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TRIAL EXPERIMENTAL DETERMINATION OF THE AVERAGE TIMES OF ACTIONS EXECUTED IN A CAD APPLICATION

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Abstract: The efficiency of CAD programs largely depends of the efficiency of their user interface. Relative efficiency can be defined as the inverse value of the effort involved during the design process. One of the possibilities for expressing the effort is to calculate, i.e. to sum up, the time required to fulfil one design task. Such value depends on the physical characteristics of the specific designer and hence cannot be valid. Another possibility is to determine average times of typical actions in the design process, such as mouse click, mouse move, typing of a number etc., and then evaluate the total effort by summing the products of average action times and counted number of actions in a design session. This paper presents an original methodology for experimental determination of the average times of the actions executed in a CAD application. In order to conduct the experiment, a web application, based on the proposed methodology, was developed. Based on the first experiences, it can be concluded that the presented methodology and application are suitable for experimental determination of the average times of CAD modeling actions. However, there is still room for improvement in its usability.

Keywords: CAD, User interface, Efficiency, Effort, experiment

1. INTRODUCTION

Assuming that CAD programs of equal functionality are compared, the most important indicator of their usability, from the user point of view, is their efficiency. The same is valid for any other CAx program. Therefore, in order to compare the available CAD programs and select the best one, it is necessary to identify and adopt an appropriate indicator of their efficiency.

Efficiency can be defined as the ratio between the cost of design and the effort invested in design [1]. It is very hard to

accurately estimate the effort, because it comprises of mental and physical parts. Mental effort is more user related. It depends on the degree of intelligence, knowledge and skills of the user. Therefore, this part of effort is not directly related to the features of a CAD program. In this paper, only the physical effort will be taken into consideration.

In the previous work of the authors, various methods for expression of the effort were considered [1]. One of those, the time based method, is used in this paper. According to the time based method, the total physical effort is calculated as a function of times spent in

performing of the particular user actions during the design process. Those actions include mouse movements, typing on the keyboard and mouse clicks. Again, those times are user dependent. In order to express the efficiency of a CAD program independently of its user, it is necessary to evaluate the average times for typical actions that users perform during interaction with CAD programs.

This paper presents the first trial results of the experiment whose aim was to evaluate average times of aforementioned actions, performed using mouse and keyboard. To accomplish this task, a web-based application was developed. Using this application, the times corresponding to typical user actions were measured. The home page of this application is presented in figure 1.

The obtained data were statistically processed in order to obtain the average values of action times.

In the next chapter, the Time based approach for estimation of physical effort is presented. Chapter three presents the results and finally, in chapter four, some conclusions and recommendations for future work are given.

Figure 1. Home page of the application for measuring times of actions

2. TIME BASED APPROACH TO DETERMINE PHYSICAL EFFORT OF DESIGN

As elaborated in [1], relative efficiency is defined as the inverse value of total effort:

$$Er = \frac{1}{E} \qquad (1)$$

and total effort is (E) expressed as the sum of particular efforts:

$$E = C + S + L + K + M + T \qquad (2)$$

where C, S, L, K, M and T represent particular efforts related to mouse clicks, wheel scrolls, left hand keystrokes, usual keyboard typing, mouse movements and movement of the hand from mouse to keyboard, respectively.

Various methods for calculation of particular efforts were explored in [1]. One of those, the time-based approach, was used in this study for its simplicity and effectiveness. Compared with the definition given in [1], the method is slightly modified in the part that relates to calculating the particular effort

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required to execute mouse clicks. This particular effort is split into partial efforts related to right, left and middle mouse clicks, as the latest experience showed that the times needed to perform these clicks were typically different, regardless of the user. Therefore, instead of (2), the following equation is used:

$$E = C_L + C_R + C_M + S + L + K + M + T \qquad (3)$$

where C_L, C_R and C_M are particular efforts related to left, right and middle mouse clicks, respectively.

The main assumption of the time based approach is that the effort is proportional to the total time required for the completion of the design process. The particular efforts, as well as the total effort, are expressed in time units, i.e. seconds. Each particular effort is calculated as the product of the average time needed to perform a specific action and number of specific actions in a design session. To make the calculations as independent from the specific user and computer hardware as possible, the average times are obtained using statistical methods. The calculations rely on an auxiliary experiment, involving a large number of users of different characteristics (age, gender, left-handed or right-handed people etc.), each of them using different hardware. Combining the experimental and statistical methods the following average times are obtained:

t_{cl} – the average time required for one left click

t_{cr} – the average time required for one right click

t_{cm} – the average time required for one middle click

t_s – the average time required for mouse wheel scroll,

t_l – the average time required for left hand keystrokes (ctrl, alt, left side shift and esc),

t_k – the average time required for typing with both hands,

t_m – the average time required for mouse movement together with hand and

t_t – the average time required for hand transfer from mouse to keyboard or vice versa.

Particular efforts related to various types of action are calculated using equations (5 – 12). For example, the particular effort (time) that corresponds to the left mouse clicks is calculated as:

$$C_L = \sum_{i=0}^{i=cl} t_{cl} \qquad (5)$$

where t_{cl} is the average time required for one left mouse click and "c" is the number of left, right and middle mouse button clicks. In the same manner, the particular efforts for the rest of the actions are defined as:

$$C_R = \sum_{i=0}^{i=cr} t_{cr} \qquad (6)$$

$$C_M = \sum_{i=0}^{i=cm} t_{cm} \qquad (7)$$

$$S = \sum_{i=0}^{i=s} t_s \qquad (8)$$

$$L = \sum_{i=0}^{i=l} t_l \qquad (9)$$

$$K = \sum_{i=0}^{i=k} t_k \qquad (10)$$

$$M = \sum_{i=0}^{i=m} t_m \qquad (11)$$

$$T = \sum_{i=0}^{i=t} t_t \qquad (12)$$

where cr, cm, s, l, k, m and t are numbers of right clicks, middle clicks, scrolls, left hand keystrokes, both hand typing occurrences, mouse movements and hand transfers recorded in a CAD modelling session, respectively.

As already mentioned, the total effort is calculated as in equation (3), with the unit of E being the second.

3. RESULTS

3.1 Time for left, right and middle mouse button clicks

The goal of this application module is to determine the mean time required for one left, right o middle mouse click. After the test has been initiated, the message is shown containing the name of the mouse button to be pressed. The first mouse button to be clicked is determined by random selection. If the user selects the correct button, a message about the selection of a new button is displayed. Selection of the left, rather than the right or middle mouse button, is required much more frequently. Thus the number of left clicks in a test is proportionally larger. The test lasts for 30 seconds.

Those data that deviated from the average value by 500% were considered to be irregular. Also, users who have incorrectly reported the year (for example year: 5) and users who did not perform the test for 30 seconds were excluded from calculations. The extreme values of time usually appear at the start of the test. This is probably due to the fact that the user need some time to understand how the application works. Also, another cause of extreme values is the lack of user concentration, most frequently caused by: message on the phone, conversation with another person, not watching the command display or continuous clicking on the left mouse button.

Table 1. Statistical results for left mouse button clicks

Number of people tested	77
Total number of left clicks	11 243
Number of discarded clicks	212
Number of accepted clicks	11 031
Age range	18 - 64
Number of females tested	23
Number of males tested	54
Average time for left click (s)	0,351
Standard deviation	0,107

Table 2. Statistical results for right mouse button clicks

Number of people tested	79
Total number of right clicks	1240
Number of discarded clicks	31
Number of accepted clicks	1209
Age range	18 - 64
Number of females tested	24
Number of males tested	55
Average time for right click(s)	0,641
Standard deviation	0,158

Table 3. Statistical results for middle mouse button clicks

Number of people tested	77
Total number of middle clicks	641
Number of discarded clicks	13
Number of accepted clicks	628
Age range	18 - 64
Number of females tested	22
Number of males tested	55
Average time for middle click (s)	0,877
Standard deviation	0,199

From above tables it can be seen that the time needed for the left click is much less than the time required for the right and middle click on the mouse. The time that an average user needs to click on the right mouse button is typically two times longer than the time he needs to perform the left click, while the time needed for middle mouse click is three times longer. Years and gender of user also affect the average time of click, which will be described elsewhere.

3.2 Time for mouse wheel scroll

This test implies scrolling of the text that is displayed in a separate text box. When scrolling the mouse, the number of rotating steps of the mouse wheel per second is measured. The text should be scrolled in both directions. The test lasts 10 seconds.

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The goal is to calculate the average time required for one rotating step.

Table 4. Statistical results for mouse wheel scroll

Number of people tested	87
Total number of samples	87
Number of the rejected samples	3
Number of the accepted samples	84
Total number of wheel scrolls	13648
Number of discarded scrolls	66
Number of accepted scrolls	13582
Age range	18-64
Number of females tested	24
Number of males tested	63
Average time for one scroll step (s)	0.080173
Standard deviation	0.050922

This test needs to be improved because it does not correspond to the real use of the mouse wheel during the scroll. In a revised test, the user should scroll up to strictly specified lines of text. Now the scrolling goes back and forth, without paying attention to cursor positioning precision.

3.3 Time for left hand keystrokes

This test is used for determining average time needed for pressing one keystroke on the keyboard with left hand. Buttons that are used are: Alt, Ctrl, Shift, Esc. By random principle the program displays the button that has to be pressed. When the test starts, program displays the first key, and only when user presses a correct key, the next key is shown. The test is 30 seconds long.

3.4 Time for combination of keystrokes

Within this test, users were asked to simultaneously press one of the auxiliary keys (Ctrl, Shift or Alt) in combination with a key representing a letter (for example, Ctrl+X, Alt+O, etc.). Upon starting the test, a combination of keys (also known as keyboard shortcuts) that are meant to be selected by the subject is displayed in a specified space. If the subject inputs the designated combination successfully another combination is displayed and so on. As in previous cases, the combinations are chosen randomly, and the time required to enter the corresponding combinations is measured. The test lasts for 30 seconds.

Table 5. Statistical results for left hand keystrokes

Number of people tested	90
Total number of left hand keystrokes	2612
Number of discarded keystrokes	21
Number of accepted keystrokes	2591
Age range	14-66
Number of females tested	25
Number of males tested	65
Average time for one keystroke (s)	0,999
Standard deviation	0,492

During the analysis of this test, all recorded instances of keystroke combinations with a duration time greater than a fivefold value of the average time were discarded. We believe that these occurrences of longer time intervals (which were discarded) were caused due to subjects being distracted by various unforeseen elements, such as: phone calls, communication with other users, etc.

In this test we had eighty six right handed participants and one left handed participant. Because of a lack of representation of left handed subjects, we will not be making any comparisons with this criterion.

Table 6. Statistical results for combination of keystrokes

Number of people tested	86
Total number of combined keystrokes	1304
Number of discarded keystrokes	19
Number of accepted keystrokes	1285
Age range	19-64
Number of females tested	22
Number of males tested	64
Average time for one combined keystroke (s)	2.0765
Standard deviation	0.6008

3.5 Time required for typing regular text

Within this test, users were asked to type a pre-prepared specific text using both hands (for example, file name or part name). This test accepts all data typed in text box, with all possible mistakes, which makes this test imperfect. The data obtained are stored in the database for further processing. Before processing, two samples with too many errors were discarded. Data processing consists of calculating average times for one keystroke for every user and then average values for all users.

Table 7. Statistical results for typing regular text

Number of people tested	79
Total number of text samples	874
Number of discarded text samples	2
Number of accepted text samples	872
Total number of keystrokes	25266
Number of wrong keystrokes	1534
Number of correct keystrokes	23732
Age range	19-64
Number of females tested	22
Number of males tested	57
Average time for one keystrokes (s)	0.388
Standard deviation	0.179

3.6 Time required for typing numbers

The goal of this test is to see how much time it is needed for one keystroke of a number on the keyboard. By random principle the program displays a number made of three whole digits and one or two decimals separated by comma. Upon starting the test program displays the first number. When the user finishes pressing all number keys (and a comma that separates whole from decimal digits), user has to press Enter so the next number can be displayed. The process is repeated for 30 seconds.

3.7 Mouse movement speed

This part of the application monitors the speed at which users move the cursor. The screen displays the small rectangle which needs to be selected with the mouse. After the rectangle is selected, it is drawn on some other part of the screen and the user needs to re-select it. The procedure is repeated 10 times. When choosing the rectangle, the time elapsed since the rectangle appears on the screen up to the moment the user selects that rectangle is recorded. In addition to the time, the distance of the mouse pointers (in pixels) is also being measured.

Table 8. Statistical results for typing numbers

Number of people tested	77
Total number of text samples	755
Number of discarded text samples	25
Number of accepted text samples	730
Total number of keystrokes	5285
Number of discarded keystrokes	175
Number of correct keystrokes	5110
Age range	20-58
Number of females tested	21
Number of males tested	56
Average time for one keystrokes (s)	0.382
Standard deviation	0.172

Table 9. Statistical results for mouse movement speed

Number of people tested	97
Total number of mouse movements	872
Number of discarded movements	0
Number of accepted movements	872
Age range	20-58
Number of females tested	26
Number of males tested	71
Average time for one movement (s)	1.039
Standard deviation	0.215

3.8 Time for transfer the right hand from the mouse to the keyboard and vice versa

Within this test, the speed of moving the hand from the mouse to the keyboard and vice versa is determined. The user is shown the rectangle to be selected by the mouse. After choosing the rectangle, he is asked to enter a

number in the text input field. After entering the number, the rectangle to be selected is displayed again, and so on. The procedure is repeated 10 times. The time follows from the selection of the rectangle to the entry of the number, as well as the time elapsed from entering the number to the rectangle selection. The user is also required to use only the numeric keypad.

Table 10. Statistical results for transfer the right hand from the mouse to the keyboard and vice versa

Number of people tested	96
Total number of transfers	2309
Number of discarded transfers	50
Number of accepted transfers	2259
Age range	19-64
Number of females tested	21
Number of males tested	75
Average time for transfers from mouse to the keyboard (s)	1,447
Average time for transfers from keyboard to the mouse (s)	1,069
Average time for one complete hand transfer (s)	2.516
Standard deviation for transfers from mouse to the keyboard	0,394
Standard deviation for transfers from keyboard to the mouse	0,351

Extreme values came out as a result of the user not reading the instructions on how the application is working, so the first samples of some users were very high values, but the later samples of users were correct because they realized how the application worked. Another interesting case of high value for some users is when it is necessary to press the BACKSPACE. It is probably because the users were instructed to use only the numeric keypad and they were confused when they saw that the application insists on pressing the BACKSPACE button.

4. CONCLUSION

The trial experiment demonstrated to be useful in testing of the methodology for experimental determination of the average times of the actions executed in a CAD application. The validity of the developed methodology is considered to be proved. Nevertheless, the trial experiment has indicated many possibilities for improvement, especially considering the methods of measuring the duration of specific activities during the design process.

The goal of the following research will be to further improve the methodology and perform a number of relevant measurements.

5. ACKNOWLEDGEMENT

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