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Developing a Motion Study Simulation Object Toolkit

Entwicklung eines Simulationstoolkits für Bewegungsanalysen

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Abstract: The goal of developing a simulation object set that supports the slowly executed movement methods is to facilitate a quicker, more flexible application in the perspective of the movement analysis and the process simulation. To achieve this purpose, the slowly executed movement methods need to be implemented into a simulation environment, such as an independent subassembly. The scientific background of the movement analysis and the requirements of the developed object, furthermore the development steps, the functionality and usefulness of the object set are introduced in the article.

1 Introduction

The continuous improvement of production efficiency requires development of both the participating workers, equipment and the working environment. This is especially relevant in the stage of planning the production volume and methods when creating new factories. The motion study and the work-requirement measurements are important elements of the efficient and ergonomic working process design phase.

The application of the motion study systems require high professional skills, a lot of practice, and experience; however this is a slow process. This analysis is an analytical manner, which can be paper-based or electronic as well. The results can be used in the later stages of planning but the process must be restarted if there are any small changes. For industrial applications a frequent tendency is to measure standard time by stopwatch or by analysing videos, and that is why the definition of the time base of non-existent posts is very difficult and complicated.

Today's production planning processes take place in the digital environment. Expected future behaviour analysis and various operating conditions can be evaluated using process simulation software. Furthermore, it is possible to enter a time constant or a stochastic function for the modelled jobs in the process simulation software. Both originate from some kind of historical data. A detailed application of any movement analysis is not manageable, as the measurement results and obtained sub-activities during the work would break the workflow into small and distinct units, which results in an unnecessarily overcomplicated model.

These factors affected the development of a motion analysis simulation toolkit. The development took place at the Department of Vehicle Manufacturing at Széchenyi István University using the Tecnomatix Plant Simulation in which the authors have significant resource and development experience.

2 Motion Study

The first widely used work measurement method was the Methods-Time Measurement also known as MTM, developed in 1948 by Maynard, Schwab, and Stegemerten. The MTM system has a detailed data card of basic motions, each associated with particular variables. The initial MTM system is known as MTM-1. Subsequent modifications were later developed to provide an easier and quicker system by condensing and reducing the number of motion options and time values. In addition, the MTM systems include MTM-V, MTM-C, MTM-M, MTM-TE, MTM-MEK, and MTM-UAS. The advantages of the predetermined motion time systems compared to traditional work measurements are that they are of greater consistency, internationally applicable, and provide a reproducible experimental description (Maynard et al. 1948; Salvendy 2001).

2.1 MOST Analysis

The development of the Maynard Operational Sequence Technique (MOST) is a significant achievement in the area of work measurement. MOST has all the advantages of MTM but provides a much quicker and easier application. The simple and universal structure also makes it efficient. The system uses sequence models moreover the main work units are no longer basic motions. Activities are described in terms of sub-activities fixed in a sequence. MOST concentrates on the movement of objects (Zandin 2003).

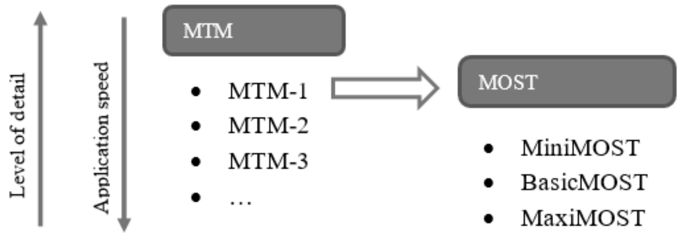

Figure 1: *Connection between industrial work-measurement techniques and the simulation (Zandin 2003)*

The goal when developing MOST was to compare its accuracy with the MTM-1 method. Another basic requirement for measuring the accuracy of a working measurement system is that the resolution of operations to base moves will help reduce user errors in the system. The most accurate systems, which breakdown activities to base moves (e.g. MTM-1), are the most vulnerable to user mistakes. When utilizing MOST users get very similar results after the analysis because of the few index and parameter intervals. The times or index values for the motions are immediately available to the analyst from data cards or, after experience, from memory or, even better, in a computer's memory (Zandin 2003).

The simple structure of MOST also makes it quicker to apply other predetermined motion time systems. The difference between MOST and other measurement methods is a consequence of the fact that MOST can perform the analysis in less time than the other methods, which use predetermined times (Zandin 2003).

Work Measurement Technique	Total TMU Produced Per Analyst Hour
MTM-1	300
MTM-2	1000
MTM-3	3000
MOST	12000

Figure 2: *Comparison of application speeds (Zandin 2003)*

So using MOST can measure 10 to 40 times faster than MTM-1. Generally one hour of work can be measured using MOST with an average 5 to 10 hours of analyst time, depending on the complexity of the work (Zandin 2003).

2.2 BasicMOST Analysis

Systems of the MOST family include three main sub-systems: Basic-, Mini-, and Maxi-MOST. The basis of the simulation toolkit is the BasicMOST. It is the most commonly used version of MOST. At the intermediate level, activities that are likely to be performed more than 150 but less than 1500 times per week should be analysed with it. An operation in this category may range from a few seconds to 10 minutes. The operations length in this category may range between 7 to 70 seconds (200 to 2000 TMU (Time Measurement Units). Distances in BasicMOST are typically analysed within reach and up to 10 steps. The majority of operations in most industries fall into this category (Zandin 2003).

The system uses sequence models; moreover the main work units are no longer basic motions. Activities are described in terms of sub-activities fixed in a sequence. MOST concentrates on the movement of objects. Users need three activity sequences in BasicMOST to describe manual work (Zandin 2003):

- General Move
- Controlled Move
- Tool Use

These activity sequences build on parameters based on the computerized analysis of tens of thousands of MTM studies (Zandin 2003).

2.2.1 General Move

The General Move deals with the spatial displacement of one or more objects. Under manual control, the object follows an unrestricted path through the air. The sequence model takes the form of fixed of parameters (letters) representing each of the various sub-activities of the General Move. The displacement of an object occurs in three distinct phases, as shown by following the General Move Sequence Model breakdown (Zandin 2003).

GET			PUT			RETURN
A	B	G	A	B	P	A

Figure 3: *General Move sequence model (Zandin 2003)*

Where:

A = Action Distance

B = Body Motion

G = Gain Control

P = Placement

BASIC MOST		GENERAL MOVE		A B G A B P A
INDEX x10	A ACTION DISTANCE	B BODY MOTION	G GAIN CONTROL	P PLACEMENT
0	≤ 5 CM			PICKUP TOSS
1	WITHIN REACH		LIGHT OBJECT LIGHT OBJECTS SIMO	LAY ASIDE LOOSE FIT
3	1-2 STEPS	SIT OR STAND BEND AND ARISE 50% OCC.	LIGHT OBJECTS NON-SIMO HEAVY OR BULKY BLIND OR OBSTRUCTED DISENGAGE INTERLOCKED COLLECT	LOOSE FIT BLIND OR OBSTRUCTED ADJUSTMENTS LIGHT PRESSURE DOUBLE PLACEMENT
6	3-4 STEPS	BEND AND ARISE		CARE OR PRECISION HEAVY PRESSURE BLIND OR OBSTRUCTURED INTERMEDIATE MOVES
10	5-7 STEPS	SIT OR STAND WITH ADJUSTMENTS		
16	8-10 STEPS	STAND AND BEND BEND AND SIT CLIMB ON OR OFF THROUGH DOOR		

Figure 4: *General Move data card (Zandin 2003)*

The index value of parameters depending on the type of activity can be selected from the data card (Fig. 4). The time to perform activities is computed by adding all index values in the sequence model and multiplying it by 10 to convert to TMU (Time Measurement Units, 1 TMU = 0,036 second).

2.2.2 Controlled Move

The Controlled Move describes the manual displacement of an object over a controlled path. That is, movement of the object is restricted in at least one direction by contact with or attachment to another object, or the nature of the work demands that the object be deliberately moved along a specific or controlled path (Zandin 2003).

GET			MOVE OR ACTUATE			RETURN
A	B	G	M	X	I	A

Figure 5: *Controlled Move sequence model (Zandin 2003)*

Where:

A = Action Distance

B = Body Motion

G = Gain Control

M = Move Controlled

X = Process Time

I = Alignment

The index values of the Controlled Move can also be determined from a data card.

2.2.3 Tool Use

The Tool Use Sequence Model is comprised of phases and sub-activities from the General Move Sequence Model along with specially designed parameters describing the actions performed with hand tools or, in some case, mental processes that are required when using a sense as a tool (Zandin 2003).

GET TOOL OR OBJECT			PUT TOOL OR OBJECT IN PLACE			TOOL ACTION	PUT TOOL OR OBJECT ASIDE			RETURN OPERATOR
A	B	G	A	B	P	*	A	B	P	A

Figure 6: *Tool Use sequence model (Zandin 2003)*

Where *:

F = Fasten

L = Loosen

C = Cut

S = Surface Treat

M = Measure

R = Record

T = Think

The index values of Tool Use can also be determined from a data card. The Tool Use Sequence Model can be used to determine the time needs for work with the following tools (Zandin 2003):

- Wrenches (T-wrench, Hexagon, etc.)
- Other Tools (Screwdriver, Hammer, etc.)
- Measuring Tools (Fixed scale, Micrometer, etc.)
- Cutting Tools (Scissor, Knife)
- Cleaning Tools (Brush, Wiping cloth, etc.)
- Writing Tools (Pen, Marker, etc.)

3 Development Steps

The platform of the developed object is an object-oriented discrete-event simulation software, called Tecnomatix Plant Simulation. Object-oriented environment is a programming paradigm based on the concept of communication between objects. The objects store data and perform operations upon request. The developed tool is an object in the given simulation environment (Bangsow 2015).

The object toolkit of MOST needs to be defined before specifying the development requirements. The appropriate tool can be created if the following objectives are met:

- provide an opportunity to analyse a wide range of operations,
- assist the work of the user with predefined sequence models and analysis decision questions,
- quick and easy application,
- possibility to edit and delete individual activities,
- the objects contain a summary overview of the used sequence analysis models and their parameters,
- the object should be imported into the software's toolbar,
- time value, which is obtained from the analysis, should be the object processing time and the material flow should be seen in the simulation run,
- possibility to use the main simulation options (entrance-, exit controls; shift calendar; failures; importer; statistics; etc.).

After defining the requirements, the main steps of the development are listed below. During the development, each task was elaborated in detail, taking into account the theoretical step of the motion analysis and the condition system of the simulation environment as well as user-friendly applicability.

1. Schematic representation of the MOST analysis algorithm, elaboration of the operating logic of the object.

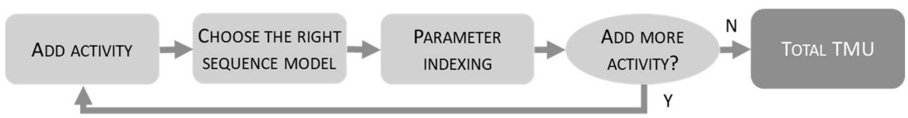

Figure 7: *Functional logic*

2. Create a graphical and functional sketch of the user interface; define the required dialog items (button, drop-down list, checkbox, etc.).
3. Create the data tables required for the MOST analysis in the simulation software. The developed object stores the index values for the specified parameters from the data tables.
4. Write the methods required for the operation of the user interface elements; these methods are the elements in the dialog or changes in its elements.
5. Implementing the functional attributes of a general material flow object into the developed object.
6. Adding help dialogs and descriptions to the object.

4 MOST Object Toolkit

The user interface of the object looks like the well-known structure of Plant Simulation. A new activity can be added on the basic label of the start screen.

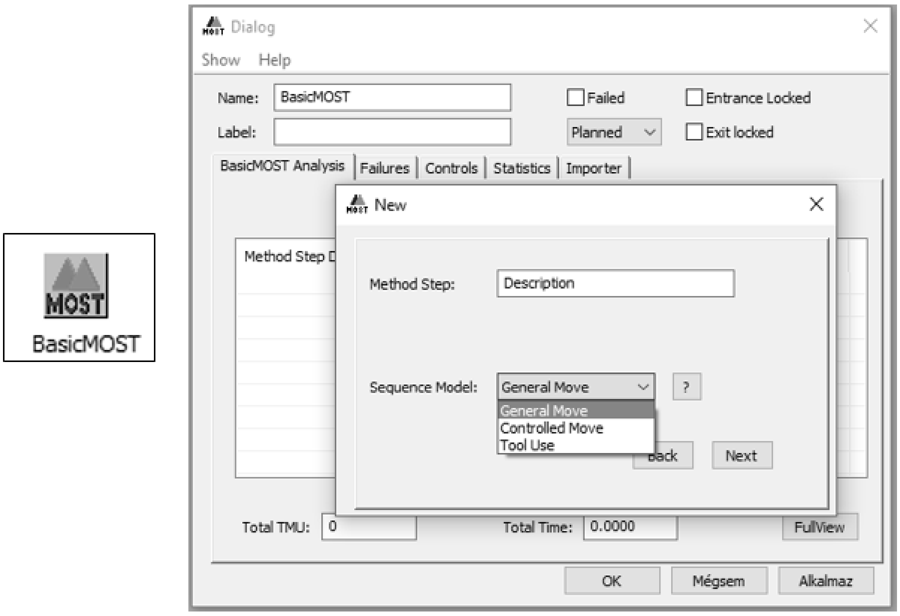

Figure 8: *Dialog window, add activity*

We can choose from three predefined sequence models (Fig. 8) when adding a new activity. Inexperienced users in movement analysis have the opportunity to click on the question mark symbol (?) where they can get information about the features of each of the sequence models in a pop up window. A dialogue window shows up after selecting the appropriate model (Fig. 9). The suitable parameters should be selected from the drop-down menu. If their frequency is partial, the checkbox next to the drop-down menu needs to be selected. Partial frequency means that there is a repetition of the partial activities (for example installing six screws) and the number of times it is repeated can be determined in the textbox called *Partial FR*. The reps of the complete operation can be configured in the textbox *Frequency*.

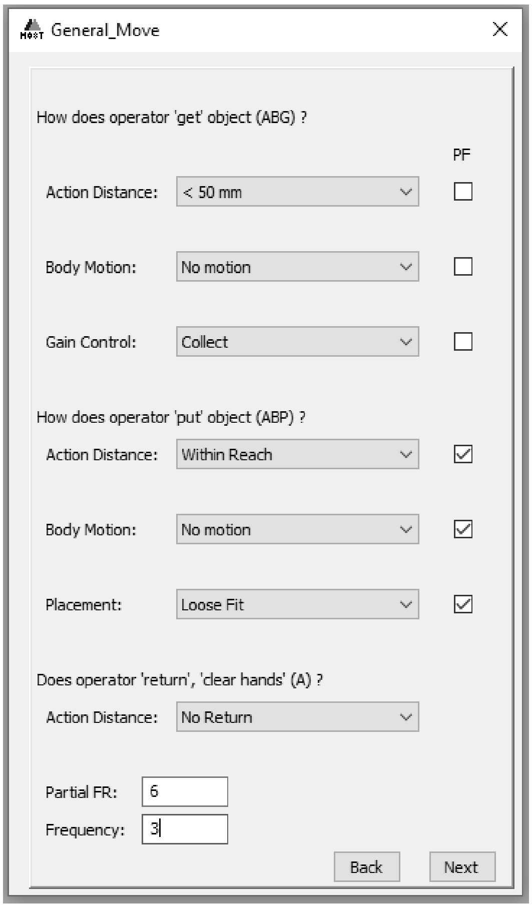

Figure 9: *General move parameters window*

After setting up the required parameters we can go back to the main window. The already taken up operations can be seen with their main parameters in a table (Fig. 10). Every operation can be edited separately; they can also be deleted if necessary, so we are able to refresh our simulation model easily according to the changes in our physical system.

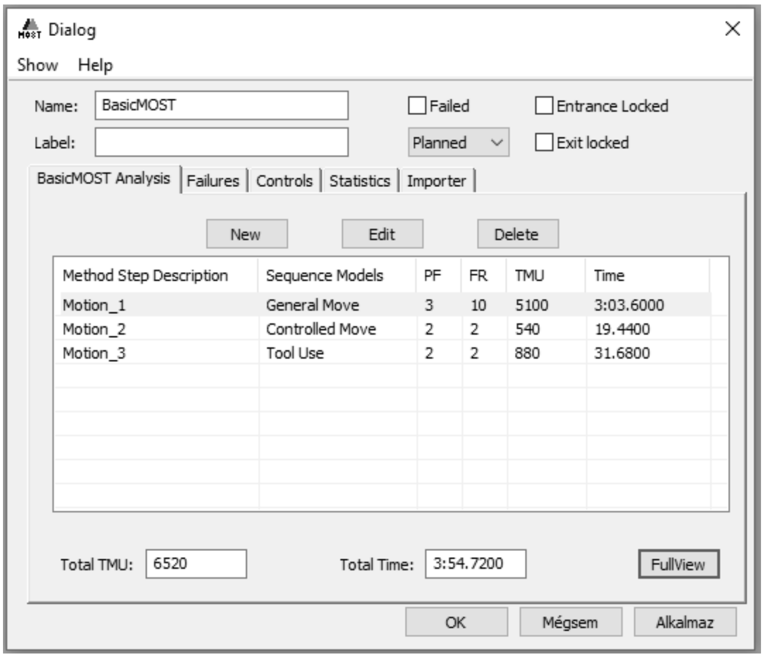

Figure 10: *BasicMOST main dialog window*

Time units belong to each activity in two different formats: TMU and *mm:ss*. The total time of the complete operation can be seen at the bottom of the interface. These time units are used by the simulation object as a "ProcTime" datatype, which means that this mobile units are spent on the operation of the object. The object gives the opportunity for the user to summarize the activities for the given workplace in one object or to detail the activities separately in the simulation model.

5 Conclusion

The MOST system can be applied directly in simulation software so it is possible to use one of the main advantages of the analysis, which is the increased application speed. In addition it is also integrally usable in manufacturing simulation or in newly planted and existing system analyses as well.

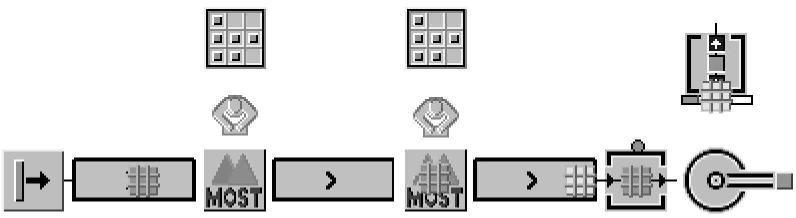

Figure 11: *Demo model*

The finished object allows the users to analyse from simple operations and activities to more complicated and complex operations. It provides transparent, simple editing for the implementation of the improvement measures. All calculations of the simulation software can be stored, eliminating the need for other additional documentation. After completing the analysis of the workstation the time value is immediately received and during the simulation this calculated value will be applied to the operation. It sets the standard time, which is required in order to perform the operation. It is also suitable to examine the working methods and associated job creation ideas concerning the establishment of an optimal workshop. The created object uses all the advantages of the method in the motion analysis so it is a widely usable tool for process simulation and optimization preparation.

The difficulties in the industrial applicability of measurement methods and the lack of usability in process simulation have together generated the need for development. The device takes advantage of the advanced simulation, which uses the benefits of work measurement methods and allows for the analysis of simple and complex activities. The set of objects includes further development potentials too. The next step is in the development of activities with a working distance measurement method. In doing so, instead of the standard values and data cards, the input values of the activities would come from material flow object-oriented simulation parameters.

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