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Hand finger gesture modeling in advanced CAD system

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ABSTRACT
The current paper presents a system for the dynamic simulation of the human hand. The simulation of the human hand offers the capability to acquire handshapes that correspond to letters of the finger alphabet, enabling an integrated representation of words and sentences. The hand model is designed using the Autodesk Inventor^{TM} and Autodesk AutoCad^{TM} design environments. The user is able to type words or sentences which are dynamically translated into postures according to the finger alphabet. The system is based on the physiometric characteristics of an average human hand. High precision design is utilized in every part through integration of all the necessary functionalities needed to perform the movements required. The system has been tested on more than 500 words with a letter representation success rate in the range of 95–97%.

KEYWORDS
CAD; gesture representation; intelligent system; application programming interface

1. Introduction

The ongoing expansion of CAD systems in a series of industry and enterprise based applications led to their usage in creating integrated applications. In many research cases, CAD based simulations are used in order to create a number of different system representations. These representations are used in a variety of areas, driving the productivity upwards to a great extent i.e. design, assembly, manufacturing, material selection, robotic applications [8, 12, 14, 15].

The aim of this research is to build a simulation system of a robotic hand, in the shape of a real human hand. The robotic hand incorporates moving and rotating joints in order to successfully simulate the alphabet using the sign language (Fig. 1). The hand prototype is designed in Autodesk AutoCAD^{TM} while the moving features were accomplished using Autodesk Inventor^{TM}.

The system is adapting to the requirements for efficient display of letter signs, ending up in better learning, while at the same time helps people that needed most. Through this aproach, the failure of the realistic sign representation as well as the probability of false oversight of people concerned, are avoided.

Sign language is an autonomous natural language system. Its vocabulary, morphology and syntax take place and operate in three-dimensional (3D) space; a fact which will be attributed by the robotic hand. The system aims to utilize both the technological developments in the 3D virtual reality space, as well as the current knowledge of the linguistic analysis of sign language, in order to make possible the construction of a functional graphical visualization environment, resembling the 'static' nature of classical sign language.

The hand finger alphabet is a simple way to display the Greek alphabet and should not be confused with the meanings. Signers, as native speakers of gesture signed language (GSL), are using the finger alphabet in two ways, either to perform acronyms and proper names or to form meanings in which the elements of the finger alphabet are used as gestures.

The basic element of meaning is the gesture itself. The gesture consists of the shape formed by the palm as well as the position of the fingers, pointing to a certain meaning. In order to create a certain meaning, the gesture must be accompanied by the proper orientation, the proper position and the proper attitude (or movement). Gestures play a very important role in communication between people and provide information that speach can not provide.

The hand is modeled as a rigid multilayer structured element of connected joints. There have been many human hand modeling efforts through robotic approaches and simulations [10,18]. The rigid elements are connected through joints, which move and activate links. The proposed model incorporates 26 degrees of freedom (Fig. 2), but the proposed approach is applicable

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Figure 1. Gestures for the Greek alphabet.

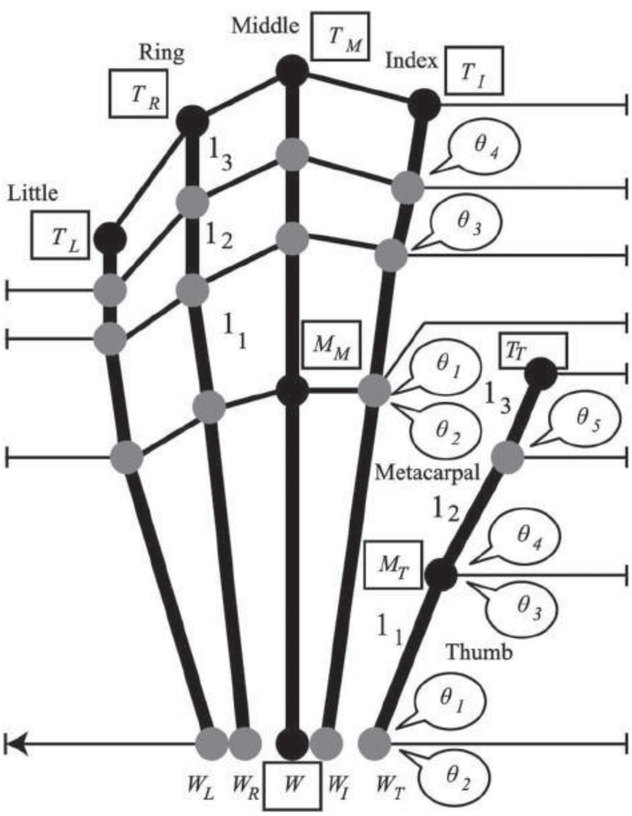

Figure 2. Hand physiometric characteristics.

to any rigid human hand. The length of the segments of the hand (finger phalages) can be measured and calculated using two parameters of human morphology; the length of the hand (HL) and the width of the hand (HB) as described in the bibliography [6, 19]. As is showing in Figure 2 θ_a are the DOF's of each join of finger's, and l_a the length of each phalages. T_a are the finger names.

2. State of the art

Human hands have been a strong means of expression and creativity since the creation of the world. Throughout the centuries, few other elements of human anatomy could play a more important role in the development of human relationships and communication between man and his environment more than hands. In music interaction, gesture is examined through communicational (expressions, emotions) and manipulative aspects (fingering, plucking, gesture control of sound). New interactive systems for the contemporary musical expression should allow for natural communication using gestures in a real-world environment, without restrictive interfaces [17].

Researchers have designed many systems of anthropomorphic robotic hand using cables for the communication and transfer of the necessary information [11, 21, 28]. While this apporoach serves the imitation of the movement of the tendon and makes it quite realistic, it also creates many problems to the users concerning the freedom of movement. Using cables the user can not move his hand freely and effectively, resulting in difficulties in the working area of the robotic system. Consequently, âĄčâĄčmany efforts have been made to develop simulation systems using pieces of software for the representation of movement in a virtual environment.

Stokoe found that American Sign Language (ASL) has 19 different basic gestures, 12 poses and 24 movements and developed a written symbol system to record these basic structural blocks of meaning [22]. With these symbols Stokoe et al. were able to record various winks and publish the first sign language dictionary mounted in linguistics principles [23]. Following this idea more researchers systematically investigated the sign language [3, 4, 27].

Cemil and Ming propose an American Sign Language recognition system, which was developed using artificial neural networks (ANNs) aiming to translate ASL words into English. The system uses a sensory glove and a 3-D motion tracker to extract the gesture features [7]. ASL finger spelling recognition systems were also developed by Allen et al. which could recognize 24 ASL letters using a neural network [1]. Wang et al. designed an ASL gesture recognition system consisting of a sensory glove using an ANN, a Hidden Markov Model (HMM), and a minimum distance classifier [26]. Hienz et al. proposed a German SL recognition system, using video-based techniques and a stochastic language model to improve performance. They use a 52 sign vocabulary, accomplishing a recognition rate of 95% [13].

Utsumi et al. proposed a vision-based hand pose recognition technique using skeleton images. A multi-system camera is used to pick the centre of gravity of the hand as well as points with the longest distances from the centre, providing the locations of the finger tips, which are then used to obtain a skeleton image, and finally a gesture recognition [25]. A technique for gesture recognition for sign language interpretation has been proposed in by Aoki et al. [2]. Other computer vision tools used for 2D and 3D hand gesture recognition include specialized mappings architecture [20] principal component analysis [24], fourier descriptors, neural networks, orientation histograms [9] and particle filters [5].

3. Overview of the proposed methodology

The basic requirement for the representation of the human hand, is to be as close as possible to the real human hand. The key factor is the agility and the ability of the joints, in order to simulate the movements of a real hand.

The main aim of the project is the successful representation of all the 24 letters of the Greek alphabet. Each part of the hand was designed step by step in order to be used in the assembly model of the final system. The design was stored in dwg format (the native format used by Autodesk AutoCad^{TM}), and after appropriate transformation was made compatible to the Autodesk Inventor^{TM} CAD system (Fig. 3).

The movement of the hand, together with the declaration of the functions defining the appropriate constraints for the proper physical containments, was made âĄčusing the Autodesk illogic^{TM} subroutines, thus achieving the final simulation of the hand (Fig. 4).

Specifically, following the design of the human hand, the next step was to define the constrains (Fig. 5) and to introduce the necessary variables for the constraints of the movements (Fig. 6). Autodesk iLogic^{TM} was used for this purpose, facilitating the writing of the necessary source code. The programming language used was Visual Basic for Applications (VBA), which is incorporated into the CAD system and made it possible to drive the movement and adjust the performance of the hand.

A total of fifteen rules have been defined in order to form the 24 gestures of the Greek alphabet. Using the appropriate commands, the values âĄčâĄčof the variables are changed and transferred to the system visualizing the required movement.

After the definition of the rules for all the Greek letters as well as the rest position, a set of macro commands were programmed. Macros are a collection of commands that optimize the performance of the program and save enough time by automating repeating series of commands. Most of the macros were written in VBA.

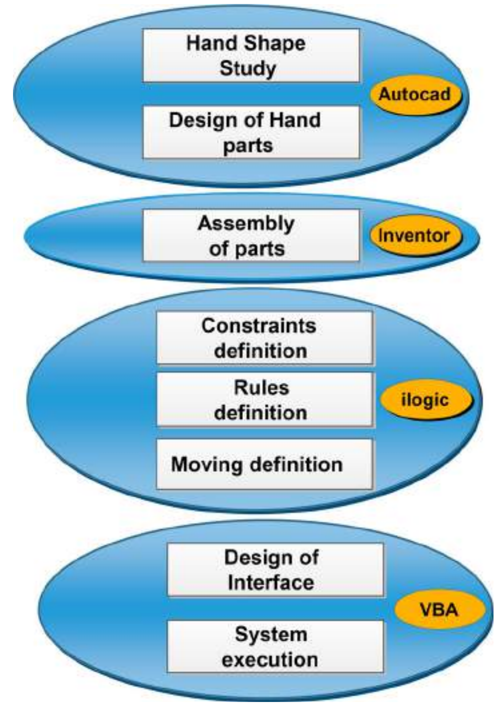

Figure 3. Methodology's overview.

The simulation and the visualization of the twenty-four letters of the Greek alphabet were achieved in two ways. The first (and simplest), was implemented by creating buttons, one for each letter, forming the virtual environment (Fig. 7). The second (and more complicated), called 'Spelling', uses an InputBox, where an entire word can be entered. The system performs the word-spelling and produces the corresponding gesture for each letter (Fig. 8). During the representation of the different letters the hand is moving smoothly from one letter to an other.

4. Experimental results - evaluation

The evaluation of the system was carried out in two steps. In the first step, distinct letters were simulated and visualized using the specific hand shape and in the second step the same outcome was evaluated using complete words. In order to use the system for complete words, the precision/recall method was used. The precision/recall method is a parameterized method that is balanced between accuracy and noise. Recall is the number of correctly represented letter represantations by the system divided by the total number of letter representations (i.e. represented and not represented letters). Precision is the

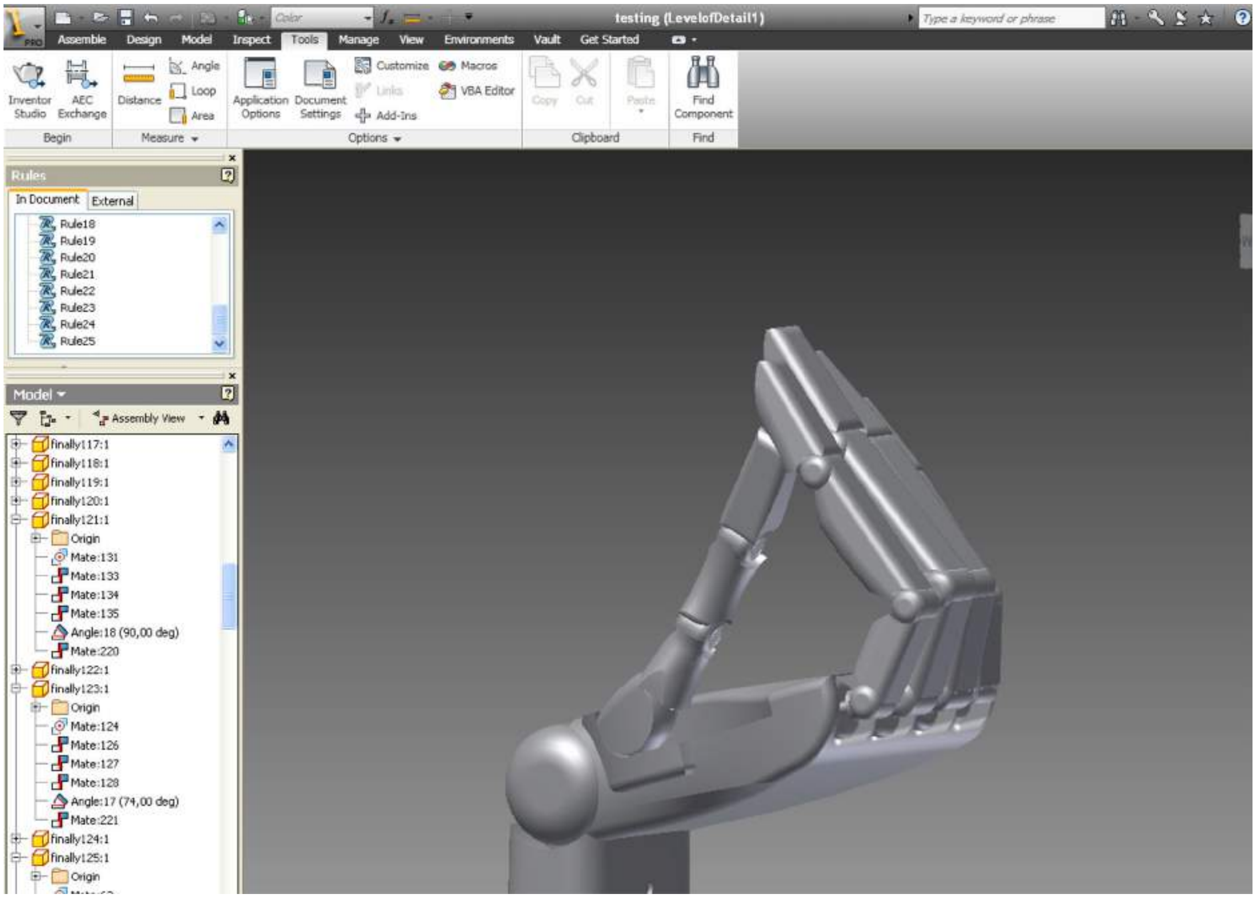

Figure 4. Human hand representation.

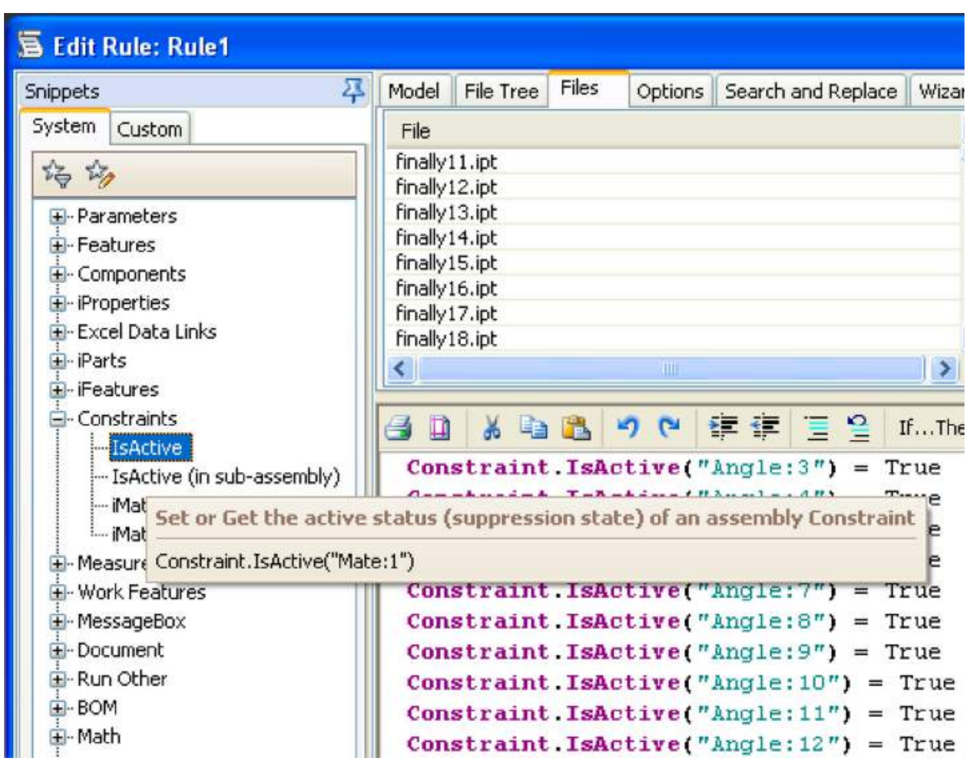

Figure 5. Constraints definition.

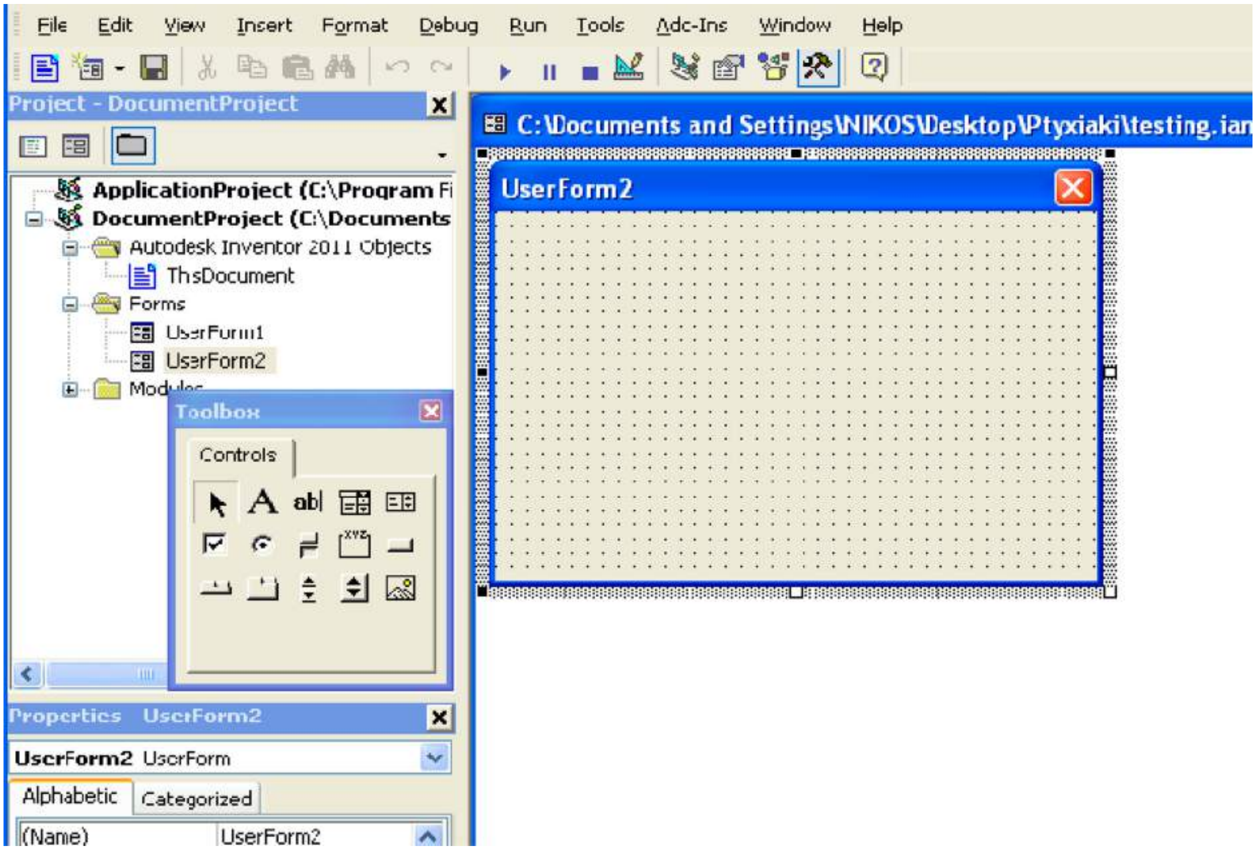

Figure 6. CAD based system programming.

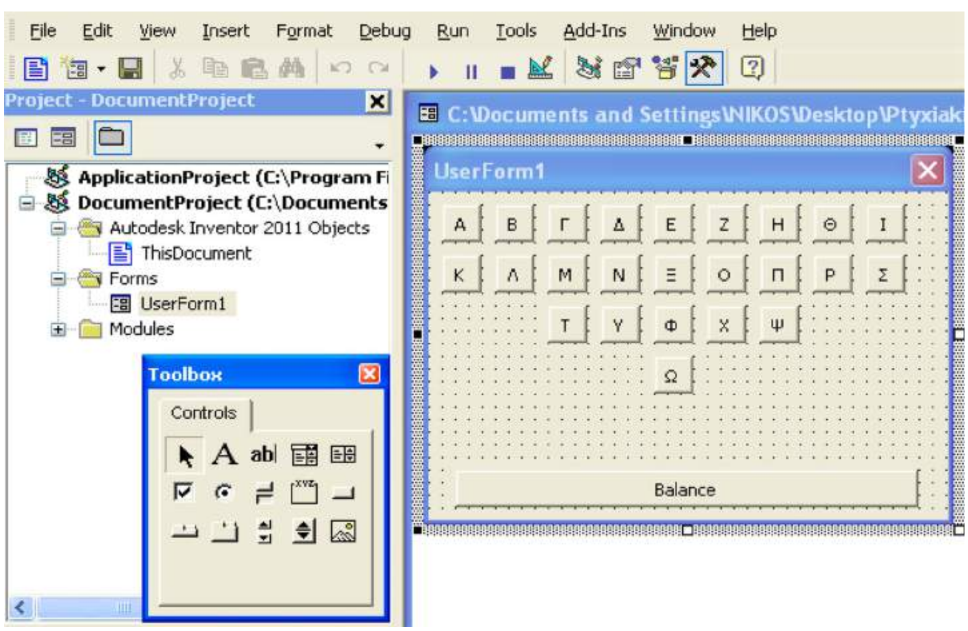

Figure 7. Letter representation.

ratio of correctly represented letters to the total number of letters represented by the system (i.e. correctly represented and wrongly represented letters). Recall, measures the sensitivity of the representation module and precision determines the accuracy of the system's module.

Under these terms, precision is the probability that the represention event is valid, and recall is the probability that the desired initial positions were represented. Equations (1) and (2) provide mathematical definitions of precision (p) and recall (r) for convenience.

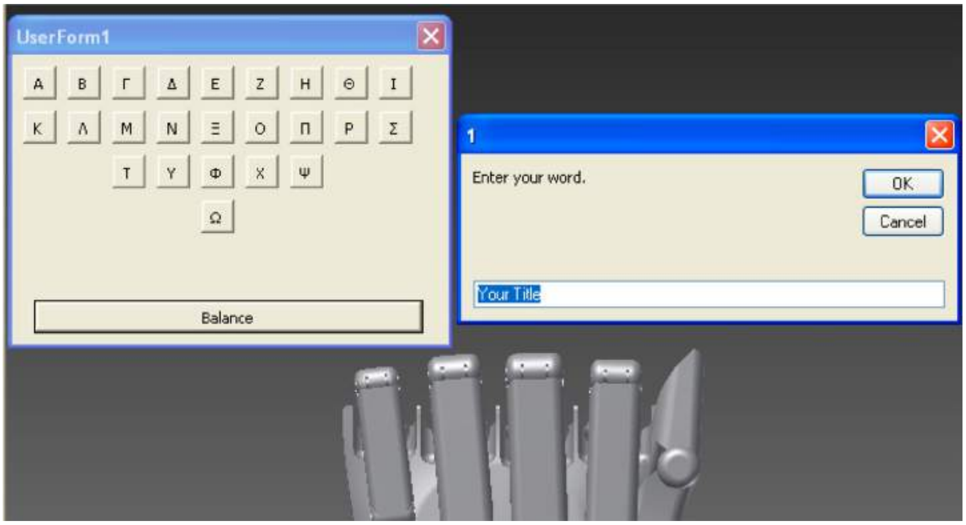

Figure 8. Word spelling.

Precision is the fraction of represented letters that are relevant to the gesture:

$$Precision = \frac{|\text{Re}\ levant\_letters \cap \text{represented}\_letters|}{\text{represented}\_letters} \tag{1}$$

Recall in information retrieval is the fraction of the letters that are relevant to the query that are successfully retrieved:

$$\text{Re}\ call = \frac{|\text{Re}\ levant\_letters \cap \text{represented}\_letters|}{\text{Re}\ levant\_letters} \tag{2}$$

The first evaluation step ended up to a 96% accurancy (only one fault letter representation). For the second step, a sample of 500 words was used. From these, a total of 475 words were correctly simulated, 16 were not correctly represented and 9 were not simulated at all. Therefore, according to equations (1) and (2) the system is considered to have a precision of 475/491 = 96.74% and recall of 475/500 = 95%.

5. Conclusion

The value of using a CAD system through the corresponding application programming interface, in order to create applications specific to hand finger gesture modeling was presented. A system for dynamic simulation of the human hand was implemented using a variety of different CAD based technologies. The technologies were integrated under a common platform and performed a great deal of testing with success.

The simulated human hand has the capability to simulate handshapes that correspond to letters of the Greek finger alphabet, with high accurancy and efficiency. The achieved values for both the precision and the recall measures were between 95–97%, which proves the validity of the proposed methodology.

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