ADVANCES IN INFORMATION PROCESSING AND PROTECTION

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Edited by

Jerzy Pejaś
Szczecin University of Technology
Szczecin, Poland

Khalid Saeed
Bialystock Technical University
Bialystock, Poland

Springer

Jerzy Pejaś
Szczecin University of Technology
Faculty of Computer Science
Zolnierska 49
71 210 Szczecin
Poland
Email: jpejas@wi.ps.pl

Khalid Saeed
Bialystock Technical University
Faculty of Computer Science
Wiejska 45A
15-351 Bialystok
Poland
Email: aida@ii.pb.bialystock.pl

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FOREWORD

The Computer Science is relatively new field which is developing very fast not only because due to the huge interest of scientists and the market request, but also because this science has created possibilities for people of investigation and solved many problems that some time ago seemed to be insolvable. Such problems had only been described in science fiction novels, like underwater journeys of captain Nemo described by Jules Verne in XIX century. At present, various human dreams are successively becoming reality exactly as the underwater journeys became possible in the XX century.

The proposed book gives you a view of the progress in such domains of Computer Science as Artificial Intelligence, Biometrics, Security of Information Technology, Computer Information Systems and Industrial Management. The works contained in the book describe the newest investigation results of devoted scientists from Europe and Asia.

The book is written in a hard scientific language. It is really valuable and I am sure it will deliver you many scientific benefits.

Professor Andrzej Piegat
Szczecin University of Technology
Faculty of Computer Science and Information Systems
and
University of Szczecin, Poland
Faculty of Economic Sciences and Management

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We also acknowledge the authors' extensive efforts in preparing their works in the way that definitely will satisfy the readers. It is because of their valuable contributions, that this book has appeared in its really useful and precious form.

Finally, our thanks go to the assistants and the publishers for their help in much of the editing work that led to what we have produced.

Editors

Jerzy Pejaś and Khalid Saeed

INTRODUCTION

This book presents selected papers given at an international conference on advanced computer systems. It brings a number of new concepts into the field, providing a very fundamental and formal approach to Artificial Intelligence, Computer Security, Safety, Image Analysis, Graphics, Biometrics, Computer Simulation, and Data Analysis. State-of-the-art theoretical and practical results in a large number of real problems are achieved with the techniques described.

All papers presented in this book are partitioning in the four topical groups

1. Artificial Intelligence,
2. Computer Security and Safety,
3. Image Analysis, Graphics, and Biometrics,
4. Computer Simulation and Data Analysis.

Section 1. Artificial Intelligence considers results of the science and engineering of making intelligent algorithms and computer programs and it includes papers concerned Humatronics, Fuzzy Logic, Robotics, Cell, Genetic, and Probabilistic Algorithms, Incomplete Data and Similarity Relations, Fast Neural Networks and others topics.

Section 2. Computer Security and Safety covers a wide range of issues: Error Detection in Block Ciphers, Parallelization of Encryption Algorithms, Visual Cryptography Methods, Neural Network for building Programmable Block Ciphers, Security and Safety in Distributed Computing Environments, Chaotic Product Cipher, and other questions.

Section 3. Image Analysis, Graphics, and Biometrics deals with difficult tasks of the study of the extraction of meaningful information from images as well as methods for uniquely recognizing humans based upon one or more intrinsic physical or behavioral traits. Papers presented in this section are concerned Word-Recognition, Signature Identification, Fingerprint Recognition, Biometric Images Pre-classification, and other issues.

Section 4. Computer Simulation and Data Analysis concerns computer programs that attempt to simulate an abstract model of a particular system and transforming data with the aim of extracting useful information and facilitating conclusions. It includes papers devoted to Processor Utilization on a Multi-Processor System, Computer-based training systems for operators of dynamic objects, Linked Computer Servers, Loops Parallelization in the .NET Environment to be used for simulation purposes, and other related topics.

I hope that the papers, presented in this book, will allow you to enlarge your knowledge in the field of advanced computer systems.

I wish you a satisfaction from reading the book.

Professor Włodzimierz Bielecki, Vice Dean
Faculty of Computer Science
Szczecin University of Technology

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PART I

ARTIFICIAL INTELLIGENCE

Humatronics and RT-Middleware

Toru Yamaguchi and Eri Sato

Tokyo Metropolitan University, Dept. of System Design
6-6 Asahigaoka, Hino, Tokyo 191-0065 Japan
{yamachan, esato}@fml.ec.tmit.ac.jp

Abstract. This paper described Humatornics for symmetrical communication between a human and robots. Recently, we use various types of systems based on electronics. However, these systems are not useful and imposes burden. The electronics for solving these problems are called “Humatronics”. Advanced humatronics are mostly needed for natural communication between human and system To realize humatronics, a system understands human using various sensor, architecture, and so on. Therefore we focused on Robot Technology Middleware (RTM). RT Middleware was developed by AIST (Agency of Industrial Science and Technology, Japan) for easily integrating robot systems by modularized software components. By constructing modules based on RT Middleware, we developed modules, which are functional elements to interact with human as components of easily system integration. Firstly this paper describes “Humatonics” and RT-Middleware. Secondly we show a system, which is based on humatronics concept using RT-Middleware.

1. Introduction

Nowadays various types of systems are used in daily life. We enjoy using the Internet at home, and helped by car navigation system when the driving. Users need to understand how to use most of these systems today. To obtain outputs, a user has to put correct inputs. However, information and systems are becoming increasingly complicated, we need more knowledge and skills to obtain outputs. Moreover, with the progress on computer technology various types of robots are developed and used. Frantic effort is needed to make full use of these systems. These systems are far from knowing intuitively. Then, ‘humatronics’ is spreading with a central focus on ITS [1]. Various sensor, tool or algorithm is needed for understanding a human. However, implementation of these sensor or algorithm for individual system is hard. Also, contractions of interaction robot or service robot which is constructed many parts is hard. Robot Technology Middleware (RT-Middleware) for easily integrating robot systems by modularized software components.

2. Humatronics

Various systems based on electronics, such as computers, cellular phones, cars and even robots, are used in our daily life. However, these systems are not useful, impose burdens, especially to elderly and handicapped people. We name the electronics for solving these problems "Humatronics". As shown in Fig 1, humatronics is divided into two stages. In this paper, we have researched on the first stage of the humatronics.

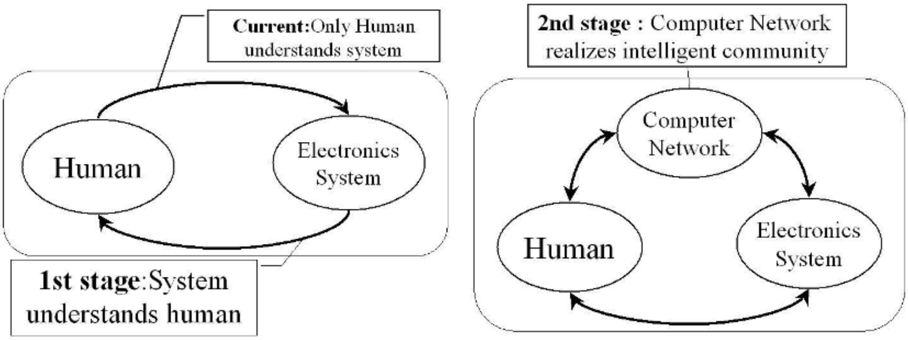

Fig. 1. Humatronics: Humatoronics is constructed two stages. The right figure showed 1st Stage. On the 1st stage, a system understands human and constructs a symmetrical interaction. On the other hand, the system forms an intelligent community on the 2nd stage. The intelligent community supports humans seamlessly.

To actualize the interaction between human and system, system must understand human intention first. Present interface, such as keyboard, mouse and so on, are unsuitable for intuitively operation or manipulation. Manipulation using natural motion based on human-to-human communication is needed. Therefore, system needs to understand human, and establish symmetrical interaction between human and system. Advance humatronics are mostly needed for natural communication between human and system. We think nonverbal communication is primitive and important for communication between human. So, we show step toward natural communication between human and robot based on interpersonal communication (Fig 2). We have researched human-robot interaction using hand motion considering situation [2], and natural interface using pointing movement [3][4].

Our laboratory has developed software, which track human motion using a camera. To recognize gesture, the system implement some cameras for calculate 3-dimensional coordinates. Additional the system include visible types robot that service to human physically. To develop a system such as collaborates tracking soft wares using camera and robots is hard. Thus, we used RT-Middleware to implement these sensor and robots in a system. In the next section, we describe RT-Middleware.

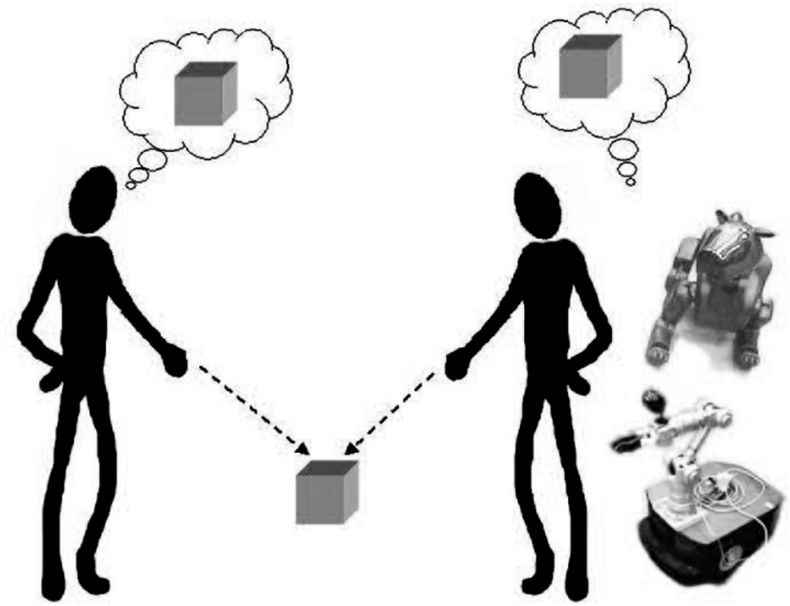

Fig. 2. Natural communication between humans and robots based on human communication.

3. RT-Middleware

NEDO (New Energy and Industrial Technology Development Organization) is leading with the standardization of robot elements as 21century robot challenging program. Recently, the committee has decided on groups to be commissioned. The group that headed by Prof. Tanie is going to develop a middle ware for modularity and an open architecture specification (RT-Middleware project). In our research, we focused on vision modules. We had studied about object tracking software using camera information. However, it is difficult to implement other systems. Firstly, we modularize this tracking software using OpenRTM-aist, which was developed by AIST (Agency of Industrial Science and Technology, Japan)[5][6][7]. Modularizing a sensor, controller, and so on as RT-component. Developers are able to connect these modules and build a system. Fig.4 showed the screenshot of Rtc-link. Rtc-link displayed each RT-component, which was connected naming server. The component (right side in Fig.4) calculates three-coordinates using the obtained coordinates from two modules (left side in Fig.4) by DTL method. In next section, we show the system that gesture recognition and obtaining object information, contacted based on RT-Middleware.

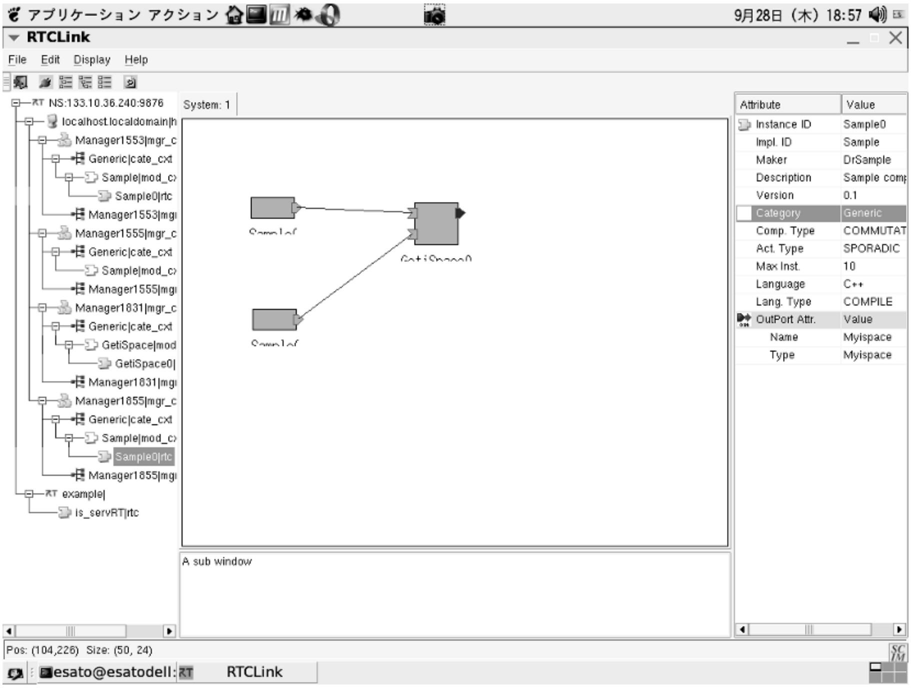

Fig. 4. Screenshot of RT-middleware: the right side modules calculate three coordinates using the coordinates, which was obtained by the left side modules.

4. Experiment of interaction system using gesture

We have researched human robot interaction using pointing movement. In the previous research, we constructed virtual room for interactive interface. Because, in actual object cannot react when a user attended it; the object in virtual room can be blink as a reaction when a user pointed out it. The user answered whether the object is what you want or not. Therefore, a user and the system can be attended same object interactively. To realize the interactive way in actual room, the system need to recognize feature of object, which a user attended. Thus, in this research, we focused on color information. If the system obtains color information of the object, for example, the system could ask whether the user pointed out something red as shown in Fig. 5. In this research, we constructed the system that obtains RGB information of pointed out object as the first step in this interaction.

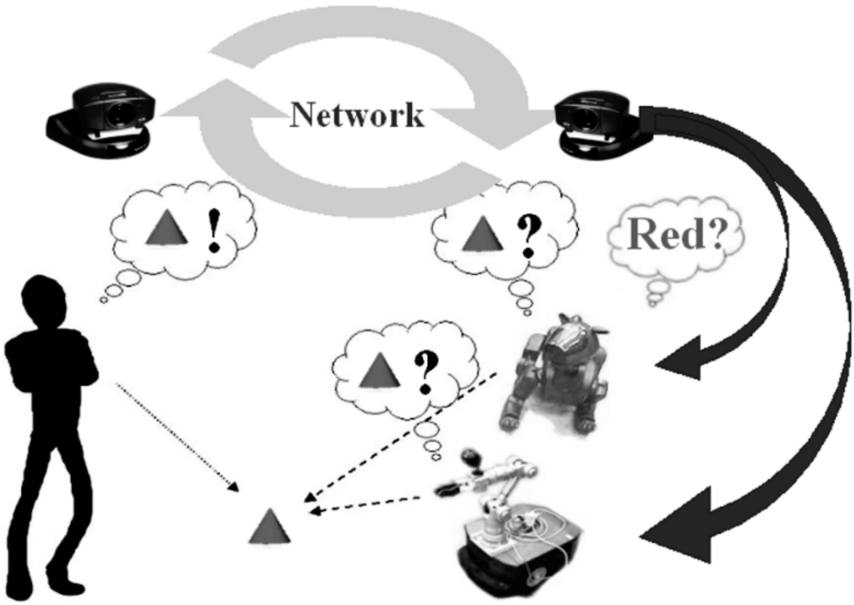

Fig. 5. Interaction using RGB information. In an actual room, robots show attended object using color information. The color information is obtained by tracking modules, which is composed a camera and PC and tracks human motions or observes the environment. Robots and tracking modules share the information by network

4.1 System outline and each components

In this system are constructed 4 steps. First step tracks a user's motion using camera. Second step calculate a 3 dimensional coordinates of user's head and hand by DLT method using 2-dimensional data, which was obtained at first part. Third step recognize indicating point using the 3-dimensional coordinates. Last step obtained RGB data on the picture, which was used at first step using 3 dimensional coordinates of indicating point. These steps related each other; it is difficult to improve each other under the previous construction method. For example, when some researcher proposes a new motion tracking we have to rewrite a program adapting our environment. Also, when we want to implement a new sensor in our system, we have to adapt the system. Therefore, we divided our system for four modules and constructed based on RT-Middleware.

We prepared two sets of equipment comprised of a camera and a PC that are a kind of unconscious robot in a room, as illustrated by Fig. 6. The users wore a cap and had a glove on their dominant hand. The unconscious robots track the cap, the glove, and the robot's markers. For tracking, we used iSpace, open source software that was developed in our laboratory for tracking objects with RGB information from cameras. 3-dimensional coordinates of the user's head and hand positions are calculated using

DLT method [8][9][10]. We describe DLT method late. The module obtained coordinates of indicated point and calculate the coordinates in picture. The system consists of 4 modules; these modules were developed using OpenRTM-aist-0.2.0. Each module in this system is connected as shown in Fig. 7.

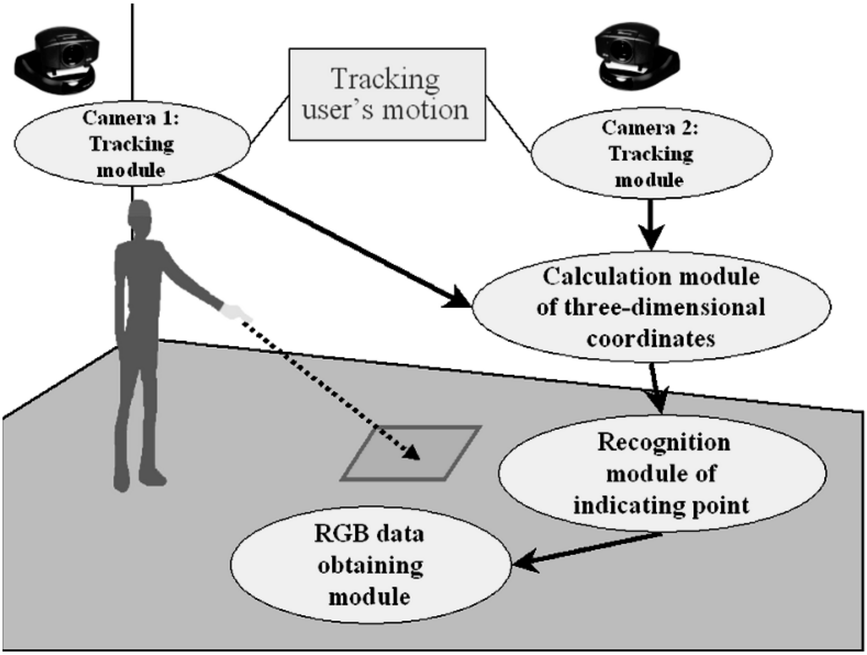

Fig. 6. Recognition of pointing movement and obtaining RGB information; Pointing movement was observed by two cameras. The cameras connected tracking module, which track user's head and hand motion. The tracking data was translated from 2 dimensional coordinates on image to 3 dimensional coordinates in real world. Indicated point on the floor was calculated by recognition module of indicating point.

Tracking module: Tracking module was used with iSpace, which can be track up to 8 objects. This module was interface to RT-modules of iSpace and has an OutPort. iSpace send tracking objects data, object no, 2-dimensional coordinates on image, and find flag as tracking status through this modules from OutPort. In this research, user's head and right hand was tracked.

3-dimensional coordinates calculation module: This module has two InPort and an OutPort. InPort received the 2-dimensional coordinates from tracking modules. DLT method was implemented this module. DLT method has few constraints that must be observed for calculating 3-dimensional coordinates. Generally, when we calculate 3-dimensional coordinates, we use two-dimensional coordinates by picture of two or more cameras. When we use to like this technique, we need to determine on many values called camera constants. Camera constants are, for example, distance between camera device and target object, established angle of cameras, binocular visions of camera lens, and so on. To exactly determine these values is difficult. DLT method has characteristic that not to determine them and to calculate camera constants using six points given 3-dimensional coordinates called control points.

Pointing movement recognition module: This module has an InPort and an OutPort. This module received 3-dimensional coordinates from the above module. In this research, indicated point the intersection point of floor with the line, which is connecting center of eyes with fingertip. The 3-dimensional coordinates of indicated point was output.

RGB data obtaining module: This module has an InPort as obtaining the 3 dimensional coordinates. This module translated the data from above module to 2 dimensional coordinates on image, and obtained RGB data of indicated point on the floor in image.

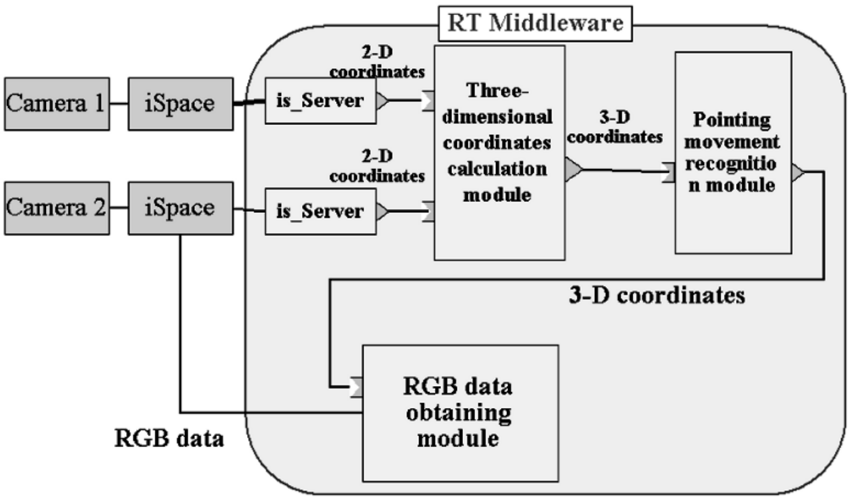

Fig. 7. Modules in this system; this system consists of 4 modules. These modules had InPort or OutPort to connect with other modules.

4.2 Result

We set on the three color papers, green, blue, and red, on the floor and participants pointed them as shown in Fig. 8. The participant pointed out, green, blue, and read continuously. Two cameras (Sony EVI-D30) are established 90 degrees each other in the room. A user wears a cap and has a glove on his right hand as markers for tracking. iSpace is booted on each Computer, and tracking modules and other modules run on Vine3.2. Fig. 9 shows experimental result. RGB data of the point, which was indicated by a user, is highest the color, green, blue, red. The color is intended point by a user every ten seconds.

Fig. 8. Experiment scenery; the participant pointed out the three color paper on the floor.

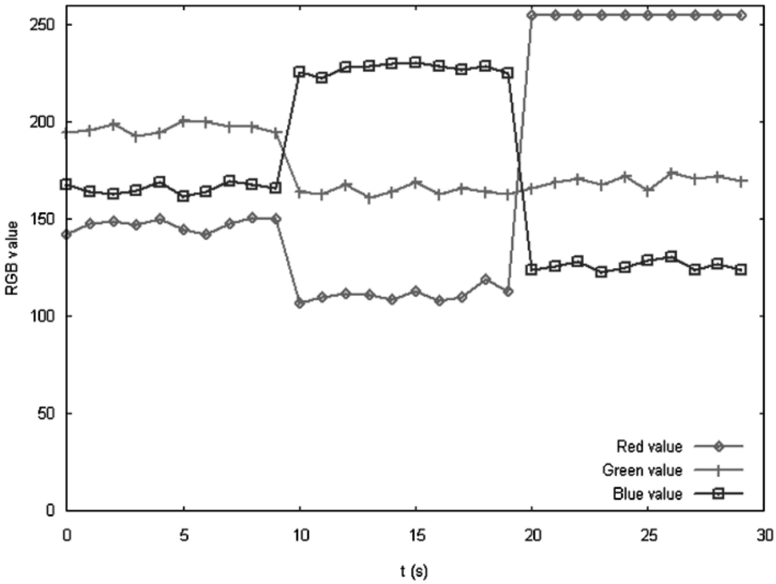

Fig. 9. Obtained RGB data. The graph shows RGB data of indicated point each sec. Each pointing movement is 10 sec approximately.

Conclusion

We describe "Humatronics" that a system understands a human and constructed symmetrical interaction. Additionally, the systems form an intelligent community for supporting human seamlessly. To realize humatronics, we showed RT-Middleware. RT-Middleware supports a robot integration using various sensors, tools and so on.

We focused on gesture interaction and developed a system, which recognize a user's pointing movement and obtained RGB information of an object using RT-Middleware. The system consisted of 4 components. Each component can be connect/disconnect on RTC-Link, which can be monitor components. Therefore, we improve the system on individual components easily. Each component will be reused when other system developed.

Step toward natural communication between human and robot, "Humatronics" is one of the important solutions. RT-Middleware supports not only an integration of robot but also construction a new system based on humatronics.

Acknowledgements

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A Fuzzy Way to Measure Quality of Work in a Multidimensional Perspective

Tindara Addabbo*, Gisella Facchinetti*,
Giovanni Mastroleo**, Giovanni Solinas*

*Università di Modena e Reggio Emilia; Dipartimento di Economia Politica
**Università della Calabria, Dipartimento di Scienze Aziendali
e-mail: addabbo.tindara@unimore.it, facchinetti.gisella@unimore.it,
mastroleo@unical.it; solinas.giovanni@unimore.it

Abstract: This paper focuses on the definition and measurement of quality of work (QL) by using a multidimensional approach, based on fuzzy logic. The multidimensional nature of quality of work has been widely acknowledged in economic and sociological literature and attempts at measuring its different dimensions can be found at European level in the work carried out by the European Foundation for the Improvement of living and working conditions. The European Commission and the International Labour Office have also identified different dimensions for quality of work and proposed new indicators to measure them. In this paper an attempt is made to maintain the complexity of the quality of work concept by using a technique that allows measurement without introducing too strong assumptions and makes the rules for judging the different dimensions of QL and their interactions explicit.

Introduction

The crucial role played by work in an individual's life has been widely stressed in the literature. In the words of Gallino (1993):

"Work produces an important share of material and immaterial culture, by greatly increasing the distance between human beings and all other species […]. By intervening in the natural environment and in the artificial environment, made of culture, work continuously changes human living conditions and therefore can be considered as one of the main agents of social evolution. [It can establish] social relations amongst people that materialize in the building of collectivity, groups, organizations characterized by different forms of cooperation, collaboration and integration. [In so doing] by requiring that everyone cooperates with others not by ideological persuasion but by an intrinsic need, work confers direction, aim, identity on individual life" (Gallino, 1993, p. 396, our trans.).

Hence work alters the environment, the characteristics of artefacts produced, and the very relations among persons. From this derives also the multidimensional character of the notion of quality of work.

More recently the multidimensional nature of quality of work has been widely acknowledged, as is visible in the research work carried out by the *European*

Foundation for the Improvement of living and working conditions (Merllié and Paoli 2001); the European Commission and the International Labour Office, too, have identified different dimensions for quality of work and proposed new indicators to measure them. (EC, 2001; ILO, 2003). Not only earnings but also other dimensions (like for instance safety at work, social protection, type of job contracts) appear relevant in an extended definition of quality of work. The literature has not only addressed the importance of extending the definition of quality of work to other than monetary dimensions, but has also dealt with questions regarding the existence of compensating differentials amongst the different elements that compose the quality (like for instance whether a lower paid job is characterized by better workplace relations or by safer work and if these elements compensate for the lower wage). If, conversely, the differentials are not such as to compensate — as occurs in the segmented labour markets — it becomes important to have available instruments that enable understanding (and measurement) as to which jobs (in terms of position, type of contract) and in which contexts (industry, type of enterprise, regional area) jobs characterized by different quality are concentrated, and whether there are individual and family characteristics more correlated to the risk of finding oneself in jobs or workplaces that can be defined as low quality.

In this paper we deal with the identification of the dimensions relevant to defining quality of work and the building of a system that accounts for different indicators of these dimensions.

The paper is the first result of an interdisciplinary partnership, between researchers in different disciplines (economists, sociologists, mathematicians) sharing a common view: since living and working conditions are intrinsically multidimensional and mediated by human interpretation and perceptions, their quantification is not well achieved by classical mathematics or statistics. Therefore the group used techniques able to tolerate vagueness and imprecision and capable of capturing the complex interrelated dimensions of quality of work according to individual perceptions.

2. Quality of work

In working on the scheme originally proposed by Gallino, we took into account six different dimensions that are defined by the combination of a relevant number of indicators and elementary variables. Each dimension allows one to analyse how, by starting from individual perception by the worker, work matches and sometimes comes into conflict with individuals' specific targets and needs. Work is of a high quality if according to Gallino every analytical dimension taken into account "shows properties aimed at significantly satisfying the corresponding needs" (Gallino, 1993, p. 393, our trans.). It is difficult to establish a ranking amongst the different dimensions and every dimension is involved in the determination of quality of work with the same weight.

The different dimensions that we will include in the definition of the quality of work are:

- Control dimension (Control): relation with colleagues, relation with management/entrepreneur, autonomy in managing working rhythms, possibility of direct agreement with colleagues.
- Economic dimension (EconomDim). In this dimension we consider earnings, seniority, job security, social insurance, profit sharing, wage, career perspectives and parental leaves and protection.
- Ergonomic dimension (ErgonDim): work environment (individual space, smokes and fumes, dust) pace and intensity, cognitive effort and stress.
- Complexity dimension (JobComplex): acknowledgment of one's capabilities, job variety and richness, effort required, training.
- Social dimension (SocialDim): In this dimension we include elements connected to others' esteem, acknowledgment of professional abilities, career perspectives, sharing firm's decision, work life satisfaction and job satisfaction.
- Work life balance (WorkLiBal): includes maternity protection, parental leaves, management and availability of paid holidays, participation of employees in management of working hours distribution and shifts, availability of family- friendly policies.

These different dimensions are the final inputs (built by means of intermediate systems that combine the elementary elements by giving different weights to each variable) of a fuzzy expert system and, for the reasons given above, every dimension in the model has the same weight.

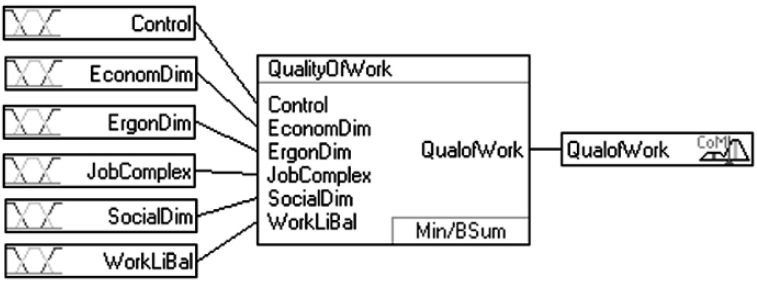

Fig. 1. Quality of work.

In turn, every dimension is the output of a fuzzy system. The sample of firms and the technique used to read the data enable one to understand how the quality of the workplace is constituted in the context of specific firms and how its elements, workplace relations and organizing structures can change with regard to the type of firm and the product market conditions.

3. Economic Dimension

In this paper we enter into details of the "Economic Dimension" system. The economic dimension is the output of these eleven inputs:

Table 1. Input variables

A01	Earnings
A02	Earnings related to seniority
A03	Job security
A04	Social insurance
A05	Profit sharing schemes
A06	Firm's pay differentials schemes
A07	Fringe benefits
A08	Learning and training
A09	Maternity protection
A10	Parental leaves
B07	Career perspectives

Each one of these elements refers to the worker's subjective perception of her job's characteristics with reference to the above elements. Fig. 2 shows the structure of the system.

In the structure of the fuzzy system some intermediate variables appear:

- 1st level of intermediate variables: career perspectives, earning level, earning variability, social protection and parental protection.
- 2nd level of intermediate variables: earnings and protections.

These are variables obtained by the partial aggregation of initial inputs, useful for better understanding of the evolution of the system. They may be defuzzified to obtain a partial output of the variables involved.

In relating input with intermediate variables and output, Fig. 2 shows the type of partition used. In building the economic dimension the elements that we have considered are: career, earnings and security.

- Career (1st level intermediate variable) synthesizes the opportunities and perspectives that are perceived by the individual together with training (input variables A08, B07).
- Earnings (2nd level intermediate variable) show workers' perception of gross income and wage differentials (1st level intermediate variables). Earnings include also fringe benefits (input variables A01, A07). Share of earning connected to seniority and to types of workers participation in firms' results as well as individual earnings differentials (input variables A02, A05, A06).
- 'Security' system (intermediate variable 2nd level) synthesizes both elements of stability and grant of job (input variable A03), and social security (input A04) and parental leaves (input variables A09, A10).

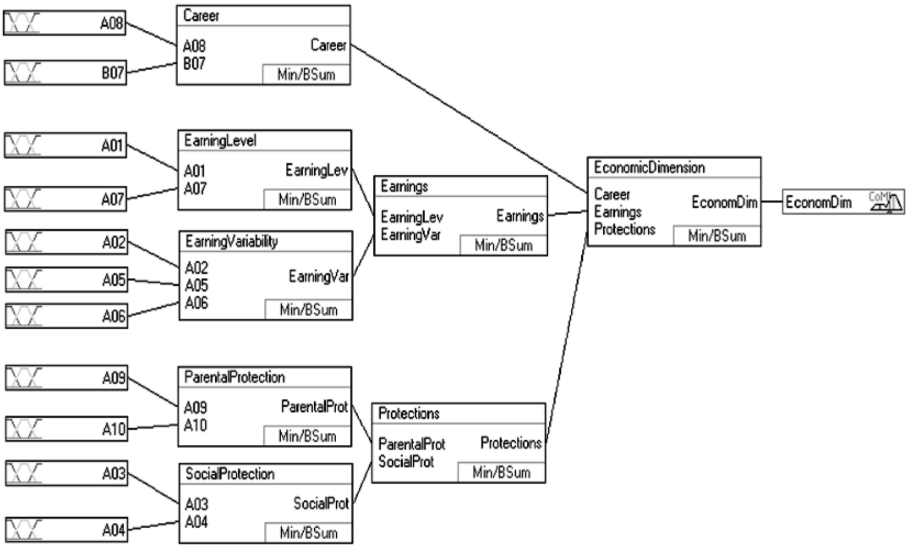

Fig. 2. System layout

In the analytical framework proposed the economic dimension will be considered of high quality if, according to the worker, it will be able to satisfy his needs, in terms of earnings, career and job stability. To close the system we had to specify weights. Weights range from 1 to 2. In creating intermediate variables of level 1 we have given more weight to the opportunities and perspectives felt by the employee than to the training content of the work. In defining earnings we have given more weight to the variable that refers to the level of gross earnings rather than to fringe benefits. We have given more weight to seniority in evaluating the dimension connected to wage variability. Variables on the job stability have a higher weight. Passing from 1st level variables to 2nd level variables we have given a greater weight to earnings level and social security than to earnings variation and parental protection.

All the inputs are described by three linguistic attributes low, medium, high:

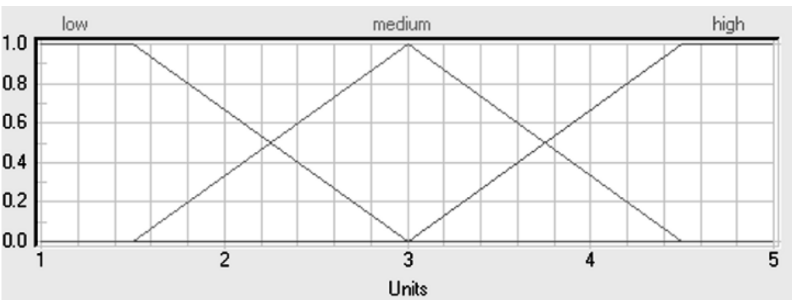

Fig. 3. Input variables layout

The first level of intermediate variables is described by five linguistic attributes like in the figure below that describes the Career variable.

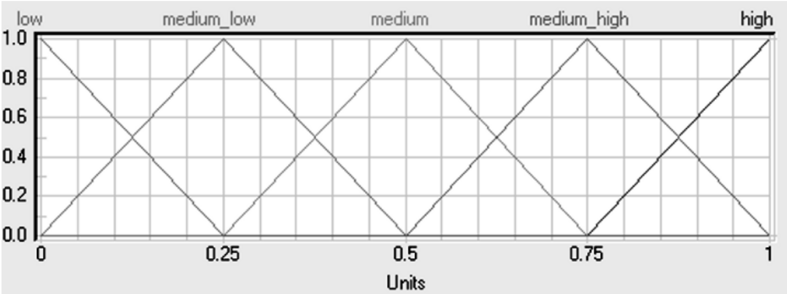

Fig. 4. First level of intermediate variables layout

The second level of intermediate variables are described by seven linguistic attributes like in the figure below that describes the variable earnings:

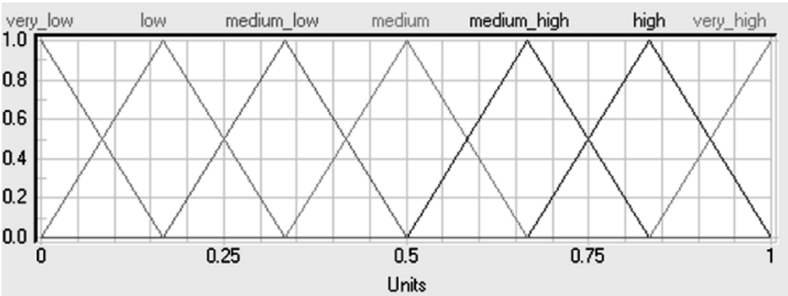

Fig. 5. Second level of intermediate variables layout

The "economic dimension" output is described by eleven linguistic attributes:

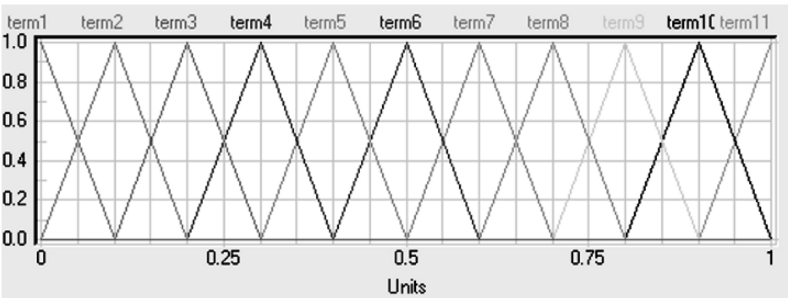

Fig. 6. Output layout

The system presents eight rule blocks for a total of 274 rules.

The rule blocks contain the control strategy of a fuzzy logic system. Each rule block confines all rules for the same context. A context is defined by the same input and output variables of the rules. The ‘if’ part of the rules describes the situation, for which the rules are designed. The ‘then’ part describes the response of the fuzzy system in this situation. The processing of the rules starts by calculating the ‘if’ part. The operator type of the rule block determines which method is used. We choose the MIN t-norm as AND operator.

Table 2. *Rules of the Rule Block “Career”*

IF		THEN
A08	B07	Career
low	low	low
low	medium	medium_low
low	high	medium
medium	low	medium_low
medium	medium	medium
medium	high	medium_high
high	low	medium
high	medium	medium_high
high	high	high

The fuzzy composition eventually combines different rules to one conclusion. We choose the Bounded Sum as fuzzy operator for the aggregation method of the result to enable all firing rules to be evaluated.

Different methods can be used for the defuzzification, resulting either in the ‘most plausible result’ or the ‘best compromise’. We choose a ‘best compromise’ method like CoA (Center of Area).

Results

The sample that we used to test the model is made up of employees working in firms of different dimension and belonging to different industries (mechanical, building, services, food industry, information technology, textiles) in the same area (Modena) having a common economic and welfare system. We have tested our expert system with 719 records of employees of these firms. The statistics referred to in this Section must be considered as referring to the sample of firms not randomly selected from the population of firms in Modena. Each firm was analysed to reconstruct its structure and dimensions connected to quality of work, and it is possible to read the results of the output of the system both by firm and by the whole sample constructed. Deeper analyses of the results are currently in progress to match the richness of the fuzzy expert system outcome with the richness of case studies.

In Table 3 we report the value of the variables that compose the analysed dimension and some individual characteristics referring to the worst cases in terms of the economic dimension.[1] Amongst 10 employees at the bottom of the distribution of the economic dimension 9 are women, 5 were born in Southern Italy and 5 are in non-standard employment. They fare very badly in each component of the dimension, and a good degree of satisfaction shown by some of them in maternity protection is not sufficient to increase the value of the whole output of this dimension. By comparing the output of the fuzzy expert system with the mean of the different variables involved in the measurement of this dimension one may find that standard techniques tend to overestimate (with respect to the fuzzy expert output) the value of the economic dimension. By neglecting the connection existing with different dimensions and by simply summing up each indicator one tends to overestimate quality of work.

Table 3. Individual records ordered by the output of the economic dimension: last 10 according to output of economic dimension.

ID	Firm	1 Sex	2 Age	3 Class	4 Place of birth	5 Degree	6a Qualification	A01_Earnings	A02_Earnings related to seniority	A03_Job security	A04_Social insurance	A05_Profit sharing schemes	A06_Firm's pay differentials	A07_Fringe benefits	A08_Capabilities acknowledge	A09_Maternity protection	A10_Parental leaves	B07_Career perspectives	**EconomDim**	**Average**
175	2	0	29	1	6	5	3	1	1	1	1	1	1	1	1	2	1	1	**0,000**	**0,023**
10	3	0	31	2	2	6	7	1	1	1	1	1	1	1	1	1	1	1	**0,000**	**0,000**
18	3	0	30	1	1	6	7	1	1	1	1	1	1	1	1	1	1	1	**0,000**	**0,000**
259	2	0	25	1	6	4	1	1	2	2	1	1	1	1	1	1	3	1	**0,033**	**0,091**
17	3	0	.	4	1	2	3	1	1	1	1	2	1	2,72	1	3	2	1	**0,033**	**0,130**
19	3	0	28	1	3	5	7	1	1	1	1	1	1	1	2	1	1	1	**0,033**	**0,023**
258	2	0	44	3	6	3	1	1	1	1	1	1	1	1	1	4	2	1	**0,060**	**0,091**
14	6	1	36	2	1	4	3	2	2	3	1	1	1	2	1	2,22	3	1	**0,060**	**0,187**
232	2	0	29	1	6	5	3	1	1	1	1	2	1	1	1	4	1	1	**0,075**	**0,091**
90	2	0	42	3	6	2	7	2	2	3	2	1	1	3	1	3	3	1	**0,083**	**0,250**

In Table 4 we report the value of the variables connected to the best cases according to the ranking of the economic dimension. Women and men are equally present in this group. There is a prevalence of workers with more than 35, with high specialization and seniority; 4 of them are in apical positions. In this case the distance between the fuzzy output and the arithmetic mean of each indicator is lower than in the bottom end of the economic dimension distribution. [A deeper analysis on the distance of the two different measures along the distribution and for different groups of workers is required to test the implications of adopting different techniques for measuring the economic dimension.]

[1] Missing values have been replaced by average value for that variable computed for each firm and each job position.

Table 4. Individual records ordered by the output of the economic dimension: first 10 according to output of economic dimension

ID	Firm	1 Sex	2 Age	3 Class	4 Place of birth	5 Degree	6a Qualification	A01_Earnings	A02_Earnings related to seniority	A03_Job security	A04_Social insurance	A05_Profit sharing schemes	A06_Firm's pay differentials	A07_Fringe benefits	A08_Capabilities acknowledge	A09_Maternity protection	A10_Parental leaves	B07_Career perspectives	**EconomDim**	**Average**
110	2	0	40	2	1	3	7	5	5	5	5	5	5	5	5	5	5	5	**1,000**	**1,000**
51	5	1	50	3	6	2	5	5	5	5	5	5	5	5	5	5	5	5	**1,000**	**1,000**
23	5	1	57	4	6	4	5	5	5	5	5	5	5	5	5	5	5	5	**1,000**	**1,000**
24	1	1	0	2	1	4	3	5	4	5	5	5	4	5	5	5	5	5	**0,940**	**0,955**
152	5	1	54	4	6	4	5	5	5	5	4	4	5	5	5	2,56	4	5	**0,917**	**0,876**
32	12	0	39	2	1	2	1	5	5	5	5	1	1	5	5	5	5	5	**0,900**	**0,818**
96	2	0	35	2	1	5	3	5	4	5	5	5	4	4	5	5	5	4	**0,900**	**0,909**
67	1	0	45	3	1	4	6	4	3	4	5	4	2,67	5	5	5	5	5	**0,875**	**0,833**
145	5	1	65	4	7	1	2	5	5	5	5	5	5	5	4	4	4	4	**0,875**	**0,909**
99	23	0	21	.	3	2	1	5	5	5	5	5	5	2	4	5	5	5	**0,867**	**0,909**

Descriptive analyses on the distribution of quality of work and its dimensions across the sample of firms analysed show a high degree of variation.

Table 5. Correlation coefficients amongst the different dimensions of quality of work

Dimensions*	Complexity	Work-life balance.	Economic	Social	Ergonomic	Control	Quality of work
Complexity	1						
Work-life balance	0.4387	1					
Economic	0.6248	0.481	1				
Social	0.6402	0.6163	0.6662	1			
Ergonomic	0.3696	0.4609	0.2942	0.4117	1		
Control	0.6408	0.5271	0.4764	0.8389	0.4089	1	
Quality of work	0.7601	0.7146	0.7174	0.8524	0.6194	0.8027	1

** For dimensions' definitions see section 2*

As Table 5 shows, the different dimensions (that have been measured by separate intermediate systems) are positively related and the final output of the system (variable quality of work) is positively related to all the dimensions, the correlation coefficients being high with respect to social and control dimensions. As far as the dimension that is central to this paper (the economic dimension) is concerned, the results of this correlation analysis show a higher correlation of the economic dimension with the complexity dimension and with the social dimension whereas the correlation with the ergonomic dimension is weaker.

This is not consistent with the literature on compensating differentials amongst the different elements that compose the quality of work and is more consistent with the existence of segmented labour markets.

Conclusions

In providing a synthesis of each dimension of quality of work, the fuzzy expert system that we have proposed here turns out to be a more flexible and powerful tool than traditional techniques used to define quality of work. The fuzzy expert system allows one to consider the relation amongst elementary variables/indicators and, therefore, amongst the analytical dimensions that we have defined, weighting and ranking them according to a system of rules that, step by step, can incorporate status of art, theoretical framework and researchers' views. The expert system can be used both to study individual cases, or particular types of work or to provide a comparative analysis of different labour markets.

The system allows one to investigate when a trade-off between the different dimensions arises. Traditional discussion on the compensating differentials between monetary and non-monetary characteristics and on segmented labour markets can therefore be tackled on completely different grounds. This technique proves to be superior to other techniques since it enables one to account for the interrelations amongst the different dimensions (it also allows the same variable to enter in different dimensions with different weight), to specify rules of judgement on the meaning of the values assumed by different variables and to relate the output of the system with individual characteristics (age, gender, education, work experience), job characteristics and characteristics of the firm (size, economic situation of the firm's good market, union presence). In other words, the system provides an output that captures labour market segmentation and could detect the dimensions, that endogenously contribute to determine segmentation.