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Interfaces for distributed remote user controlled manufacturing: Working individually or in collaborative group?

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Abstract

The present invention is directed to manufacturing, wherein each component of the outsourced process and system can be remotely controlled in decentralized manufacturing process, integrating resources and stakeholders in a global chain, that utilizes ubiquitous computing systems virtual and networked enterprises concepts, for anywhere-anytime control. Experiment involved 68 subjects, Serbian students that have used the interface for remote collaborative control to control CNC machine located in Portugal. Usability evaluation measures of the distributed remote user controlled manufacturing system, such as percentage of task completed, its accuracy and time to complete task, are measured on two types of "client" user interface ("Wall" and "Window"), in two modes of presentation (desktop and video beam), working individually or in small collaborative group consisted of two persons, results were statistically tested. Percentage of task completed is equal for both types of interfaces, while accuracy of task is significantly better for "Wall" interface. Time of task execution is longer for individuals when desktop is used comparing to video beam. There exist significant differences when work is conducted in groups via video beam and time is longer when desktop is used. Also, work time is longer with "Wall" interface. When working in group, work time is shorter than the time when working individually, whereby the working time on desktop is longer than on the video beam. Also, the time is longer when working individually using video beam, using "Wall" interface on desktop, and "Window" interface on video beam. These results show that group work consumes less time in most working options, giving the best results when working in collaborative small group on "Wall" interface via video beam.

Keywords: Distributed remote user controlled manufacturing system; Usability evaluation measures; "Wall" and "Window" Interface

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1. Introduction

In order to remain competitive in a growing global marketplace, product manufacturers today are forced to find new solutions to satisfy their customers. The process of globalization and free movement of goods between the markets of countries around the world and especially after the economic crisis few years ago, once more has proved the fact that the classical vision and the production oriented company way of functioning is no longer sustainable in the economic reality [1]. The needs for a high degree of specialization and flexibility today have to be successfully merged and the solution for that could be found in the networking of small and medium-sized production systems. In Europe more than 5 million enterprises operate in the manufacturing and the construction sectors while of these, 99.6% are SMEs [2]. Special emphasis should be put on micro industrial companies with less than 10 employees, that count more than 80% of SMEs in manufacturing sector companies and employ 39% of Europeans [2], because they most often, due to insufficient marketing activities, have a very high percentage of unused production capacities. Also, the Standish Group Int.`s report [3,4] has shown that IT projects success rate is less than 40% while non-technical factors (94%) dominate over technical factors (6%), confirming in that way the fact that soft factors, such as human factors issues are not solved. The objective of sustaining competitive advantage has given birth to third generation ubiquitous manufacturing, which is a recent catching wave [5]. According to that new wave, this survey is directed to manufacture of a product, wherein each component of the outsourced manufacturing process and system can be remotely controlled in decentralized manufacturing process, integrating resources and stakeholders in a global chain, that utilizes ubiquitous computing systems and virtual and networked enterprises concepts, for anywhere-anytime control. The experiments done in this survey test few usability evaluation measures of the distributed remote user controlled manufacturing system to get an answer does working individually or in collaborative group give better results when working in different environments.

Nomenclature

TET	task execution time
PTC	percentage of task completion
POA	percentage of accuracy
WA/WI	"Wall" or "Window" interface
S/G	single (individual) or group work
D/V	desktop screen or video beam presentation

1.1. Previous research

The fusion of latest technologies with traditional manufacturing aids in remote control, which is one of the aims of ubiquitous manufacturing (UM) [5, 6]. Critical success factors of ubiquitous manufacturing are rarely surveyed and literature, when exists, usually ignores the soft dimensions [5, 6] noticed that teamwork is very important factor for successful implementation of UM systems while effectiveness, efficiency and representational fidelity are three important indicators for the usability construct, while collaboration effort, awareness/involvement and co-presence are the indicators for the collaboration construct. Dubay [5] also have found that the nature of collaboration as one area of identified importance where hardly any research has been undertaken. Straub [7] emphasized the importance of good metrics for net enhanced organizations and stated that “the unique characteristics underlying the Web may require new metrics or at least the careful evaluation of existing ones, to facilitate the development of innovative solutions to emerging problems”. Collaborative manufacturing networks and manufacturing grids are the subject of survey done by Liu and Shi [8], while Murakami and Fujinuma [9] extend it to ubiquitous networking. Accordingly, Pappas [10] proposed the Distributed Collaborative Design Evaluation (DiCoDEv) platform with real-time collaboration of multiple users and tested it on a pilot case. Wang [11] propose architecture design of real-time monitoring and remote control of networked CNC machines and conclude that remote users still need active and visual supports to coordinate their efforts in a distributed environment. On other side, proposals for new measures of usability are also continuously emerging in literature [14], and some of them are sociability [13] and flow [12]. Communication and new communication channels should be especially emphasized in the synergy of networking and multimedia technologies through computer supported cooperative work.

2. Interfaces for distributed remote user controlled manufacturing: Working individually or in collaborative group?

Human – machine communication channel, representing the basic architectural pattern for remote control of complex distributed manufacturing systems, is in the center of this investigation. The user interface for the remote controlling functionality that is the subject herein, as described in [15], has several components: control panel for remote machine controls, communications controls, panel to see absolute and relative positions of each axis as the feedback information from the machine movements, and video frame to get live video feeds. The "client" user interface of the distributed manufacturing system belongs to the Ubiquitous Manufacturing System Demonstrator, as described in [15, 16] as an extension and improvement of idea proposed by Wang [11] that Wise-Shop Floor solution provides "clients" web-based shop floor environment where real-time monitoring and remote control of CNC machines are undertaken. Two distinct types (versions) of user interface are examined: 1) Window and 2) Wall Interface. The remote user or the "client" operates on a remote cell while simultaneously receiving live video feedback as well as CNC machine status feedbacks, as shown in Fig. 1 and 2 [15,16]. Both versions of user interfaces were used on computer desktop screen and using video beam presentation. Projecting on a wall via video beam presentation opposite to the computer screen gives a real-time life-size live picture of the remote cell like being close to the cell physically. Two-way multiplex communication is tested both working individually or in small collaborative group consisted of two persons.

Fig. 1. “Wall Interface.”

Fig. 2. "Window Interface" [14].

The experiment has been done on the sample of 68 students, at Faculty of Mechanical Engineering, University of Belgrade, Serbia, that represent the future users of the interface for remote collaborative control of manufacturing systems. Students had an average age 23.07 years, regardless the gender. Propensity to work in group, using proportions based comparisons there were no statistically significant differences between them (working in groups or individually). They rated their computer skills with mark 3.98 in average on the Likert scale between 1-5. Purpose of students` work was to remotely control the cell settled at the laboratory at Universidade Minho, Guimarães, Portugal, as shown in Fig. 3. The task was to connect to the remote cell, start a CNC machine, upload a

(a) (b)

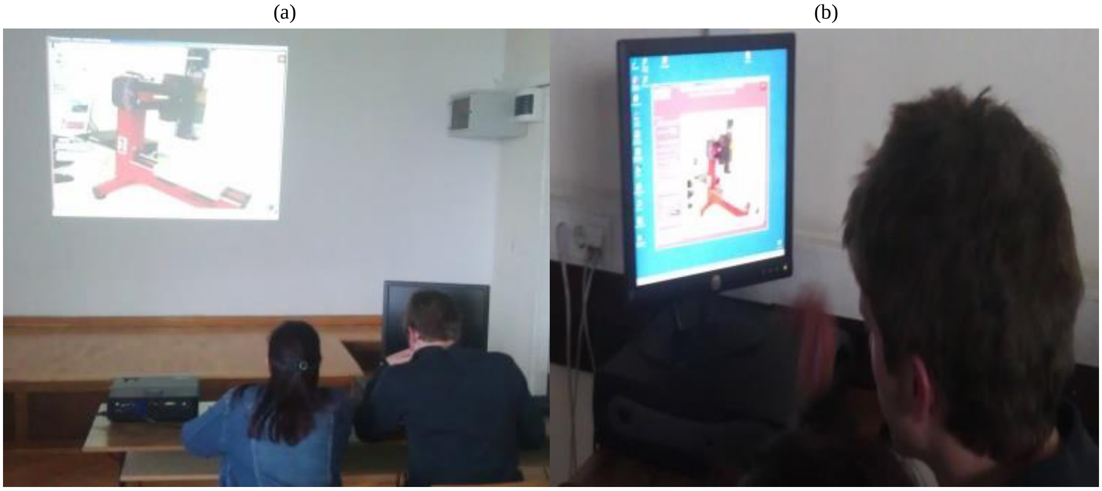

Fig. 3. (a) "Wall Interface," Video beam presentation mode, working in group; (b) "Window Interface," Desktop presentation mode, working individually.

g-code CNC program to conduct operations on the machine, remotely use the emergency stop button (which exists physically on the CNC machine), move axes, asses the status of the machine and real-time positions of the axes with addition of button usage on “Wall interface”.

3. Methodology and results

During the experiments on both interface types using desktop screen and using video beam presentation and both working individually or in small two person collaborative group task execution time (TET), the percentage of task completion (PTC) and the percentage of accuracy (POA) were measured using Likert scale (1-5). Descriptive statistics regarding those measures is given in Table 1.

The first step in data analysis was to describe data using descriptive statistics, in order to determine further tests that will be used. The first check point was value of coefficient of variation. For homogeneous data further examination by Kolmogorov tests were performed to establish if distribution is normal. In case of non-normal distribution, nonparametric method, i.e. Mann- Whitney test was used [17].

Table 1. Descriptive statistics for TET, PTC and POA data.

Parameter	N	Mean	Median	St.Dev.	Coef.Var. (%)	Kolmog. signif.	Method
PTC WA	68	4.529	5.000	0.701	15.48	<0.01	nonparametric
PTC WI	68	4.515	5.000	0.743	16.46	<0.01	nonparametric
POA WA	68	4.559	5.000	0.677	14.86	<0.01	nonparametric
POA WI	68	4.559	5.000	0.608	13.34	<0.01	nonparametric
TET S WA D	68	2.721	3.000	0.730	26.83	<0.01	nonparametric
TET S WA V	68	2.941	3.000	0.689	23.41	<0.01	nonparametric
TET S WI D	68	2.559	2.000	0.699	27.33	<0.01	nonparametric
TET S WI V	68	2.750	3.000	0.699	25.42	<0.01	nonparametric
TET S D	136	2.640	3.000	0.717	27.15	<0.01	nonparametric
TET S V	136	2.846	3.000	0.698	24.53	<0.01	nonparametric
TET S WA	136	2.831	3.000	0.715	25.27	<0.01	nonparametric
TET S WI	136	2.654	3.000	0.703	26.49	<0.01	nonparametric
TET G WA D	34	2.353	2.000	0.485	20.62	<0.01	nonparametric
TET G WA V	34	2.706	3.000	0.676	24.96	<0.01	nonparametric
TET G WI D	32	2.344	2.000	0.653	27.86	<0.01	nonparametric
TET G WI V	34	2.471	2.000	0.563	22.80	<0.01	nonparametric
TET G D	66	2.348	2.000	0.568	24.19	<0.01	nonparametric
TET G V	68	2.588	3.000	0.629	24.29	<0.01	nonparametric
TET G WA	68	2.529	2.000	0.610	24.12	<0.01	nonparametric
TET G WI	66	2.409	2.000	0.607	25.20	<0.01	nonparametric

Regarding interface efficiency it can be concluded that task realization percentage is the same for “Wall” and "Window" interfaces. Meanwhile task accuracy is statistically significantly greater when “Wall” interface is used, comparing to "Window" interface (Tab. 2).

Table 2. Percentage of task completion (PTC) and the percentage of accuracy (POA).

			p-value	significance
PTC WA	=	PTC WI	n.s.	
POA WA	>>	POA WI	0.0083	<0.01

For task execution time different combined comparisons were conducted and presented in Table 3.

Table 3. Comparisons of different combined test subjects for single, group testing of "Wall" and "Window" via desktop and video beam displays.

			p-value	significance
TET S D	>	TET S V	0.0241	<0.05
TET S WA	=	TET S WI	n.s.	
TET S WA D	=	TET S WA V	n.s.	
TET S WI D	=	TET S WI V	n.s.	
TET G D	=	TET G V	0.087	
TET G WA	<	TET G WI	0.0222	<0.05
TET G WA D	>	TET G WA V	0.0159	<0.05
TET G WI D	=	TET G WI V	0.071	
TET S D	=	TET G D	n.s.	
TET S V	>	TET G V	0.011	<0.05
TET S WA	=	TET G WA	n.s.	
TET S WI	=	TET G WI	n.s.	
TET S WA D	>	TET G WA D	0.0107	<0.05
TET S WA V	=	TET G WA V	n.s.	
TET S WI D	=	TET G WI D	n.s.	
TET S WI V	>	TET G WI V	0.0457	<0.05

According to results in Table 3, it can be concluded that at statistical significance level <0.05 there exist the following differences:

- Task execution time is longer when single person works on desktop relative to video beam;
- Task execution time is longer for groups working with "Window" interface;
- Task execution time is longer for group working with "Wall" interface if they use desktop rather than video beam display;
- Task execution time is longer when single person works with video beam display instead in group, regardless interface in use;
- Task execution is longer when single person works with desktop display instead in group, with "Wall" interface and
- Task execution is longer when single person works with video beam display instead in group, with "Window" interface.

4. Conclusion

The main aim of this survey was testing of few usability evaluation measures of the distributed remote user controlled manufacturing system and get an answer does working individually or in collaborative group give better results when working in different environments. After testing the following conclusions appear. Percentage of task completed is equal for “Wall” and “Window” interfaces, while accuracy of task is significantly better for “Wall” interface comparing to “Window”.

Time of task execution is longer for individuals when desktop is used comparing to video beam.

There exist significant differences when work is conducted in groups via video beam and time is longer when desktop is used instead a video beam. Also, work time is longer with “Wall” comparing to “Window” interface.

When working in group, work time is shorter than the time when working individually, whereby the working time on desktop is longer than on the video beam. Also, the time is longer when working individually then in group using video beam, using “Wall” interface on desktop, and “Window” interface on video beam. It can be concluded that group work requires less time than single work.

Best result can be obtained by group work on "Wall" interface with use of video beam display. Therefore, these preliminary results show that group work consumes less time in most working options, giving the best results when working in collaborative small group on “Wall” interface via video beam.

Finally, participants were asked which group size is optimal according to their opinion, and answer of mean value about 2.65 persons with standard deviation 0.96 has been received. Accordingly, the future research can test a little bit larger groups - with 3 students collaborating in remote control of CNC machine.

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