HUMACS

Organizational Aspects of Human-Machine Coexisting Systems

Final Report

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Contributors: HUMACS Partners

Editor: Shunji Yamada, Yamatake Corporation

1. Introduction

HUMACS represents *HU*man *MA*chine *C*oexisting *S*ystems. The HUMACS project was carried out as part of the IMS program, with research partners from Switzerland, EU, Japan, and USA, focusing on interdisciplinary research on "human/social/organizational aspects" in the fourth category of IMS-TOR. The project was concluded in March 2002 after five years of international research following the endorsement by ISC in February 1997.

Whenever next generation manufacturing systems are discussed, it is almost the case without exception that research priority should be placed on respect for human dignity. In recent years, manufacturing industries are exposed to increasingly intensifying global competition. With manufacturing facilities further automated and upgraded, how to help people working there effectively display their creativity and innovativeness is drawing attention as an influential factor working on corporate competitiveness.

The spread of information technology and the expansion of networks are accelerating the standardization of management and products under the name of "global standards." This means that differentiation by product or manufacturing process technology will inevitably become short-lived. It is even said that knowledge of workers in a company is the only resource that can produce an ever-lasting competitive edge.

In order to make the most effective use of factory workers as human resources, it is imperative to restore their human dignity by freeing them from alienation of individuals, which is one of the evils of the rationalization of production in recent years. The reason is that they will not be able to come up with creative or innovative ideas unless they can establish their identities in their workplace and get a sense of satisfaction or fulfillment from their jobs. This will also significantly contribute to higher productivity by directly reducing human errors, labor accidents, and damage to health at work sites.

We thus believe that overall improvements in manufacturing will arise from efforts to ensure the optimum coexistence of human and machine based on the proper analysis and evaluation of these human factors. This research project was initiated to reflect such background and motives. It is not a mere pursuit of the optimal design of man-machine interfaces. It is a challenge to properly evaluate human factors from diverse perspectives, based on basic research in the organizational, sociological, and human engineering fields.

We have achieved a successful development during this project of several practical methods for restoring dignity of human beings which was prone to be neglected behind the rationalization of production, and for enabling workers to have a sense of satisfaction and fulfillment making their lives worth living. There is no doubt that they will contribute to a great extent to overall improvements in manufacturing productivity by reducing human errors and labor accidents along with activating improvement efforts and organizational knowledge creation. This will also lead to helping fulfill the social requirement for next-generation industries of being human-and-environmentally friendly.

The final report briefly outlines the specific achievements. More details are available in a CD-ROM: HUMACS Project March 2002, and the PSIM Book. The former was compiled under the initiative of the Japan consortium, while the latter published by the European PSIM consortium, although the former includes the contents of the latter as well.

2. Project Overview

2.1 Project Objectives

The HUMACS project aims to pursue a practical methodology to establish an optimum relationship between human factors and manufacturing facilities. This methodology should be developed based on multidisciplinary research on the next generation manufacturing systems including ergonomical informational, and sociotechnical study fields.

HUMACS puts emphasis on problems relevant to human resources management in the manufacturing enterprises, i.e., how to mobilize the human power for manufacturing; how to preserve and enhance technical skills for manufacturing; and how to exploit information technology to resolve human-factors issues in manufacturing enterprises.

In the short term, the objectives of HUMACS are threefold:

1) To develop and implement practical methodologies for ergonomically and sociotechnically optimal design of manufacturing systems;
2) To create systems environments to uphold creativity and innovativeness of motivated humans in manufacturing organizations;
3) To explore extensive application of advanced technologies to address human-factors issues in manufacturing environments.

2.2 Project Structure

The project was launched under the initiative by the Japan consortium with participation by a partner from USA defining the following workpackages associated with four perspectives as: activity or function; organization; information; and resources, where a factor of resources means a viewpoint of “human factors” that is to be shared in common:

WP 1: Optimum design of human-machine coexisting systems:

To seek to develop and implement a practical methodology for an optimum work load partitioning between humans and machines in intelligent manufacturing systems, while releasing workers from dehumanization that is often caused by mere pursuit of higher efficiency of machines.

WP 2: Sociotechnical factory organization:

To address decision-making mechanisms adaptable to changes in and outside production processes caused by reorganizations, accidents, etc. as well as changes in customer demand, supply of raw materials, and energy conditions, while also pursuing an optimal solution to work methods in manufacturing factories, based on the sociotechnical study on relationship between an individual and organizations, and on mutual relationship between individuals.

WP 3: Organized human-machine cooperative systems:

To tackle effective handling of such information as is inexpressible by such conventional means as text or drawings, or as lies in the tacit dimension of individuals, with the best possible support from advanced information technologies.

Under the umbrella name of HUMACS, its European module PSIM project emerged. What it aims at is most closely related to WP 2, but it also has so much relevance to other workpackages. Accordingly, PSIM is reasonably positioned as another workpackage viewed from a different dimension of the project as defined in the following:

PSIM: Participative Simulation environment for Integral Manufacturing enterprise renewal:

To develop and pilot-demonstrate a simulation environment for use in assembly operations and to advance integral renewal in a competitive, changing environment by supporting continuous improvement processes. PSIM uses a *P*articipative improvement process involving specialized staff, management and production personnel. PSIM shows *S*imulated assembly lines in the state-of-the-art ICT(Information and Communication Technology). PSIM is on *I*ntegrated renewal, which means that technological, organizational, and human factors are all concerned in optimization. It is focused on intelligent *M*anufacturing to assist human and technological creativity.

2.3 Project Goal

Figure 1 below shows the unified goal image of the international project in relation to platform technologies and backbone knowledge. In the center of the figure, "human-factors centered manufacturing enterprise" is placed as a target object to be supported by a technical environment to be developed anew. The upward arrow symbolizes continuous improvement and ever-lasting evolution to be developed in a spiral way in such a manufacturing company. A company uses humans that operate in networks and need motivation. The target enterprise is the one where people involved give full play to their capabilities from every perspective with full sense of fulfillment and satisfaction.

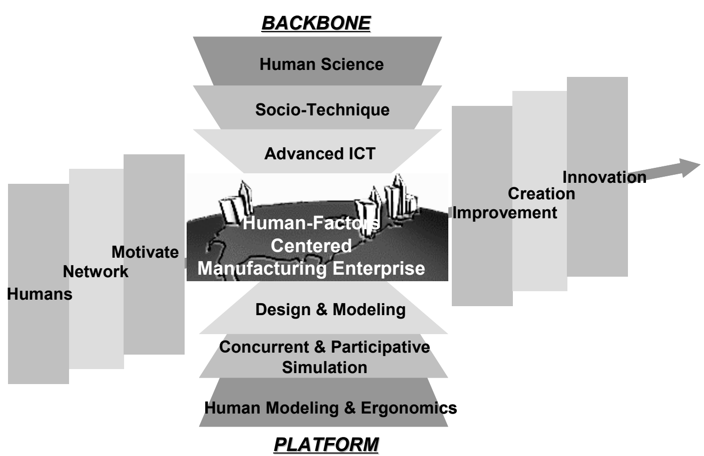

Figure 1 HUMACS Project Goal Image

For this support, three types of platforms are defined as shown in the figure in order to facilitate: 1) evaluation of human workloads from diversified perspectives, both physical and mental; 2) concurrent and participative simulation to cope with abrupt environmental changes, or to check in advance on new ideas for improvement; and 3) design and modeling of collaborative work.

In the meantime, backbone knowledge is needed in the field of human science, sociotechnique and advanced ICT. Enhancement of existing knowledge in the backbone knowledge area is requested in the course of the project development along with creation of new knowledge.

The outcomes from workpackages mentioned in the preceding section are effectively organized into a unified systems environment supporting “human-factors centered manufacturing enterprises” as the easy-to-understand project goal described above.

3. Achievements Summary

3.1 WP1: Optimum Design of Human-Machine Coexisting Systems

Task1.1: Info-Ergonomics Modeling

- A new field of technology named “Info-Ergonomics” has been created by establishing a simulation system environment capable of performing simulation detailed enough for precise ergonomic evaluation, thereby facilitating process and motion design in pursuit of an optimum design of human-machine coexisting systems in manufacturing.
- A methodology has been developed for a bone-based human model(BBHM) as a 3D object that is precise enough to meet evaluation of human motion, coupled with a mapping algorithm in accordance with human actions captured from the real world.
- A combination has been established of info-ergonomics with other technologies under development in another project such as “3D action capturing from multi-view images” and “spatiotemporal object database technology”, resulting in completion of a total prototype system.
- Industrial feasibility has been confirmed on application of the info-ergonomics simulation system to work samples obtained from industrial sites, including the data from the PSIM project.

Task1.2: Image Playback Model

- A psychological adaptation model of humans has been developed. In particular, modeling of direct labors’ adaptability to their jobs has been established with “scene of success” acting as a yardstick for measure.

3.2 WP2: Sociotechnical Simulation of Factory Organizations

Task2.1: Human-Oriented Production System Architecture --- Production Auction System

- A management architecture for human-oriented production systems has been established for facilitating positive usage of those factors only humans have such as will and volition.
- A prototype system has been developed and implemented with an active database as a nucleus coupled with a real-time scheduler, thereby providing a system environment ensuring production management on an auction basis.
- Feasibility has been verified albeit on a simulation basis for application of the proposed architecture to an actual manufacturing lines at an industrial partner within the project.

Task2.3: Short-Term Decision Support System

- An architecture and design algorithms have been developed for a decision support system in response to real time to short- and medium-term changes in environment conditions. Those algorithms take into consideration not only uncertainties and noises but also cognitive biases and volatile nature of humans.

Task2.4: Human-Factors Centered Organization Model

- A conceptual model has been proposed for a human-factors centered organization hinted by flexible mechanism of living beings in order to cope with dynamic changes in manufacturing environments.

3.3 WP3: Organized Human-Machine Cooperative Systems

Task3.1: Psychophysiological Evaluation

- Building of a virtual working environment for desk work in office has been completed.
- A design methodology for an integrated system has been established based on the results of a series of experiments in the virtual environment with data obtained from measurement of psychophysiological response.

Task3.2: Design Intention Modeling

- A technique for representing designers' intentions has been established.
- A design-process management system has been built up with the design-process database accommodating design intention for facilitating more efficient reuse of designers' intention.

Task3.3: Integrated Collaboration and Concurrent Engineering Environment(ICCEE)

- A new systems environment ICCEE has been established based on a concept of collaborative interface model with the aim of supporting collaborative work among workers with diverse viewpoints and experiences encompassing the whole design process from requirement acquisition to performance evaluation.
- A methodological validation has been applied to a variety of domains of collaboration such as production management, mechanical parts design, software developing process, and medical information processing.

3.4 PSIM: Participative Simulation for Integral Manufacturing enterprise renewal

The goal of the project known as PSIM (Participative Simulation environment for Integral Manufacturing enterprise renewal) is to develop a system that supports assembly process improvement. The system supports in an integrated and on-going manner using advanced simulation software. This new simulation system includes the latest ICT systems with the most recent knowledge of sociotechnique and ergonomics. Firstly, the requirements are defined by Volvo, Finland Post, Ford, CRFIAT and Yamatake in workpackage 1 (wp1). To make the connection with different users and existing software a language is defined (wp2: the ontology). This ontology is of course used in the procedure (a kind of handbook), which is also developed in wp1.

In the first year the first paper and pencil versions of parts of the ergonomic and sociotechnical tools were developed and tested (wp3). Between month 12 and 18 both the ergonomic and sociotechnical tool were adapted to put them into software. Data from the tests were used to prepare the software versions. Also, the software versions were developed. At conceptual level the software is integrated into one tool: the E/S tool.

Also, the technology that is able to connect the users and packages (wp4: navigator) is developed and finalized. A part of the procedure is to test the effect of suggested improvements partially in the existing data of the ERP systems. To enable this simulation the integrator (wp5) is made. With the integrator PSIM can use existing data in ERP systems. In the last 6 months the different PSIM parts are tested (wp6). The results are presented in a workshop for industry on March 18, 2002 and in a PSIM book.

4. Industrial and Economic Impacts

The following impacts are to be expected from industrial and economic perspectives to be brought from the research and development in the project:

1) Info-ergonomics simulation, human adaptation model, and methods for psychophysiological evaluation on working postures, and the PSIM environment; all of these will greatly contribute to reducing labor accidents and health damage, both physical and mental, to direct workers. Their application will also lead to a lower turnover rate of direct workers, thus resulting in a decrease in training cost and an increase in productivity at production sites.
2) Application of the production auction system will substantially improve productivity at work sites through reduced time for change-over and realization of mutual support. This will lead to a reduction in labor cost for assembly and processing as well as to an improvement in yields.
3) Adoption of methods for representing design intentions and application of the ICCEE (Integrated Collaboration and Concurrent Engineering Environment) will reduce time for product and process design, thus leading to lower production cost and shorter lead time.
4) After application of PSIM in renewal or design of the production line, human operators will work more motivated with acceptable workload in an efficient workflow.

5. Project History

5.1 Transition Period

The HUMACS consortium was first formed in 1994 led by then Yamatake-Honeywell Co. following a pre-study on an optimal design of human-machine coexisting systems in the Japan domestic arena of the IMS program. Efforts continued for inviting potential partners overseas toward formation of an international project with expressions of interest to participate in the full-scale IMS program. In the early stage, more than twenty proposed partners from Finland expressed interest. There were partners joining from USA, and Canadian partners followed expressing their intention to participate. Thus the first version of a full proposal was compiled in 1996 after endorsement by ISC of the abstract proposal.

A successful approval by ISC of the full proposal as an international research project came in February 1997 after recompilation of the proposal. However, the project faced a fatal hardship. The consortium in the European region, which had the largest number of partners, was forced to dissolve due to change in business conditions in its key partner. It was fortunate that a trend emerged for a new consortium to be formed in the region in line with official endorsement by the European Commission of the IMS program. The trend led to creation of the PSIM project under the umbrella of HUMACS.

5.2 Formation of the Full-Scale HUMACS Project

With the advent of the PSIM project, HUMACS was put on the right track to a full-scale international project in real terms. Although another certain period of time was needed before PSIM was granted public fund from the European Commission, the activities toward a full-scale project were virtually launched in October 1998, when an interregional meeting was held in Amsterdam between PSIM partners and Yamatake as ICP from Japan. The major events thereafter are shown in HUMACS Chronological Table in Appendix.

The official launching of the PSIM project came in April 2000 as a twenty-four month project, when HUMACS became a full-scale international project in both words and deeds. In the meantime, the project faced a need for screening partners, resulting in non-active partners left to be dropped off. Lack of a public funding scheme was crucial for withdrawal of partners from both Canada and USA regions, while in Japan a bad effect seen of the prolonged economic slowdown. After twists and turns mentioned above, the current formation of the global consortium became completed.

Since the research work conducted by the Japan consortium preceded several years to PSIM, the outcomes from HUMACS Japan could be positioned to serve as inputs to the PSIM project. The Japan consortium had concentrated their efforts on development of practical methodologies on the platforms shown in the figure of the project goal image cited earlier. The flexible feature of the PSIM architecture made possible integration of different tools and software packages, thereby resulting in smooth collaboration, albeit on a conceptual basis at the beginning, between PSIM and HUMACS Japan consortia.

6. Project Administration

The project decided on adoption of a simpler structure for project management than initially planned. This is partly because the size of the global consortium became so small in the half way as mentioned in the project history. And another reason is that the PSIM consortium with majority of the global partners has its own scheme of project management. Thus it is quite reasonable to avoid as much as possible a double-tier structure of management.

Accordingly, the only structure we have held for global project management is the International Project Steering Board(IPSB). It is composed of international coordinating partner(ICP), regional coordinating partners(RCPs), one representative from each of industrial and academic partners per region with ICP serving as chair, although there are regions having only a single partner. Its responsibility is defined as: to address issues relevant to Consortium Cooperation Agreement(CCA) and intellectual property right(IPR) when surfacing during the project; to oversee the progress of the global project; and to resolve any other issues to be raised from among partners during the project development.

Regarding the HUMACS CCA, it was drawn up based essentially on the model CCA recommended by Japan IMS Promotion Center which was supposed to be compliant with the IMS Terms of Reference. Minor amendments were made after receiving comments from secretariats of all the regions, resulting in stricter conformity confirmed with the TOR.

No serious claims were raised within the consortium. The only issue tabled for discussion was on language and law to be applied to interpretation of CCA. Since there is no specific law named international law, the expression of “ be interpreted in accordance with the law of Japan,” was accepted in line with the law of a country ICP of the project came from.

7. Technology Transfer and Dissemination

Technical transfer and dissemination have taken place at several levels:

- Exchanges of technical information within the consortium were carried out as appropriate through intensive use of electronic media and regular meetings major events of which are cited in the table given in Appendix. In the PSIM consortium, specific web sites and net-work scheme also were available for use facilitating effective information sharing and transfer.
- Technical transfer took place in various forms within the consortium toward practical application to industrial sites. The most typical example was an application of the HOMS architecture to the upgrading of an assembly line at Yamatake. There was another type of technical transfer performed through test and evaluation of the PSIM pilot-system at five test sites, not only in the EU, but also in Japan.
- Dissemination events open to the public were held in the form of annual technical conferences in Japan, IMS special sessions in academic conferences, and so forth. At the conclusion of the full-scale international project, two technical events took place, one in Yokohama, November 27-30, 2001, and the other in Amsterdam, March 18-19, 2002, the technical contents of which are given in the CD-ROM: HUMACS Project March 2002.
- Publication of the research results was made through academic and technical journals, and international and domestic conferences. Selected publications are given in the same CD-ROM, albeit apologies for papers from PSIM partners being dropped off.
- The PSIM project will result in the PSIM book which is available for the public and is presented on several conferences, including the PSIM workshop for industry on March 18, 2002.

8. Consortium Composition

Regions Involved: Switzerland, EU, Japan, USA

International Coordinating Partner: Yamatake Corporation (Japan)

Regional Coordinating Partners:

Switzerland: ETH Zurich

EU: TNO Arbeid

Japan: Yamatake Corporation

USA: Delmia Corporation

8.1 Current Consortium Partners

Switzerland Region: ETH Zurich

EU Region: TNO Arbeid, Baan Development, Charmers University, C.R. Fiat, Data Consult, Finland Post, Finish Institute of Occupational Health, RWTH, TU Eindhoven, University of Patras, Volvo Car Corporation

Japan Region: Yamatake Corporation, Toyota Motor Corporation, Osaka University, Sophia University, Waseda University, Yokohama National University

USA Region: Delmia Corporation

8.2 Former Consortium Partners

Canada Region: CIRANO, Ecole Polytechnique de Montreal, Automation Specialties

EU Region: Ekono Building Engineering, ABB Flakt, ABB Installation, Ahstrom I-valo, Digital, E. Hiltunen Inlook, Ensto-Automation, ESMI, Extor, Fickars Power Systems, GWS Systems, Halton, Helvar, Honeywell, ISS Servisystem, Kone Cranes, Landis & Gyr, Nokia Aluminium, Parmaco, Puolimatka, Rautaruukki, Sarlin, Satel, Telecom Finland, Telepoint

Japan Region: Obayashi Corporation, Kubota Corporation, Taisei Corporation

USA Region: SRI International, Drexel University, California Polytechnic State University

APPENDIX

Year	Month	Day	Domestic events in Japan	Venue	Day	International events	Venue
			HUMACS CHRONOLOGICAL TABLE (October 1998-March 2002)				
							March 2002
1998	10				29	HUMACS Intl Meeting	Amsterdam, NETH
	11						
	12	9	HUMACS MTG (2nd F1998)	YC HQ, Tokyo			
1999	1	13	HUMACS MTG (3rd F1998)	YC HQ, Tokyo	14-15	PSIM Meeting, Turin	Turin, IT
	2				4	HUMACS Intl Meeting	Tokyo, JPN
			Annual Proposal to IMS Center				
	3						
			Annual Research Report Published		30-31	PSIM Meeting, Zurich	Zurich, CH
	4						
	5						
	6	22	HUMACS MTG (1st F1999)	YC HQ, Tokyo		PSIM Proposal Submitted to EC	
	7	14-15	IMS Technical Conference 1999	TIME24, Tokyo			
	8						
	9				22-24	2nd IMS Intl Workshop	Leuven, BEL
	10						
	11	17	HUMACS MTG (2nd F1999)	YC HQ, Tokyo			
					24	IST Conference	Helsinki, FIN
	12				7	HUMACS Intl Meeting	Troy, USA
2000	1	17	HUMACS MTG (3rd in F1999)	YC HQ, Tokyo			
			Dr. Jan Goossenaerts's Lecture	YC HQ, Tokyo			
	2						
			Annual Proposal to IMS Center		16-18	PSIM Kick-off Meeting	Turin, IT
	3						
		31	Annual Research Report Published				
	4				1	PSIM Officially Launches	
		26	HUMACS MTG(1st F2000)	YC HQ, Tokyo			
	5				10-12	PSIM Meeting, Noordwijkerhout	Noordwijkerhout, NETH
		13-14	HUMACS Domestic Workshop	Laforet Shuzenji			
	6				5-7	HUMACS Intl Kick-off Meeting	Tokyo, JPN
	7	11-12	IMS Technical Conference 2000	TIME24, Tokyo			
	8	2-4	IMS Special Session at Society of Mech. Engineers, Japan	Meijo Univ, Nagoya.			
					31	Ann. Monitoring Rep. to IRS	
	9				6-8	PCM 2000/IMS Special Session	Detroit, USA
					14	HUMACS Intl Meeting	Troy, USA
					25	TUTB/SALTSA Conference	Brussels, BEL
					27-28	PSIM Meeting, Goteborg	Goteborg, SW
	10				19	e-Business and e-Work 2000	Madrid, SP
	11						
		29	HUMACS MTG(2nd F2000)	YC HQ, Tokyo			
	12						

Year	Month	Day	Domestic events in Japan	Venue	Day	International events	Venue
2001	1						
					19	Invited Talk at IMS Forum Korea	Seoul, KOR
	2	6	HUMACS MTG(3rd F2000)	YC HQ, Tokyo			
		16	Annual Proposal to NEDO		19-21	HUMACS Intl Meeting at ETH and RWTH, Intl Workshop at TNO	Zuruch, CH, Aachen, GER, Amsterdam, NETH
	3	27	IMS Poster Session at Society of Mech. Engineers, Japan	TMU & HU, Tokyo	8-9	PSIM Meeting, Aachen	Aachen, GER
		31	Annual Research Report Published				
	4						
	5	11	HUMACS MTG(1st F2001)	YC HQ, Tokyo			
	6				1	Ann. Monitoring Rep. to IRS	
					13-15	PSIM Meeting, Helsinki	Helsinki, FIN
	7	10-11	IMS Technical Conference 2001	TIME24, Tokyo			
	8						
	9				18	8th IFAC/IFIP/IFORS/IEA Symposium on Human-Machine Systems - HMS 2001	Kassel, GER
					27-28	PSIM Meeting, Corfu	Corfu, GR
	10				8-10	Intl IMS Project Forum 2001	Ascona, CH
					18-19	IST Conference	Venice, IT
	11				21	PSIM Meeting, Gothenburg	Gothenburg, SW
					27-30	ER 2001 / Int'l Conference on	Yokohama, JPN
						Conceptual Modeling	
						Workshop: HUMACS2001 (HUMACS Open Day)	
	12						
2002	1						
	2						
	3	22	Annual Research Report Published		18-19	PSIM Intl Workshop (Closing Meeting)	Amsterdam, NETH
		22	HUMACS Completion Document (CD-ROM) Published				