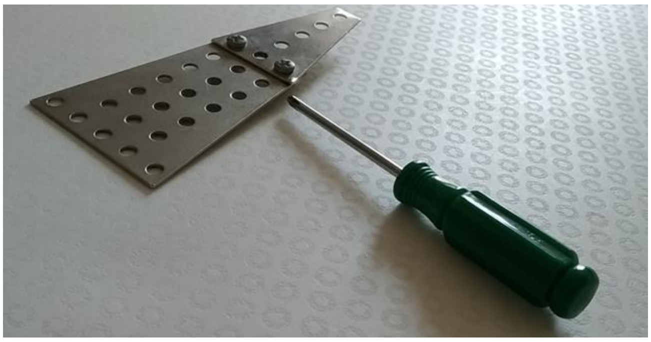

Fig. 5. Example of a subassembly and tool

Table 4. MTM analysis

MTM code	Multiply	Description	Time
R50B	1	reach for the subassembly (LH)	18.4
G1B	1	grasp the subassembly (LH)	3.5
M50B	1	move the subassembly (LH)	18
R50B	1	reach for the screwdriver (RH)	18.4
G1A	1	grasp the screwdriver (RH)	2
M50C	1	move the screwdriver (RH)	21.8
P2SSE	1	position the screwdriver (RH)	19.7
M2A D2E G2 P2SSE	12	unscrew the first bolt (RH)	24 90 67.2 236.4
G2	1	grasp the bolt (LH)	5.6
G2	1	grasp the nut (RH)	5.6
M30B RL1	1	put away the bolt and nut (RH, LH)	13.3 2
R30B	1	reach for the subassembly (LH)	12.8
G1B	1	grasp the subassembly (LH)	3.5
M30C	1	move to the second bolt (RH)	15.1
P2SSE	1	position the screwdriver (RH)	19.7

M2A D2E G2 P2SSE	12	unscrew the second bolt (RH)	24 90 67.2 236.4
G2	1	grasp the bolt and parts (LH)	5.6
G2	1	grasp the nut (RH)	5.6
M30B RL1		put away the bolt, nut and parts (RH, LH)	13.3 2

The measured data was used to create a training set for MLP NN. The inputs of neural network included attributes, such as (Table 5):

- Number of connecting elements.
- Length of connecting elements.
- Tool type.
- Type of process, such as: assembly and disassembly.

The output of NN is the time standard. The NN structure is presented in Fig. 6.

Table 5. Neural network training, testing set

	NN inputs				NN output
Case No.	Number of connecting elements	Length of connecting elements	Tool	Assembly/ disassembly	Time standard [s]
1	2	0.5	manual	disassembly	61
2	1	6	no	assembly	47
3	2	0.5	no	assembly	55
4	2	1	no	assembly	69
5	1	0.5	no	assembly	48
6	1	0.5	no	disassembly	28
7	1	0.5	no	assembly	22

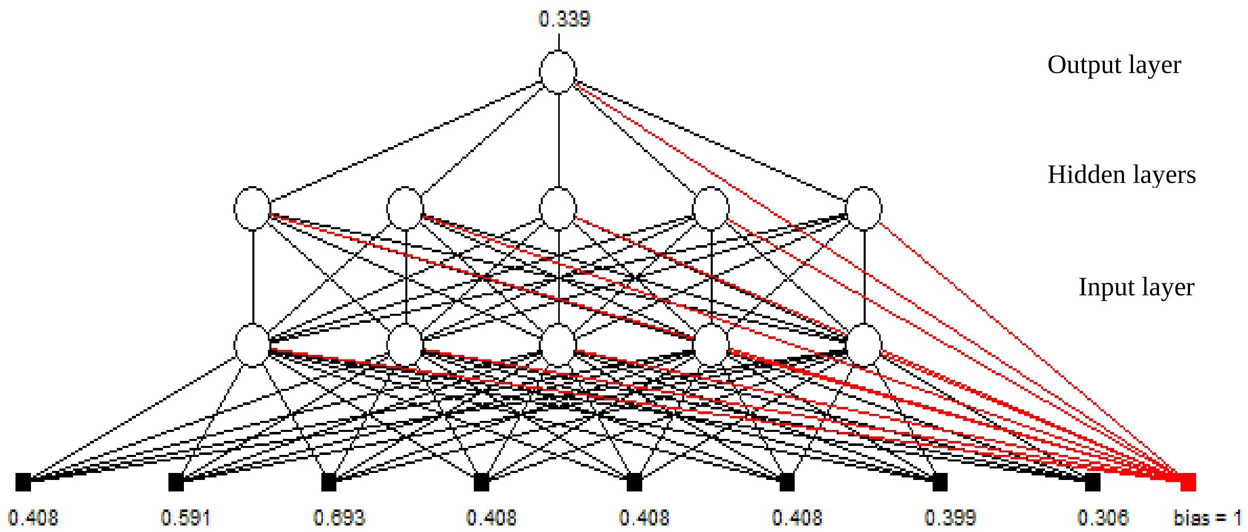

Fig. 6. Neural network structure for a predictive model

The training process is presented in Fig.7. The predicted results of NN are presented in Table 6.

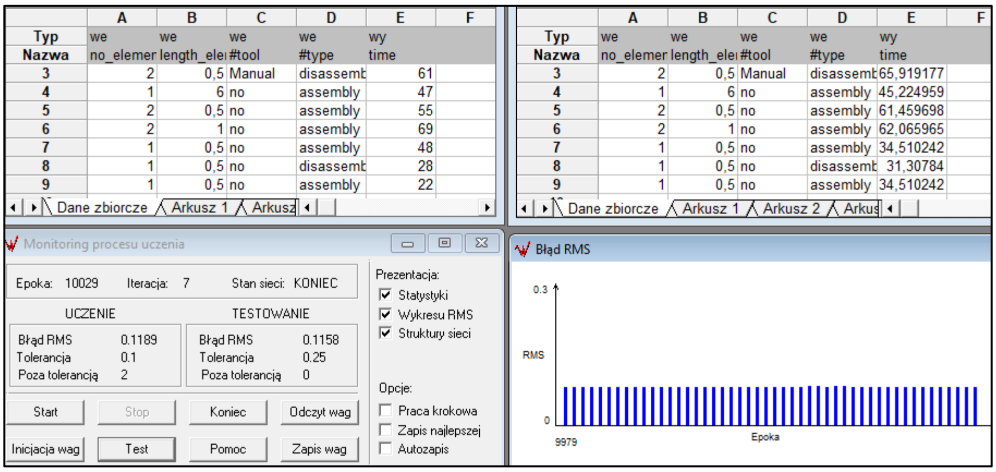

Fig. 7. NN training process

Table 6. NN predicted results

Time standard TS [s]	Predicted time PT [s]	Error EM EM=TS-PT [s]
61	66	5
47	45	–2
55	61	6
69	62	–7
48	35	–13
28	31	3
22	35	13

5. CONCLUSIONS

Neural network can be successfully applied to time standard setting in assembly process. NN model development of the assembly process can based on the following steps: development of training and testing sets and finding the best NN structure which is a model of the assembly process. The assembly process was analyzed and features (attributes) which influence time standard were selected. Attributes were divided into following category: workstation layout attributes such as distances, way of feeding; connection type between components such as fastener type, force needed; product component characteristic such as size, weight, shape, material; and tools, equipment such as tool type, equipment type. Features which influence time standard can be divided into two main category: constant and variable feature. Constant attributes have got the same value for whole assembly process and can be used for process characteristic. Variable attributes are different for various assembled products. Neural Network training set can be created with the use of attributes which has got value variable.

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