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USE OF CHILDREN'S GAMES IN ROBOTICS

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Abstract: The aim of this paper is overall proposal of artificial or robotic player for the game Rock – Paper – Scissors. The main contribution of this paper is the algorithm, which guarantees invincibility of artificial player against human player. Such algorithm could be than expanded by probabilistic model imitating other human players. As the basic hardware component RGB-D camera was chosen. Developed software is based on free libraries like OpenNI or OpenCV allowing wide distribution of such artificial player among scientific and professional public.

1 Introduction

Game Rock – Paper – Scissors is a simple and well known game. This game was created in the 19th century in Japan and it is played by two players, which swing the one hand up and down for three times. In the third swing the player must choose from one of the following gestures: rock, paper, or scissors. Relations between the gestures are defined:

- Paper defeats rock.
- Rock defeats scissors.
- Scissors defeat paper.

In the case both players chose the same gesture, they must repeat whole round. It may seem as a lottery, but the game make possible some training, which allows the player to recognize opponent's gesture. The aim of this research is to propose such system (Fig. 1) which will be unbeatable in this game. Such system must use suitable visual systems, which allows detection of the gestures of human hands. Moreover, the system must be extendible to playing with robotic hand.

2 State of the art

The most known and probably the only robot that always beats the human in Rock – Paper – Scissors is named Janken [1]. This robotic hand was developed in Japan and it uses high speed camera (600 fps) with the resolution 1280x700 pixels. Due to used high speed camera, the whole system is unbeatable by human [2, 3]. Janken is equipped by three fingers allowing it to show all the gestures (Fig. 2). First version of this robot recognized the human gesture after the human hand stopped its movement. Consequently system recognized the gesture and represented the opposite gesture by the rules of the game. This version had time delay 20 ms. As the human is able to recognize time delay between 30 and 60 ms, the human player does not aware the principle used in Janken. However, when the game is recorded by high speed camera, it is clear that robotic hand reacts later than human hand [1].

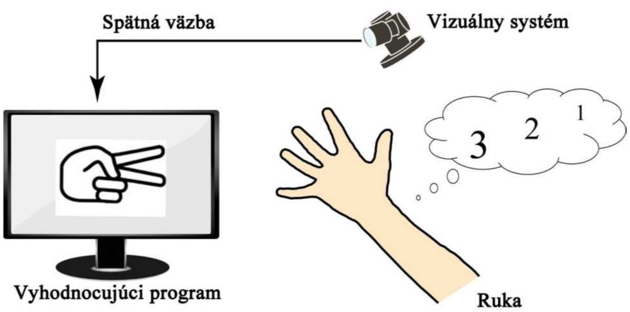

Figure 1 Architecture of the system

Second prototype of Janken solves this timing problem and the gesture of the robot is represented together with human one. Janken have 8 joints and 3 fingers [2]. Generally this robotic hand is characterized by low weight, high speed, acceleration and accuracy. Janken have 9 DOF.

Another robot playing this game is called Berti (Bristol Elumotion Robotic Torso) (Fig. 3). It is a humanoid robot, which was learnt to play the game [2]. This robot does not use any visual system. Human opponent must use artificial glove, which is used for the gesture recognition. Such system is slow despite the fact that Berti is not used only for this game.

Figure 2 Robotic hand Janken from the University of Tokyo

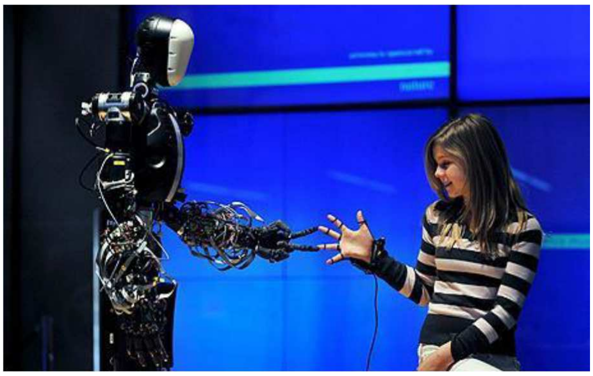

Figure 3 Robot Berti

As the suitable visual system for the game Rock – Paper – Scissors camera Microsoft Kinect [4] was selected. There were several reasons:

- Is is cheap.
- It has depth measurement.
- It is easy to find human skeleton with the usage of already existing libraries.

Despite these advantages, there are some disadvantages, which may make it difficult to solve. Especially lower camera resolution and frame rate are the properties, which are disadvantageous compared to above mentioned applications.

3 Gestures detection

Infrared emitter used in Microsoft Kinect transmits the structured pattern with the wave-length 830 nm. Deformations of this pattern are detected by coupled camera. Consequently distances of each pixel on RGB camera are computed. Measuring range is dependent on used technology. With the usage of OpenNI library [5] 0.4 m minimal measuring distance and 4.5 maximal measuring distance can be achieved (Fig. 4). Accordingly the human player must stand in front of the Kinect camera somewhere between these two distances.

Figure 4 Disparity map obtained from Microsoft Kinect. Black dots represent incorrect measurements. This is due to objects situated closer than minimal measuring range or visible light, which transilluminates the transmitter.

Gestures detection implemented in the algorithm is based on the detection of hand, palm and fingers. First step of the algorithm is to find the human player. This was done with the NiTE library [6], which already contains functions to find human bodies and their skeletons in the Kinect data. Output of the library can provide identification of human body (skeleton) with up to 15 joints. Consequently, only right hand of the human player is chosen from this skeleton. Synchronization of the game is performed by point, which must be "touched" by human player's right hand (Fig. 5). Let's name this point a red point. This point represents some imaginary centre of the palm. If the red point touched the synchronization point (green circle) then the game is started and the algorithm starts to trace the hand's movement.

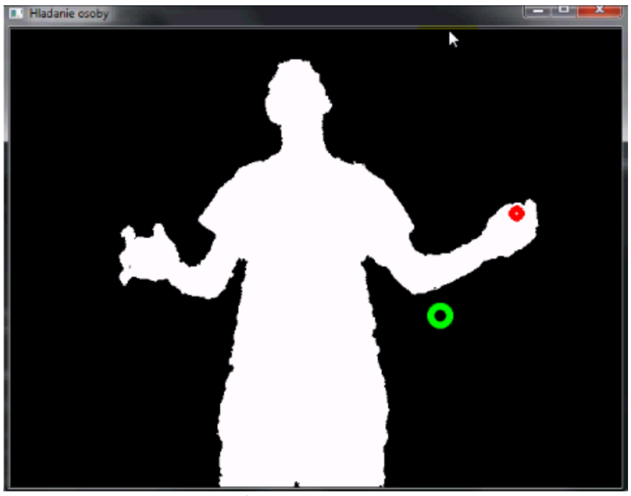

Figure 5 Skeleton identified by NiTE library. A red circle marks the right hand (human stands in front of the camera) and a green circle is the synchronization point.

Second step of the algorithm uses the detected joint of the right palm. Consequently, ROI around this joint is created (Fig 6). Actual gestures of the right hand are detected by the positions of the fingers. These positions are determined by the simpler objects, e.g. contours. Such contours are easy to create, for example algorithm Suzuki85 can be used [7] (Fig. 6).

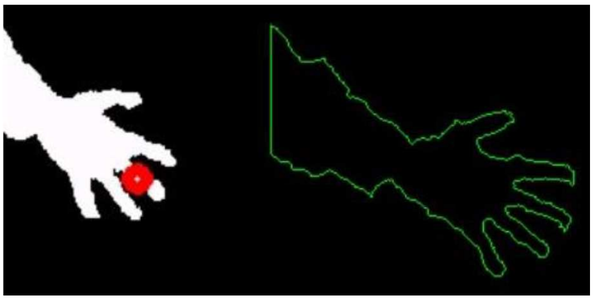

Figure 6 ROI around the right palm and corresponding contours detected by Suzuki85 algorithm.

Detection of the fingers is based on the convex defects. Therefore it is needed to create the convex hull of the hand. Convex hull is defined as the smallest set of the points in the Euclidean space, which contains all of the given points. It can be easily visualized as an elastic band stretched around all of the given points. For the detection of the convex hull Skalansky82 algorithm (Fig. 7) can be used [8].

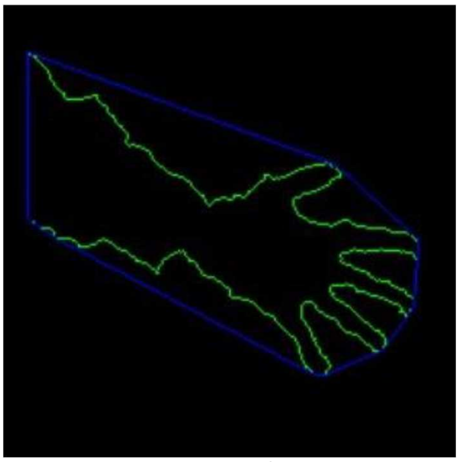

Figure 7 Convex hull of the right hand.

Convex defects (or convexity defects) of the hand are shown in Fig. 8. Black line marks the convex hull. Convex defects are defined as a space between contours of the object and its convex hull. On the hand 8 convex defects can be defined.

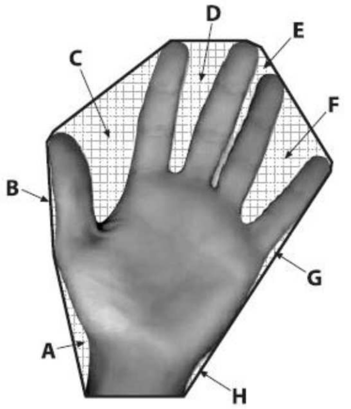

Figure 8 Convex defects between contours and convex hull of the hand. Defects are marked by the letters A – H.

Proposed algorithm identifies these three states (Fig. 9):

- The number of the defects is more than four – the human player showed the gesture of paper.
- The number of the defects is in the range from one to four – the human player showed the gesture of scissors.
- The number of defects is in the range from zero to one – the human player showed the gesture of rock.

This gesture detection was derived empirically.

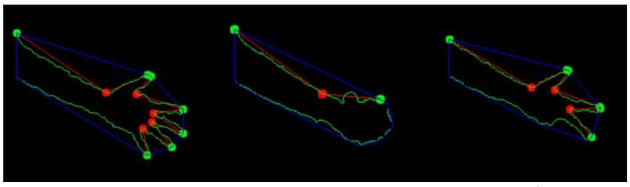

Figure 9 Three gestures distinguishable by number of convex defects (red circles) and points of convex hull (gree circles) (from left to right: paper, rock, and scissors).

The game Rock – Paper – Scissors does not consist only of detection of gestures, but also so-called "hip hap hop" movement of hand must be performed and well detected. In proposed algorithm this is done by the detection of red point, which remarks the position of the right hand (Fig. 5). However, the library NiTE does not detect the hand with 100% accuracy. This causes the detection of hand's movement despite the hand is in static position. Such noise should be filtered – if the difference between two consequent points in the y axis is positive and is larger than:

$$\frac{30px}{HandDistance/1000} \tag{1}$$

Then the hand moves upwards. The movement downwards is detected in similar way. If the difference is negative, then the hand moves downwards. The parameter *HandDistance* is determined by depth measurements of Kinect camera. If the Kinect is not able to determine the distance to the hand (i.e. red point marking the hand), then the closest pixel with value different from 0 is taken into account. The general purpose of this computation is the various movement of the hand measured in the pixels, which is dependent on the distance between human and Kinect sensor. Within the last movement of "”hip hap hop” algorithm detects the ROI with corresponding gesture.

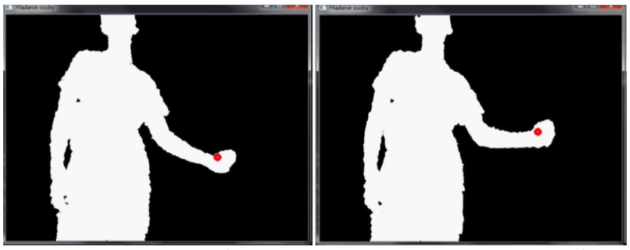

Figure 10 Scanning of the hand's movement – movement of the hand between two consequent frames.

4 Results

Accurate percentage of success gesture's detection cannot be expressed, because it is dependent on several conditions:

1. <u>The distance of human player from the camera.</u>

With increasing distance of human player from the camera, the resolution of the hand in the image is reduced. Consequently, the number of pixels representing the hand is reduced and the algorithm is unable to determine the convex defects. Lower number of defects and corners of convex hull causes wrong detection of the gesture. Sufficient resolution of the hand is provided, when the human player stands in the distance range from 0.6 to 1.2 meters (Fig. 11).

a) *b)*

Figure 11 Resolution of the hand in the image – a) insufficient in the distance 2 m b) sufficient in the distance 0.7 m.

2. <u>Accurate detection of the gesture itself.</u>

If the gesture is detected, there can be problem with distinction between gestures scissors and rock. This is shown in Fig. 12. Such situation could occur when the scissors and rock gestures have equal number of defects (red points) and convex hull points (green points). Correct detection of the scissors gesture may be increased by the rising the thumb. The largest number of correct detections was obtained within the gesture paper.

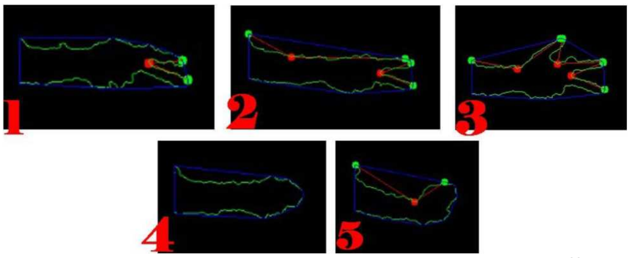

Figure 12 Problematic distinction between two different gestures – scissors in 1 and rock in 5.

3. <u>Capture of the hand's movement.</u>

This is the largest source of the errors of the whole algorithm. If the algorithm does not correctly register all the six hip-hap-hop movements (each is defined by two consequent moves – up and down), whole process fails. In that case the game is needed to be restarted. Other error can occur if the right palm is incorrectly detected in NiTE library.

4. <u>The position of the human player with respect to the camera's position.</u>

If the position of the human player is not perpendicular to the camera, or the hand is covered by the player's body, the detection of the hand may fail. Correct position of the human player is shown in Fig. 13.

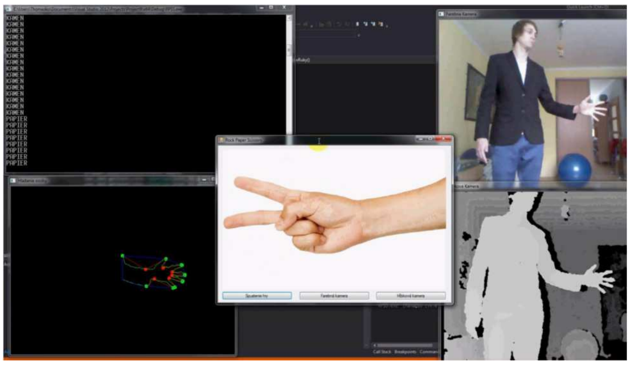

Figure 13 Correct position of the human player with respect to the camera's position.

If all these conditions are fulfilled, then the algorithm is almost unbeatable. From twenty attempts algorithm won over our human player eighteen times. Both non-winning attempts were caused by incorrect detection of the hand's movement (hip-hap-hop).

5 Conclusion and future work

The most common problem of created artificial player was scanning of hand's motion. It was based on the available libraries for Kinect. These libraries not always return correct position of the joints, which means complete stop of the actual game. If the scanning is correct then the accuracy of gesture detection is over 95 %. This was also confirmed by testing of the application on the event Istrobot 2016, where the game was played by random passers-by. However, this testing also revealed that human players are anticipating some movement of virtual hand and there were some problems with the initial posture of human players. That is why the future work on this project will require the usage of more accurate sensor. This could be provided by sensor Kinect 2.0, which is more accurate than its first version. Moreover, the resolution if Kinect 2.0 is higher, so we are excepting also higher accuracy of hand's scanning. Improvement in enjoyment of the game should be bring also by a real robotic hand, e.g. Shadow Dexterous Hand [9], or 5-Finger Servo Electric Gripping Hand SVH from company SCHUNK [10,11]. However these robotic hands are very expensive (their price may be higher than a few thousand of EUR), and at that moment we had not owned any such device. It is obvious that proposed system is almost unbeatable, but it also allows some fun for humans in a modern way. This is confirmed by recorded video [11].

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