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Ontological Framework of Arm Gesture Information for the Human Upper Body

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Abstract. In the research of the human motion analysis, the characteristic movements of the human upper body are intensively investigated for many applications such as sign language recognition, robot control and gait analysis. The human upper body consists of many body parts such as both arms including fingers, facials and head movements. Previously, many researches proposed various sensors to record arm movements and the acquired data are used to train the computer understand the behavioral motion of arms movements by using various algorithmic approaches. However, the current challenge is to increase the knowledge level of the computational systems to recognize gestural information containing in arm movements. The objective of this paper is to construct and derive the arm movement's model based on the conceptual of ontology. The gestural information is investigated from characteristic features of arm movements. The knowledge of the computational systems about gestural information is developed by describing the characteristic features of arm movements in the form of the ontological framework. The ontological framework is defined as a structure containing characteristic features placed in mathematical order and has the relationship among them. Based on the mathematical model as proposed in this paper, the ontology framework could be used to describe knowledge of the arm gesture and could recognize it with a higher accuracy.

Keywords: Arm Gesture, Ontology, Gesture Database.

1 Introduction

In computer science and information science, an ontology formally represents knowledge as a set of concepts within a domain, and the relationships between those concepts. It can be used to reason about the entities within that domain and may be used to describe the domain. In theory, an ontology is a formal, explicit specification of a shared conceptualisation. An ontology renders shared vocabulary and taxonomy which models a domain with the definition of objects and concepts and their properties and relations. Ontologies are the structural frameworks for organizing information and could be used in artificial intelligence, the Semantic Web, systems engineering, software engineering, biomedical informatics, library science, enterprise bookmarking, and information architecture as a form of knowledge representation about the world or some part of it [1,2,3,4]. However, nowdays, many researchers give efforts on the development of Semantic web, especially researches in the fields of computer science. More researches on ontology, which are related to engineering should be done by scientists from the field of engineering. The creation of domain ontologies is also fundamental to the definition and use of an enterprise architecture framework.

Ontology engineering in computer science and information science is a new field, which studies the methods and methodologies for building ontologies. Nowdays, many researchers trying to use the conceptual of ontology in engineering. In the other hand, researchers and engineers work very hard to employ the conceptual of ontology toward engineering [1,2,3,4]. Researchers believes ontology could solve occlusion problem in image processing by combining two conceptuals, which are mereology and mereotopolog [5-7]. R. Mizoguchi et al. published many results on the application of ontology in engineering such as in power plant, nuclear, biofuel Problems, medical domain and Artificial Intelligence (AI) [8-12].

In this research, the concept of ontology is employed for the purpose of recognizing arm gestures. To investigate the framework, 5 geometrical gesture data are used. In the conventional approaches, all gestures are stored in the database, and each gesture is presented by several features such as arm trajectories, hand shapes and hand motions [13-15], however, the features have no relation among them. By using ontological approach all features are described based on topological relation such as part of relation, boundaries and similarity measures.

The outline of this research paper is as follows. Section 1 describes the background of the research. Section 2 discusses the related researches to the research projects. Section 3 discusses the acquisition of geometrical gesture and section 4 discusses the pre-processing of the signals. Section 5 discusses the proposed ontological framework of the arm gesture and section 6 describes the recognition of arm gesture. The conclusions of this research is discussed in Section 7.

2 Related Researches

Previously, several approaches to recognize arm motions were proposed for the implementation in the various digital applications [13,14,15,17]. Arm movements contain many physical quantities, and modelling algorithms are required to form mathematical quantities from the available physical data [18,19]. Furthermore, movements data obtained through the tracking devices are low-level information and it needs to be combined to produce higher-level semantic features information, which can be used to investigate various motion features [20]. Once arm movements data have been collected through tracking devices, it needs to be analyzed for the systems to understand the behavior of the characteristic arm features through various computational approaches. The conventional approach to model arm movements is by using deterministic approach, which is based on artificial intelligence methods [21,22,23,24]. However, the performance of the proposed arm movement's model could be improved by using a knowledge-based approach. In this paper, an ontology approach is proposed to model the arm gesture information. Ontology is a structural framework for organizing information as a form of knowledge representation and is used in artificial intelligence, the semantic web, systems engineering, software engineering, bioinformatics, library science and information architecture. At present many researchers employ ontological approach to the development of the semantic web, especially researches in the fields of computer science [1,2,3,4]. The concept of ontology could be expanded to the various applications in the engineering field.

Ontology engineering in computer science and information science is a new research field, which studies the methodology for building the ontology's structure. R. Mizoguchi et. al discuss about the applications of ontology in various engineering fields such as in the power plant, nuclear, bio-fuel problems, medical domain and artificial intelligence (AI) [8,9,10,11,12]. As the applications of ontology in engineering, they developed the ontological mapping systems to monitor the power nuclear plant in Japan. R. Mizoguchi introduces the application of ontology not only in engineering domain, but also many applications in medical domain are proposed [12].

Based on the literature search conducted, the arm movements could be modeled by using the conceptual of ontology. A statistical approach could be used to describe a relationship among characteristic features of arm movements. In the conventional approaches to model arm movements are based on the patterns of characteristic features, which are stored in the database as a reference. The characteristic features are extracted and investigated in the random experiments. However, the recognition performance in term of the accuracy is still lower than the expected, and the most crucial is the systems are not sustained when facing with various environments. The reason is some important characteristic features of arm movements have similar characters. Thus, the conceptual of ontology for describing the ontology framework of arm gesture information is seen possible to overcome the sustainability and accuracy problems of the arm gesture recognition systems.

3 Acquisition of Geometrical Gesture

Qualisys motion capture (MOCAP) was used to capture the movement of the subject's right arm while performing arm gesture. For the purpose of modelling ontological framework, one subject was involved in the experiments. A reflected marker was attached to the subject's right hand and the subject was instructed to perform five geometrical gestures. Fig. 1 shows the environment of the experiment and Fig. 2 shows a set of geometrical gestures used in the experiments **G** = {Round, Square, Diamond, Triangle, Eight}.

Fig. 1. The environment of the data collection experiment.

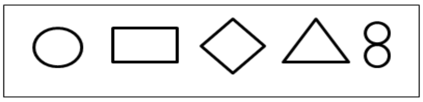

Fig. 2. Five geometrical gestures used in the experiments.

The MOCAP consist of 5 Oqus cameras that are able to capture image with resolution 200 fps to track the movements of the reflective marker attached to the subject's right hand. The MOCAP produces three-dimensional position data of the moving reflective marker x, y and z-exes.

4 Pre-Processing of Arm Gesture Data

Based on the position of a reflective marker, the characteristic features of the arm motion of a subject were computed. Since motion features were time-interval based data, and difficult to differentiate between them because its change according to the speed and the size of the motion. To obtain the distance-interval based data, a resampling algorithm was used [25,26] and by following their approach it is easy to do comparison of data. The resampling result produced 30 resampled points in term of distance, and is also known as reference points of gesture data. The selection of 30 reference points are sufficient for a large amount of data after conducting numerous testing of significant value for resampled points. After the resampling process, these data were normalized in the same scale value. These normalized data were used to design the ontological framework. Fig. 3 shows the gesture data after the normalization process with 30 reference points.

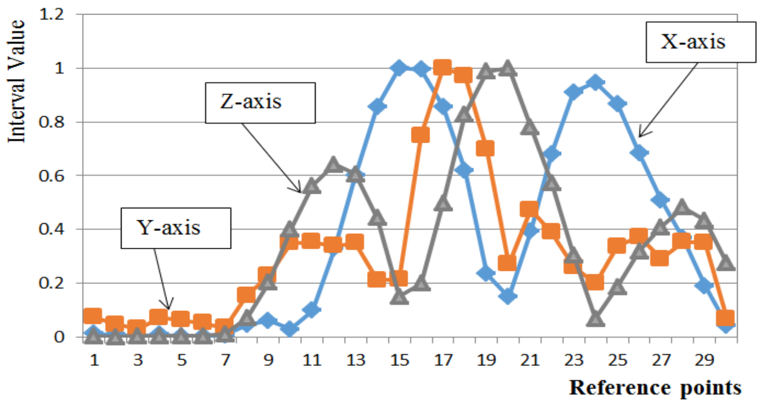

Fig. 3. Resampled point of position data for x, y and z-axes.

5 Ontological Framework of Geometrical Gesture

As discussed in the previous chapter, ontology is the structural frameworks for organizing information, which describes a particular thing or event. Ontology can be described in three domains as mentioned by W. Fang et. al. [27]. These domains are knowledge, attribute and process. In this paper, a knowledge domain is defined as a level that contains the extracted features from the raw arm gesture data. In this domain, a raw data produced by MOCAP systems are resampled and normalized. The attribute is a level that contains several sets of feature that each has similar attribute. Each feature is presented in 30 reference points or resampled points. In the research, the attribute domain contains position ($\boldsymbol{P_G}$), velocity ($\boldsymbol{V_G}$) and acceleration ($\boldsymbol{A_G}$) of the moving marker. **G** is the registered gestures, which are five geometrical gestures {Round, Square, Diamond, Triangle, Eight}. The attribute $\boldsymbol{P_G}$, $\boldsymbol{V_G}$ and $\boldsymbol{A_G}$ are shown in equations 1, 2 and 3. $P_{G,x}$, $P_{G,y}$ and $P_{G,z}$ are the positions of the marker. $V_{G,x}$, $V_{G,y}$ and $V_{G,z}$ are the velocities of the marker. $A_{G,x}$, $A_{G,y}$ and $A_{G,z}$ are the accelerations of the marker in the three-dimensional coordinates space. The number of attributes could be increased by adding more reflective markers to the subject's arm or by using multiple sensors. Moreover, the number of elements in each attribute could be increased by combining them each other for example $P_{G,x}$ & $P_{G,y}$, $P_{G,y}$ & $P_{G,z}$, $P_{G,x}$ & $P_{G,z}$ and $P_{G,x}$ & $P_{G,y}$ & $P_{G,z}$. Similarly, the combination could be determined for $\boldsymbol{V_G}$ and $\boldsymbol{A_G}$.

$$\boldsymbol{P_G} = \{P_{G,x}, P_{G,y}, P_{G,z}\} \tag{1}$$

$$\boldsymbol{V_G} = \{V_{G,x}, V_{G,y}, V_{G,z}\} \tag{2}$$

$$\boldsymbol{A_G} = \{A_{G,x}\ , A_{G,y}, A_{G,z}\} \tag{3}$$

$$\mathrm{R}=\begin{bmatrix} \mathrm{R}_{\mathrm{G_m G_n Res\_1}} & \cdots & \mathrm{R}_{\mathrm{G_m G_n Res\_1}} \\ \vdots & \ddots & \vdots \\ \mathrm{R}_{\mathrm{G_m G_n Res\_30}} & \cdots & \mathrm{R}_{\mathrm{G_m G_n Res\_30}} \end{bmatrix} \tag{4}$$

The process domain is level that contains the relation relationship between elements of the attribute. The relationship R could be expressed by using the distributed resampled points as discussed previously. Moreover, the probability density function (pdf) is used to address the distributed resampled point. The relationship R can be represented in semantic matrix form as denoted in equation 4. R describes the relation of the resampled points Res_n = {Res_1, Res_2, Res_3,---, Res_30}. m and n are two registered gestures {Round, Square, Diamond, Triangle, Eight}. Due to Res_n are distributed points, and R can be expressed in several ways like a mereotopology connection, similarity measure distance and fuzzy inference technique. In the mereotopological connection, the conceptual relationship that can be used like a proper part, overlap, underlap, over-crossing, proper overlap and proper underlap. Other than mereotopological connection, the similarity measure distance could be used to express the relationship R among the distributed resampled point of five registered gestures [28]. The combination of information in knowledge, attribute and process domains serves as a database of the five registered gestures. The complexity of the ontological framework could be increased by adding multiple sensors, produces more features and attributes, and creates more relationship R between elements in the attributes.

6 Recognition the unknown input gesture

Recognition of the unknown input gesture G_i process is similar with the information retrieval in the ontology-based applications. The information retrieval process produces the matching and ranking compared with the registered gestures in the ontological framework. The matching process is to compare the query vector $\boldsymbol{q}(G_i)$ against each registered gesture $\mathrm{G}_{n\{\mathrm{Round,Square,Diamond,Triangle,\ Eight}\}}$ by using Jacad similarity measure. It measures the similarity between finite sample sets, and is defined as the size of the intersection divided by the size of the union of the sample sets as given by the equation 5. Jac (RG_i, RG_n) is representation of a Jaccard similarity coefficient. RG_i and RG_n are the possible relationship of the unknown input gesture and the registered gestures. Then, if RG_i and RG_n are both empty, we define Jac (RG_i, RG_n) = 1. Subsequently, a Jaccard similarity coefficient is between [0,1] as expressed in equation 6. Jaccard distance d_J measures dissimilarity between sample sets, which is complementary to the Jaccard coefficient. Jaccard distance d_J is determined by using equation 7. The ranking process is conducted based the similarity value obtained from the matching process.

$$\mathrm{Jac}\ (RG_i, RG_n) = |RG_i \cup RG_n| / |RG_i \cap RG_n| \tag{5}$$

$$0 \leq \text{Jac}\,(RG_i, RG_n) \leq 1 \quad (6)$$

$$d_J\,(RG_i, RG_n) = 1 - \text{Jac}\,(RG_i, RG_n) \quad (7)$$

7 Conclusion and Future works

Ontological framework for the presentation of five geometrical gestures performed by the arm movements is presented in this paper. A motion capture system (MOCAP) is used to track the reflective marker attached to the subject's right hand. The acquired three-dimensional position signals are resampled to 30 reference points. The proposed ontology framework has three domains, which are knowledge, attribute and process. Knowledge domain contains lower-level data that are pre-processed until achieve the 30 normalized features points. In this domain, all the possible features are gone through resampling and normalization algorithms. The attribute domain contains a collection of features and the relations between them are presented in the form of semantic matrix. The semantic matrix presents the ontology framework of the geometrical gesture information. The process of gesture recognition is similar with the information retrieval of the ontology-based applications. The gesture recognition contains matching and ranking processes. In the matching process, a similarity measure technique is used to determine the distances of the query vector to the registered gestures in the ontology framework. Moreover, the ranking process is to rank the similarity distance between the query vectors with the registered gestures in the ontology framework. In the future, a further investigation will be conducted to evaluate the performance of the ontology framework based on the individual features and the combining features in the knowledge domain.

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