Taylor in the digital age

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Photos and video shots were first used in factories as the development created by Frederick W. Taylor. The main question raised by the authors is that how digital technique can be used to create efficient workflow analysis and optimization at a manufacturing company. A lot of companies are not aware of the reference time periods regarding the processes, so cost reduction and productivity growth cannot be accomplished. With this newly developed program by the authors the duration and the content of the processes can be recorded. After the uploading of the records, computer use dedicated software to mark the special events of the process. Then they transfer frame data into spreadsheets where time periods will be calculated. Afterwards the results are analyzed. It is possible to make statistical reports which contain the approved time regarding the quantity of production during a given time period and the expected performance. With these features the production schedule can be supported. There are other advantages of this program, for example, it provides useful basis for ergonomic examinations. According to the results of the analysis it is possible to provide suggestions regarding the perfection of workflows. Furthermore, these data can be used for training, education and for work studies, as well.

Keywords: ergonomics, time standard, video recording, work study

1. Introduction

The objective of motion studies is to recognize and filter the superfluous, exhausting, long and less efficient motions from human interactions. Instead of this the main aim is to create a comfortable and effective series of motions. One of the goals is to ensure an appropriate productivity. People completing monotonous tasks are affected by unhealthy stress in the case of quickly recurring jobs. One of the reasons for that is time pressure, as you have to repeat a short task quickly and workers may take certain postures for long hours. On the other hand this work is worsened by uncomfortable postures which have to be kept sometimes very long. As a consequence, from a psychological point of view, these workers under these conditions do not identify themselves with their jobs. They are often not even aware of the significance of the manufactured piece, this is why they feel neither the outcome of their work, nor their repsonsibility (*Nahlik* 1983).

As a result of this, performance will decline since workers are getting tired very soon. The quality of the product will deteriorate and the number of job accidents may increase. (*Zeller* 1996).

For this reason ergonomical questions are to be considered for the business to be successful (*Rowan–Wright* 1994).

Some decades ago different ergonomical workstudy methods for solving this problem were developed which have been deployed successfully for analysing and developing various workflow.

The study of work processes was first published in the USA. As the effect of the second industrial revolution, technical tools, machines were improved suddenly and affluent raw material was at service. On the other hand, the workforce was few and expensive and it was not adaquately skilled for the more complex tasks, such as leading or being organisational (*Chikán–Demeter* 2006).

Frederick W. Taylor (1856–1915) as a mechanical engineer saw this problem of the American industry: he supposed that it would be possible to produce effectively, but the production and the realization of the process was neither properly received, nor harmonized. Right principles and methods had to be found to function. He did most of his research at Midvale Steel Company in Philadelphia through observing, analysing and measuring the time needed for the work of turners in order to specify their daily performance. His leading theory received scientific title since it was based on regular and method-based measurements, time and motion studies. The fundamental principle of his work is the organisation based on measurements, which means detailed technological, operational study followed by motion analysis. All the details were described, then standard time date was defined on the basis of the measurements. The detailed motion analyses allowed excluding superfluous motions through which an ideal range of motion was created. As a result, productivity increased whereas the physical load on the workers decreased or became more balanced. Taylor extended standardization not only for the motions, but also for the orders and the working tools. His goal was to establish the same tools and conditions for the same work (*Koltai* 2001, *Ho–Pape* 2001).

Henry Ford (1863–1947) built the first assembly line in his factory on the basis of taylorian principles, with which he eliminated the final barrier from mass production. Ford wanted to produce cheap motor vehicle so he considered decreasing the costs as his primary task. The solution was the assembly line. This meant a new challenge from the point of view of work study since every operation had to take for nearly equal time so as not to stop the line, as it was extremely ceremoniuous to restart the process and it made a lot of damage.

First the Gilbreth couple dealt with motion study. They used motion pictures for the first time. Their aim was to make work simple and decrease workload (*Tuczai* 1994).

With the management of H. B. Maynard motion studies were made with motion pictures in the range of 10.000 in the presser plant of Westinghouse clockfactory in the 1940's. Maynard published his results as MTM method – Method Time Measurement – or 3M as its Hungarian translation is “Mozdulatelemzéses Munkatanulmányozás és Munkakialakítás”. It is an elemental timestandard system that dismantles human and physical activities pliable by humans to basic motions, to which it assigns definite time values, and whose extent depends on the feature on the influential factors (*Végh* 1989, *Kristensen* et al 1997).

The film version of the multimoment technique on the basis of traditional frequency study was described by Susánszky János as one of the possible methods of rationalisation. The synchronous concentrated multimoment technique was used primarly with the purpose of recording workdays (*Susánszky* 1984). This technique was also used at the University of Chemical Engineering at Veszprém, Hungary (the present University of Pannonia).

The goals of the REFA Association – created in 1924 (Reichausschuss für Arbeitzeitermittlung – Empire committee for working hours investigation) – are to improve workstudy, to elaborate the policies of the execution of work on which time studies are based, as well as economical plant organisation. Beside this research their consulting and publisher activities are significant (*Kovács* 2001). REFA is expedient to be used in the case of companies that want to produce with shorter scanning time, lower costs and planed delivery deadlines. By using this, the decrease in production time and in costs is achieved without significant investment and reaching better quality, and in addition, more efficient work is gained.

PCs, whose performance developed highly, gained ground in the 1990's. By signing the general technological convergence information technology and video technology coalesced. (*Clemmet* 1995, *Gregson* 1995).

The advantage of using video and computer is that they provide the opportunity to analyse the data later, if our observation is recorded in field notes instead of video recording, lots of things could be looked over or we might simply be unable to note every single detail accurately. On the other hand the recorded material can be rewound, played in slow motion or stopped for detailed data collection. As a result data are more precise, since time data are also gathered from computerised material and not from a stop-watch data collected by us or by a colleague. During motion analysis one should work with seconds and it is both difficult and complex work take to measures with a stop-watch.

Nowadays, several companies deal with electronic time analysis, an example of which is UMTPlus[1]. The hardware used is a PDA, which can be considered as a kind of stop-watch. The software consists of a database where we can choose which operation to be measured. Having executed the measurement, data can be downloaded to a PC, where another program makes their statistics. Alike the above, some solutions have been developed by other companies. These developments solve the problem of electronic measurement, datastorage, dataprocessing however, specific motion cannot be observed, rewound the exact same operation due to their given characteristics, which means they do not offer the possibility of videorecording and/or videoprocessing. MVTA method was developed by the two researchers of Wisconsin – Madison, in cooperation with an industrial and a governmental consortium[2].

Currently it may be the most highly developed workflow analysis system. In essense it enables the analysis of work processes built in the function of videoanalysis on the computer. Certain points of the video recording can be marked for instance at the beginning or at the end of a motion with the software, based on which the program calculates the time of the motion. This will lead to more exact outcomes as compared to human measurement, and further more, it enables the analysis of micromotions. The program is able to handle analogue videoplayer and operates digital MPEG and AVI formats, as well. The program completes various time studies, calculates frequency and provides statistics. MVTA is a separate modul of Synchronized Video and Data Acquisition (SVDA), which together with video and audio track, enables the recording of seperate datatracks and the import to computer. This means one can measure several features, such as distance, weights, pitch, during recording of the material. As a consequence, a more detailed analysis is allowed.

This videotechnique is used for observing business life in Japan. It is used extremely efficiently in three fields. It gives one help in developing ergonomical methods, statistical methods and technology. On the one hand the user's everyday behaviour is observed through this method, and on the other hand the employees' work, for example during fixing gaspipelines. Consequently using this method the statisfaction of consumers and the safe work of employees will be increased at the same time (*Matsunami* 2007). Video recordings were made during picking processes in car industry when several hours of work was recorded. The aim of the recording was to allow the employee to click on those motions in the recorded film during the evaluating program, called VIDAR, which caused them pain or made them feel uncomfortable, and his clicks were recorded by the program. The results showed that through this method the company received data, which could be used for changing processes and for the ergonomic analysis of complex work analysis succesfully (*Kadefors–Forsman* 2000).

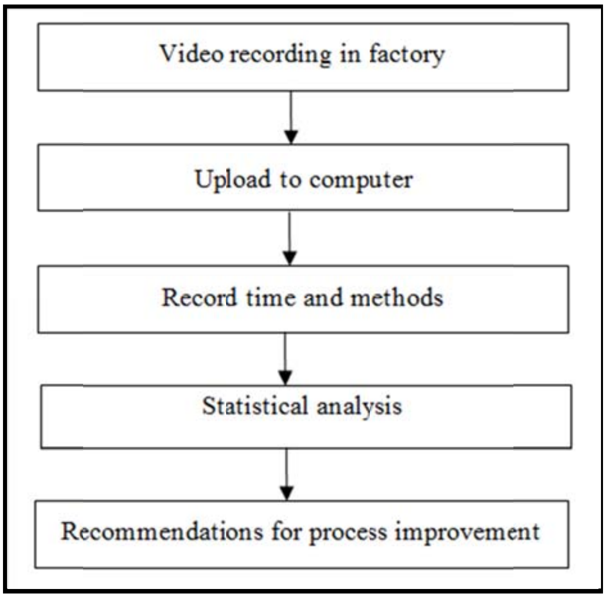
2. Own improvement

2.1. Process

According to the method elaborated by our team the process is completed through the following steps:

[1] http://www.laubrass.com/en/products/statique/umtplus.html
[2] http://www.simweb.com.tw/mvta.htm; http://mvta.engr.wisc.edu/

Figure 1. Steps of elaborated method



Source: own construction

In the factory at the selected workplaces, the process should be recorded several times. The amount of the repeated recordings can be defined with statistical methods in order to gain significant results. Long and continuous recordings are needed, so that they better represent reality. There is no "spoiled" recording, as an error at the workplace and the interruption of the material flow may have the same importance as perfect motion operation for ergonomic reasons. It is worth recording each workplace from several positions. Beside the basic processes, the different additional processes (e. g. material supply, product delivery, asset change) should be recorded, as well. The recording may include burst operations, product repairs, or other activities.

The usage of the camera tripod is mandatory, as during the follow-up a stable image ensures better analysis, which is impossible to achieve during long and continuous recordings. The power supply can be provided through high capacity batteries or network, if the work is not hindered by them.

2.2. Processing

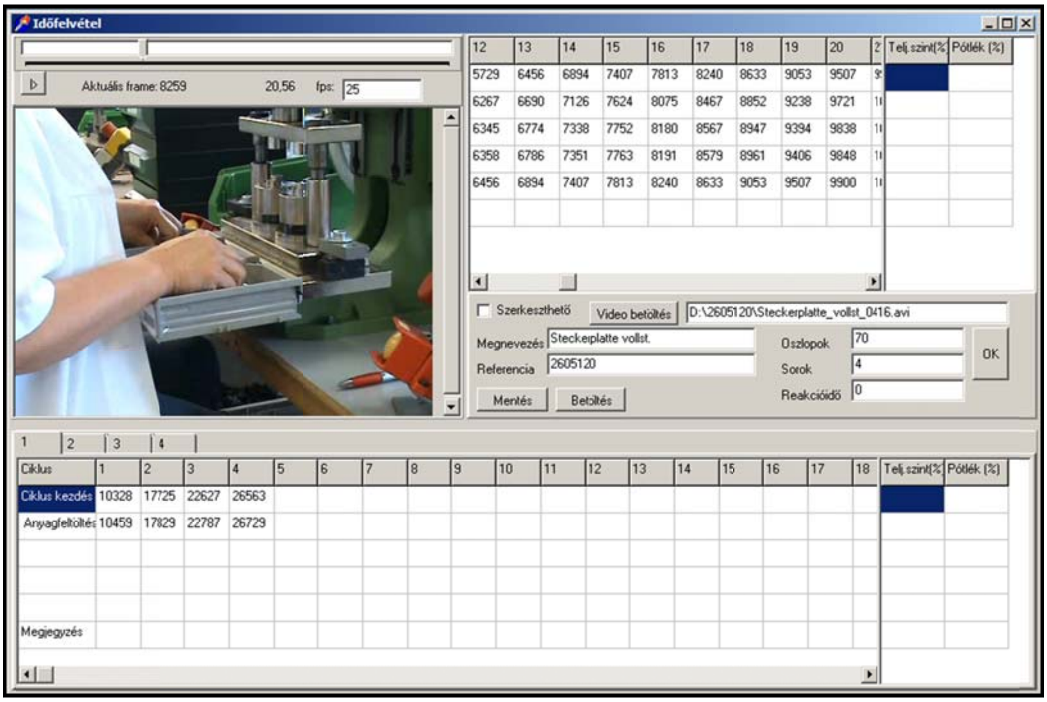
After recording the material has to be transferred to computer. This process is very simple these days if the camera records digital (DV), the video can be transferred via FireWire or USB port. For easier portability it is useful to compress the recording, as one hour duration DV material needs about 12–13 GB space on the storage media. DivX compressing is excellent for this purpose. During the process the quality of the compressing should be set to about 2000kbps, and what even further, it is possible to resize the image (720x576 → 384x288). It is essential to change the maximum distance of the two key frames, from the default 300 to 5–10–20. The less value it has, the quicker skip is possible in the video forward and backward however, with the same bit rate it results in poorer quality. The goal of the program is to extract the time data of the recorded workflow which will be processed in a spreadsheet.

3. Application experience

3.1. PreCon

This study introduces the application of the program through the example of a pressing operation of the Precision Controls Ltd. in Veszprém. At this workplace, the workers insert the components and two pieces of Steckerplatte into the compactor, then push the buttons on the machine (double machine), and finally they remove the finished product from the machine and bulk it into the storage box on the right side.

Figure 2. The user interface of the program



Source: own construction

25 cycles were recorded. The cycles were divided into separate sections, according to the different processes. The different columns of the tables contain the data of each cycle. The starting time (position) of the cycle sub-processes is shown horizontally. The different tables belong to different operations. The main work was interrupted as an additional one was inserted and the operator had to leave for material. Works of this type should be represented in the table at the bottom. The data recorded in the program can be processed in different ways. In this study, an Excel spreadsheet was developed at the Department of Management, University of Pannonia. The recorded frame data of the program can be inserted into the Excel spreadsheet through the clipboard. The user has to fill in the green fields, some of which originat from the program.

Figure 3. The recorded frame data of the program in an Excel spreadsheet

	Basic time																
	Activity	1. Cycle	2. Cycle	3. Cycle	4. Cycle	5. Cycle	6. Cycle	7. Cycle	8. Cycle	9. Cycle	10. Cycle	11. Cycle	12. Cycle	13. Cycle	14. Cycle	15. Cycle	16. Cycle
	Start cycle	68	609	1100	1625	2189	2728	3248	3723	4228	4727	5266	5729	6456	6894	7407	7813
1	Material put in	338	883	1381	1913	2487	2963	3490	3964	4450	5009	5537	6267	6690	7126	7624	8075
2	Sp put on	478	999	1506	2073	2590	3098	3592	4107	4617	5194	5656	6345	6774	7338	7752	8180
3	Engine	494	1016	1520	2086	2602	3112	3604	4121	4632	5208	5669	6358	6786	7351	7763	8191
4	Put out	609	1100	1625	2189	2728	3248	3723	4228	4727	5266	5729	6456	6894	7407	7813	8240
5																	
6																	
7																	
8																	
9																	
10																	
	Quantity	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Number of activities:	4															
	Material supply	Additional time 1															
	Start cycle	10328	17725	22627	26563												
1	End cycle	10459	17829	22787	26729												
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
	Quantity	21	17	12	9	1	1	1	1	1	1	1	1	1	1	1	1
	Number of activities:	1															

Source: own construction

For clear identification, the head of the table and the time recording program indicate which workplace and which product is processed, as well as further additional data, for example, the time unit, more precisely, how the values from the time recording (frames) can be converted into seconds. In this case 25 units equal to one second (Frame rate). The first table contains the main time data and the second contains the additional time data.

Figure 4. The main and the additional time data

	Calculation of times																
	Activity																
	Operational times: (s)																
	Activity	1. Cycle	2. Cycle	3. Cycle	4. Cycle	5. Cycle	6. Cycle	7. Cycle	8. Cycle	9. Cycle	10. Cycle	11. Cycle	12. Cycle	13. Cycle	14. Cycle	15. Cycle	16. Cycle
1	Material put in	10,8	10,96	11,24	11,52	11,92	9,4	9,68	9,64	8,88	11,28	10,84	21,52	9,36	9,28	8,68	10,48
2	Sp put on	5,6	4,64	5	6,4	4,12	5,4	4,08	5,72	6,68	7,4	4,76	3,12	3,36	8,48	5,12	4,2
3	Engine	0,64	0,68	0,56	0,52	0,48	0,56	0,48	0,56	0,6	0,56	0,52	0,52	0,48	0,52	0,44	0,44
4	Put out	4,6	3,36	4,2	4,12	5,04	5,44	4,76	4,28	3,8	2,32	2,4	3,92	4,32	2,24	2	1,96
5		HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS
6		HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS
7		HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS
8		HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS
9		HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS
10		HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS	HAMIS
	Total:	21,64	19,64	21	22,56	21,56	20,8	19	20,2	19,96	21,56	18,52	29,08	17,52	20,52	16,24	17,08
	Quantity	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Cycle times are valid	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	Calculation of times				
	Material supply				
	Operational times: (s)				
	Activity	1. Cycle	2. Cycle	3. Cycle	4. Cycle
1	End cycle	0,249524	0,24471	0,53333	0,737778
2		HAMIS	HAMIS	HAMIS	HAMIS
3		HAMIS	HAMIS	HAMIS	HAMIS
4		HAMIS	HAMIS	HAMIS	HAMIS
5		HAMIS	HAMIS	HAMIS	HAMIS
6		HAMIS	HAMIS	HAMIS	HAMIS
7		HAMIS	HAMIS	HAMIS	HAMIS
8		HAMIS	HAMIS	HAMIS	HAMIS
9		HAMIS	HAMIS	HAMIS	HAMIS
10		HAMIS	HAMIS	HAMIS	HAMIS
	Total:	0,249524	0,24471	0,53333	0,737778
	Quantity	21	17	12	9
	Cycle times are valid	1	1	1	1

Source: own construction
Note: „HAMIS" signs mean „FALSE".

Next, the table converts the frames into seconds, and then calculates the mean and the amount. The insertion of the component into the compactor took 9.09 seconds on the average, the placing of the Spule took 4.72 seconds, the running of the machine took 0.47 seconds, finally the removal from the machine and the bulking took 3.44 seconds.

Figure 5. The filtered data, differing with more than 50% from the mean

	Operational times after Activity	Additional time 2															
	Activity	1. Cycle	2. Cycle	3. Cycle	4. Cycle	5. Cycle	6. Cycle	7. Cycle	8. Cycle	9. Cycle	10. Cycle	11. Cycle	12. Cycle	13. Cycle	14. Cycle	15. Cycle	16. Cycle
1	Material put in	10,8	10,96	11,24	11,52	11,92	9,4	9,68	9,64	8,88	11,28	10,84		9,36	9,28	8,68	10,48
2	Sp put on	5,6	4,64	5	6,4	4,12	5,4	4,08	5,72	6,68		4,76	3,12	3,36		5,12	4,2
3	Engine	0,64	0,68	0,56	0,52	0,48	0,56	0,48	0,56	0,6	0,56	0,52	0,52	0,48	0,52	0,44	0,44
4	Put out	4,6	3,36	4,2	4,12	5,04		4,76	4,28	3,8	2,32	2,4	3,92	4,32	2,24	2	1,96
5																	
6																	
7																	
8																	
9																	
10																	

Source: own construction

Afterwards, the program filters the data, differing with more than 50% from the mean. Screening can vary depending on the type of work and the workplaces, and in addition significant interruptions should not be counted into the developing of the norm. The interruptions should be eliminated instead of counted as normal. After filtering, the program recalculates the mean, the amount and the deviation.

Figure 6. The proposed time standard

Quantity propotional times :					
Times		Unit time (sec)	Unit time (min)	Unit time (hour)	
Basic time		17,23547	0,287258	0,004788	
Additional time:					
Material supply		0,316	0,005267	8,78E-05	Additional time 1
0		0	0	0	Additional time 2
0		0	0	0	Additional time 3
0		0	0	0	Additional time 4
	(other)		0	0	
	(other)		0	0	
	Total:	17,55147	0,292524	0,004875	
Other addition	0	0	0	0	
Other addition (%)	0,1%	0,017551	0,000293	4,88E-06	
Target time:		17,569	0,29282	0,00488	204,91
		second	minute	hour	2 unit/hour
Approved time:		**18**	0,3	0,005	200

Source: own construction

Different additional time data can be specified, as well (here 10%, which means, the time unit should be multiplied with 1.1). Finally, the program indicates the table of the proposed time norm (19.72 sec) in the summary. Rounded up to 20 seconds, this can be approved.

Figure 7. The calculation of expected performance

Quantity independent times:					
Setup time (preparation and finish):		300	5	0,08333	
			0	0	
			0	0	
Total:		300	5	0,08333	
		second	minute	hour	
Quantity to be produced:	1				Performance:
Allowed time:		318	5,3	0,08833	11,321
		second	minute	hour	2 unit/hour
Allowed time calculation example:					
Quantity to be produced:	1000				Performance:
Allowed time:		18300	305	5,08333	196,72
		second	minute	hour	2 unit/hour

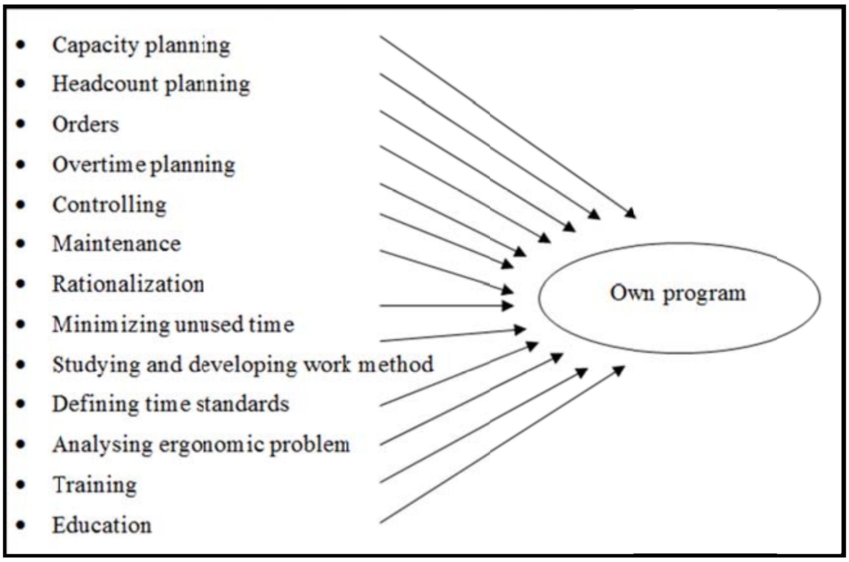
Source: own construction

In addition, expected performance can be calculated, considering the preparation and the completion times.

3.2. Application possibilities

The program and the relevant analysis can be applied in all cases, where the goal is better at understanding of the workflow related sub-processes:

Figure 8. The program can support the analyzer and the designer, work in multiple ways



Source: own construction

3.3. Development opportunities

The program is not only suitable for determining time data: the video playback functions (winding backward and forward, frame skipping) can be used for ergonomic analysis which is the main opportunity for future development. Possible further functions may be changing the speed, continuous repetition between two points allowing a more effective ergonomic analysis. An even more developed method is possible, if beside video and sound tracks, further data tracks are attached. This way factors, which are not or just partly visible on the recordings, such as weights, loads and distances, could be measured.

4. Conclusions

In this study we examined the relationship between digital technology and work analysis and furthermore, identified the areas where the computer application can be extended. We found that this method results in faster, more accurate and more effective outcome than stop watch measurement and the post-input of the data.

A possible method for the computer analysis of video recordings was presented in which the opportunities of our own program and Microsoft Excel are combined. Our own development is suitable for a convenient and accurate identification of the time data which can be used in Excel to generate statistics, for example for defining time standards. Taylor is still with us...

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