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MODEL-BASED DESCRIPTION OF HUMAN BODY MOTIONS FOR ERGONOMICS EVALUATION

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Abstract: This paper presents modeling of Working Process and Working Simulation factory works. I focus on an example work (motion), its actual work(motion) and reference between them. An example work and its actual work can be analyzed and described as a sequence of atomic action. In order to describe workers' motion, some concepts of Atomic Unit, Model Events and Mediator are introduced. By using these concepts, we can analyze a workers' action and evaluate their works. Also, we consider it as a possible way for unifying all the data used in various applications (CAD/CAM, etc) during the design process and evaluating all subsystems in a virtual Factory.

Key words: Motion Modeling, Info-Ergonomics, Model Event, Mediator

1. INTRODUCTION

Recently some new applications supporting the designing process of a virtual factory, simulating its work are gaining popularity in areas like process planning and work scheduling and any other evaluation. In addition to the CG, they involve many new other types of data, such as video and X-ray images, sensing information, etc. High complexity of those data causes a lot of difficulties to the researchers and developers. Here we must point out two problems which should be methods for solved for the future development. First, as those applications have been using mainly application-oriented data, methods for sharing data with other applications are quite difficult and very often --- impossible. In our opinion, a flexible automation system requires data about a given product to be used in all applications. Second, we think that human factors are usually overlooked or underestimated in eco-factory. Human labor has an important role in the manufacturing process. It is examined from the viewpoint of industrial engineering, ergonomics, etc. and results are used in product planning, working analysis, and work environment design. But aspects like efficiency of works and comfort of the workers are not explored completely.

As a promising solution to the above problems we have proposed the use of Real World Database (RWDB) and ergonomic simulation[1]. RWDB is able to capture various types of data, namely characters, video images, 3D graphics, and shapes of 3D objects. We call all those *Real world data*. The data of all types are unified and stored in a Multimedia Database (MMDB).

On the other hand, we consider it necessary to focus on human-machine cooperation, especially for employees in the factories and analyze their work evaluation, environment, and amenities against this background. We proposed the human body modeling method from two viewpoints in the framework of Info-Ergonomics Concept[2][3][4]. One proposed modeling method is description of precise human body and by using the model, motion evaluation system from medical point of view is offered[2]. As the other modeling method, we also introduced mediator-based modeling of workers' (body/structure and motion) in a factory. The mediator-based model is transformed from measured data, and standardized to common models of body/structure and motion. However, from another point of view, measured data from real world have low-level semantics such as a worker's hand is touching to drill[3][4].

In this paper, we offer a model for analyzing employee's work evaluation and using the results in the manufacturing process design. We also propose a methodology for modeling of the human body and its motions in order to store and query them on a database. For storing all available data about human motion, we need a precise human body model as well as method for representing its motions.

2. DESCRIPTION OF HIERARCHICAL PROCESS AND ACTUAL WORK

In factory work, a process is designed with hierarchical structure divided into such classes of a process, element works, and element operations[5]t is usually carried as shown in Figure 1. An aim of such design is the increase of efficiency by schematizing the workers' work, and making manuals for them.

From a worker's point of view, a process and element of work have targets of each work. It can be called intention of the work. However, in actual work, even the intention is the same, the sequence of work operation changes with individual, time, degrees of skill and/or fatigue, etc. The sequence is also different from the process as it was design to be performed. For instance, if two products are manufactured simultaneously in parallel in the same process, the efficiency of work can be increased. Identically a difference can appear between the experts and the unskilled operators. Only an individual evaluation of the difference to process can support an evaluation of this difference in their efficiency and the improvement of the performance of the work (process).

Figure 1 show a concrete example of process hierarchy in a real factory. In this process with ID “B24” is decomposed into five phases, i.e., element works. In the example, the process is dedicated to the assembling of a transmission box named “kbt024” in this factory. Its first element work is to bring the material object (named “kbt024-1” which is an exterior part of “kbt024”) and to set it on the workbench. The second element work is to put a gear into the material. Then the third is to fix it up, the forth is to verify and to confirm mobility, and the fifth is to put the complete object in a specific place. Each element work is described via some typical operation, i.e., element operation.

From another view, a designer can design a process hierarchical as a manual like Figure 1. As opposed to this, in actual works, all workers do not work in the same operation. For example, right side of Figure 2 shows an example of element operation description for the element work “B24-3” of left side of Figure1. In the example, stretching arm to pick up a screw bolt from the box of screws, twisting the bolts, and pushing an electric screwdriver to tighten the bolts are described as element operations. It is thought that this process description is the general description applied by each worker. It is what described the intention of work to each worker.

In order to compare Workers’ motion in the same elementary operation and evaluate their actions, some methods which can describe actions different from designed elementary operation (action standardization) and difference in workers’ action in same elementary operation (action description and modeling) are required. For description and modeling of action, we introduce Event Graph, which actualize comparing motions in same action by querying motions of a part of workers’ body. On the other hand, for schematization of workers’ motion, we introduce Mediator based modeling, which actualize comparing actions in same operation by querying kinds of operation.

3. SCHEMATIZATION OF FACTORY WORKERS BEHAVIOUR

3.1 Atomic Units

Here we define the basic elements in our model. We introduce atomic units as simple primitives, which at the same time contain enough information for deriving the higher-level semantics.

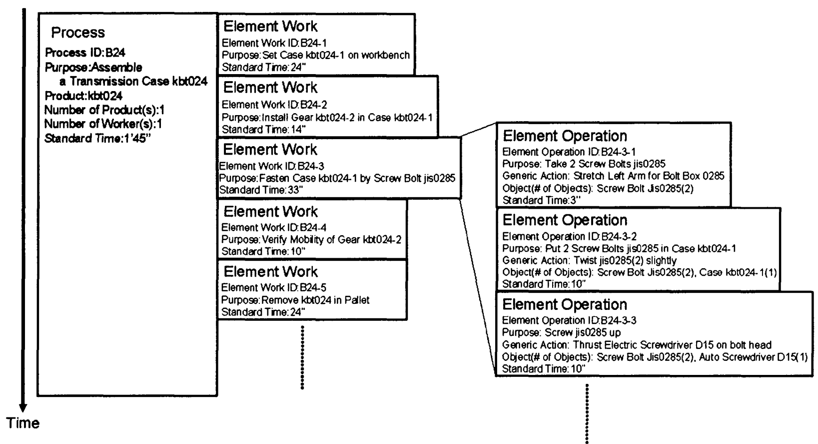

Figure 1. Example of Hierarchy of process, Element Work and Element Operation

Definition: We call an atomic unit (or AU) the tuple (*T, P, O, S, R*) where *T* is a time instant, *P* is a point in 3D space, *O* is a 3D object located in point *P* at the time instant *T*, *S* is a subject in relation *R* with the object *O*.

R is a relation that can be observed and detected in a given point of time, independently from the preceding and succeeding time instances. Also *R* is independent from the view point in the 3D space. Examples of such relations are "touches", "is inside", "is close to", etc. Right part of Figure 2 shows an example of an AU instance. Following from the definition, AUs don't have temporal duration. Those basic atomic Unit of motions can be detected automatically by analyzing video image[6]. The reason for choosing such representation is that we assume all media to be in digital format, therefore (in case of time-dependent media) we have some sampling rate with clearly defined time instants and they determine the highest resolution at which media can be observed. In addition, the existing methods for automatic detection of video features are mainly frame-based. Since evolving in time is an essential characteristic of events, AUs cannot express it and can be regarded as semantics-free in the context of event semantics. In some cases, some of the components of an AU instance may be omitted. For instance, if we want to specify just the existence of a subject at a given point of time and at a given location, then no values need to be specified for the object and relation components.

3.2 Event Graph

The basic idea of introducing event graph is to form a part of the database that contains knowledge about the typical features of action and to use it for extracting action instances from the raw video data on the basis of the detected AUs. An event graph is defined as a directed graph $G_{ME} = \{N, TOR, TDR\}$, where

$$N = \{N = i\},\ N_i \in \{S_i \times O_i \times R_i\}$$
$$TOR \subseteq \{N_i \times N_j\}$$
$$TDR \subseteq \{N_i \times N_j\}$$

N represents a set of nodes. Each node consists of a subject S_i object O_i, and relation R_i, between them. The meaning they represent is similar to the AUs, but in case of event graph nodes, subject and object are generalized and refer to a class of subjects/objects in the AU's meaning. For instance, while in case of an event graph node an example of subject value can be 'Auto Screwdriver' in the AU it would be 'Auto Screwdriver D15(1)'

TOR is a set of one-way edges, representing temporal relations between nodes. The tuple $<N_i, N_i>$, representing the edge from N_i to *Nj* means that is before Nj in time. If both $< N_i, N_j >$ and $< N_j, N_i >$ are presented, that means N_i and Nj are simultaneous. Since nodes, like AUs, are instantaneous, all possible temporal relations between them are 'before' 'after' and 'simultaneous'. *TDR* is a set of two-way edges representing temporal distance between nodes. In many cases it is not enough to define only the order of AUs, since the time between their occurrence is important, too. Temporal distance relations are labeled with minimum and maximum time limit values expressing these requirements. *TOR* and *TDR* are semantically independent. It is possible, for instance, to have some temporal distance requirement without relation to the order in which AUs are happening. An example of event graph is shown in Figure 2. It represents the action "screwing of a screw", which consist of taking a screw from the box with screws, fixing the screw in some position, and then applying the screwdriver in the same position. Here we assume that if the worker's hand is inside the box of screws, then a screw is taken. Also, the requirement for a very small temporal distance between the second and the third node represents approximately the moment when the screw is released.

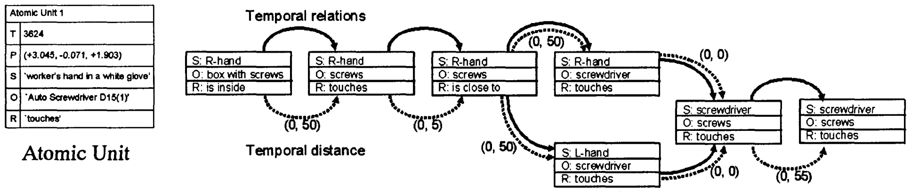

Figure 2. Example of Atomic Unit and Event Graph

3.3 Correspondence between Atomic Units and Event Graph

We introduce here action instances in order to represent the correspondence between AUs and event graph. An event instance represents the occurrence of an action in the real world and its order/causality is expressed by some event graph. The event instance can be visualized by playing the respective part of the video data or by CG Simulation.

Each action instance is determined by a set of AUs in the following way. Each event graph node corresponds to exactly one AU from the set that matches the node components and satisfied all temporal relations included in the event graph. Matching between AU and event graph node holds if and only if: (i) the AU's subject/object values are elements of the class, represented by the respective subject/object values of the node: (ii) both the AU and event graph node have the same value of their relation component. Temporal relations can be verified easily by using the values of time and place components of AUs. Action instances develop in time and occupy some time interval that includes all AUs involved, i.e. the temporal closure of all time instants. There may be various algorithms for calculating it, depending on the specifics of the application field, but the topic is beyond the scope of this paper.

4. SEMANTICAL CORRESPONDENCE BETWEEN EVENT GRAPH AND WORKERS' MOTION

In order to descript a worker's body/motion data, and to store all data into database, we offered "Mediator" Concept about human body/motion in our previous research[3][4]. Our Mediator-based modeling is a model-based modeling which has link with intensions of action, which we call it 'Hub', and actual motion which are detectable from video images. In this section, we mention reference between Mediator data and event graph. We suppose the human's motions are sequence of postures, consequently we define the human's Motion Mediator as collection of characteristic internal postures, namely, relative time and joint angle(value) of each Shape/Structure Mediator in this time, in which characteristic internal postures of a motion of a human. On the other hand, Motion Mediator is made for each motion of a human, and represent differences each motion of a human.

A Hub is the information for expressing the essence in common and standardizing it about human motions. *Motion Hub* is expressed with the intermediate posture along which it surely passes in case it appears in common with the motion is performed using the mutual position relation of the human body parts in shape and a structure Hub.

It can be said that the Hub shows the minimum "item" for describing the characteristics about shape, structure and motion of the human. When Motion Mediator is created from a Motion Hub, it is important what intermediate postures are chosen as a Motion Hub. At a present stage, the designer has to design an intermediate posture for every motion. For example, a characteristic intermediate posture sequence which generally raises Motion which tightens a screw with a drill in a factory can be show as follows.

The postures of tightening a screw using a drill:

- I: Starting Motion - The person is touching the drill
- II: Motion
  - II-1: The person located the drill at the tip of a screw.
  - II-2: The person finished tightening a screw with a drill
  - II-3: Next II-1, repeat sometimes
- III: Ending Motion -- T the person turned the drill.

Generally, it is very difficult to extract human's posture and its semantics precisely from videos by using stereo video cameras etc. But, if it restricts to the specific postures specified by the Motion Hub, the analysis of postures (joint angles) can be carry out easily by means of detection of corresponding points of characteristic points on the human body. Therefore, the Motion Mediator can be created from the Motion Hub. Figure 3 shows a relation of Hub-Mediator-Real World data about a motion of tightening a screw using a drill of worker in factories. The posture sequence about Hub, Mediator and Real World Data is shown in Figure 3, which displays joint value data of motion for convenience as a shape of a posture.

5. CONCLUSION

In the present paper we have reported the description method of detectable factory workers' action in the framework of Info-Ergonomics. For the purpose of representing their actions precisely, we have introduced

Atomic Unit, Event Graph Concept and Mediator Concept. By using these concepts, we can compare their motions and evaluate it. Such approach will benefit to Manufacturing Process Design.

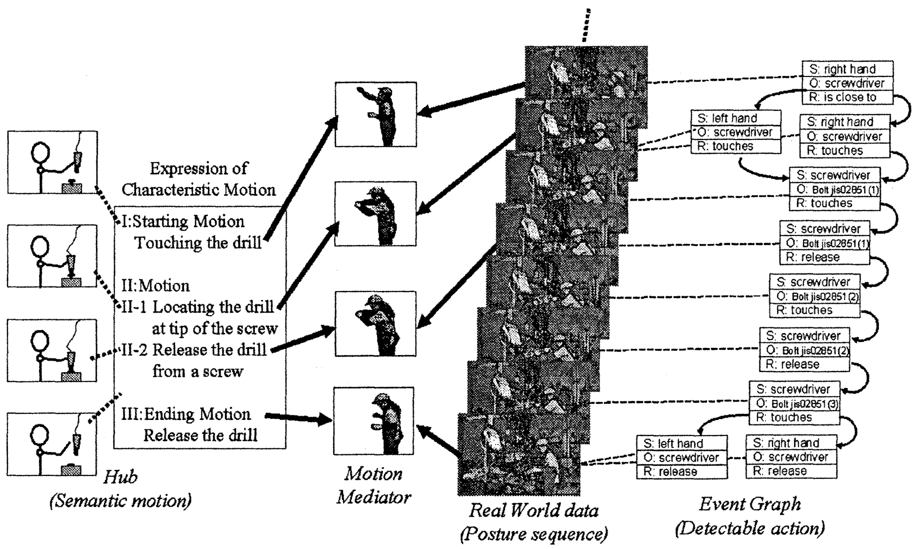

Figure 3. Correspondence of Motion and Event Graph

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