Ability of humanoid robot to perform emotional body gestures

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Abstract. This paper presents an analysis of humanoid robot ability to perform human upper body language regarding several typical human emotional states. A young actor has been involved as a model of affective states. Experiments on real robot have been carried out in order to find its dynamics. A criterion that allows us to detect robot possibility of performing emotions by movements is defined. Analysis of how to compensate robot shortcomings such as limited degrees of freedom and joint's activation in performing emotions is given.

Keywords: Humanoid robot, cognitive robotics, social robots, humanoid body gestures

1 Introduction

New generation of personal robots, as a form of service robots for the support to humans, is expected to have cognitive behavior which would be similar to the behavior of a human being. This means that the new generation of robots needs to have individual personality and temperament as factors of the cognitive emotional behavior which is usually called emotional intelligence. Individual characteristics of humans, for example personality type and temperament, but also external factors of influence, for example socioeconomic factors and living conditions, determine the degree of emotional intelligence [1].

Emotional intelligence (EI) is the ability to identify, assess, use and control the emotions of oneself, of others, and of groups as well [2]. The term EI first appeared in sixties, but EI gained popularity in the nineties when it was thoroughly analyzed and presented [3]. Robots which are emotionally intelligent (with strong personality characteristics) show a better ability to socialize and integrate in the community of humans.

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In this fashion, new types of service robots are becoming more desirable and more accepted by the users. This is the case because of the easier interaction with the social environment and a greater degree of mutual cooperation and understanding.

Personality of a person is usually assumed as a special complex, integrated and stable set of individual's psychological characteristics that determine their behavior and social acceptance in the community. Personality is a constant "variable" and it does not change over the person's lifetime. It is acquired as a consequence of the genetic code of that person. Similar to personality, person's temperament is assumed to be a person's characteristic way of emotional reactions. Speed, intensity, duration and type of reaction will depend on person's temperament. Characteristics of a person are expressed by their specific affective and social behavior in various situations and social environments. In psychology theory, various personality characteristics of a person were presented and defined and some of them are: introverted or extroverted, sensing or intuitive, feeling or thinking, perceiving or judging [4]. If on combines these four dichotomies, sixteen different types of personality can be defined. Also, there are four known person's temperaments and they are: sanguine (optimistic, active and social), choleric (short-tempered, fast or irritable), melancholic (analytical, wise and quiet) and phlegmatic (relaxed and peaceful) [5]. The main idea of this paper is to develop an algorithm which would test the ability of humanoid robot to perform emotional body gestures of a human being. These tests were performed on a humanoid robot named Robothespian [6] and these results were analyzed and discussion was given. Also, ideas for future research were presented.

This paper is organized as follows. In the first section of the paper the main idea of the research was presented along with basic terms which will be used throughout the paper. In the second section, the review of the research papers from this area were presented and analyzed. The third part of the paper presents the results and analysis of the research, while in the fourth section conclusion remarks and plans for future research are given.

2 State-of-the-Art

Behavior of human beings while expressing different emotions attracted the researchers ever since Darwin's classic volume presented in [7]. Authors made big progress in this area of research during the twentieth century, but this topic became even more interesting for scientists in the nineties. One of pioneer papers is [8]. In that paper, authors make a question whether body movements and body postures are indicative of specific emotions. Some papers before [8] have found evidence for specific body movements accompanying specific emotions. The study reported by authors was an attempt to demonstrate that body movements and postures to some degree are specific for certain emotions.

The work analyzed in [8] inspired a lot of researchers who started doing similar investigations on robots. Authors of [9] dealt with emotion and sociable humanoid robots. They presented the scientific basis underlying their humanoid robot's emotion models and expressive behavior, and then presented how these scientific viewpoints have been adapted to their implementation. In [10], authors explored the possibility of using humanoid robots as instructional tools for teaching a second language in Primary school. Authors reported about design and testing of five instruction scenarios for teaching second language. Based on their empirical experience, they provided suggestions for future research directions in the realm of robots for language education. Authors of [11] addressed cooperative gestures as an effective signaling for humanoid robots. They conducted within-subjects, video-based laboratory experiment, measuring time to cooperate with a humanoid robot making interactional gestures. Authors manipulated the gesture type (beckon, give, shake hands), the gesture style (smooth, abrupt), and the gesture orientation (front, side). Also, they employed two measures of individual differences: negative attitudes toward robots and human gesture decoding ability. The results presented in the paper showed that people cooperate with abrupt gestures more quickly than smooth ones and front-oriented gestures more quickly than those made to the side.

There are a lot of papers which test the ability of adults to interpret different positions displayed by a robot. These tests would be used to help the people during rehabilitation or with similar problems. In [12], authors present this analysis on children. Based on results from this paper, body postures and head position could be used to convey emotions during interaction with a robot. Another paper which deals with similar problems is [13]. Authors presented an approach to enhance the interaction abilities of the Nao humanoid robot by extending its communicative behavior with non-verbal gestures (hand and head movements, and gaze following). A set of nonverbal gestures were identified that Nao could use for enhancing its presentation and turn-management capabilities in conversational interactions. Authors of paper [14] dealt with robot-specified social cues in emotional body language. They tried to apply aspects of human communication to ease the interaction between robots and users. The study reported in this paper is a pilot study to not offer simulated emotion but to offer an abstracted robot version of emotion expressions and an evaluation to what extent users interpret these robot expressions as the intended emotional states.

Natural social human–robot interactions (HRIs) require that robots have the ability to perceive and identify complex human social behaviors and, in turn, be able to also display their own behaviors using similar communication modes. In [15], authors dealt with recognizing the emotional body language displayed by a human-like social robot. Their work focused on extending this concept to robotic affective communication during social HRI. Namely, authors explored the design of emotional body language for human-like social robot named Brian 2.0. In the emerging world of human-robot interaction, people and robots will work together to achieve joint objectives. Paper [16] discussed the design and validation of a general scheme for creating emotionally expressive behaviours for robots, in order that people might better interpret how a robot collaborator is succeeding or failing in its work.

3 Experimental results

Human motion mapping to a robot is an intuitive approach of embedding emotional behavior to the robot. An analysis of mapping possibility is carried out and includes certain measurements on the robot and on the actor (Fig. 1.).

Fig. 1. The actor performing movements

Actor is allowed to have one personality and several typical emotions while performing upper body movements. Joints' angles of actor are determined and compered with obtained dynamic performance of RoboThespian.

3.1 Measurement of body gestures by XSENS sensors

Measurement of body gestures by XSENS sensors has been realized by motion tracking of actor human upper body with nine XSENS IMU sensors [17]. The sensors are placed on head, chest, left and right biceps, left and right wrists, left and right hands and pelvis. Since RoboThespian has no legs, the actor was told to stand in one position while performing tasks using only the upper part of the body. In such a way, there will be no compensation in body movements regarding to legs movement of actor. All angles of joints are found with quaternion-based fusion scheme that includes raw sensors' data.

Fig. 2. presents an example of captured right shoulder pitch angle for five typical emotional states: sad, angry, excited, happy and content.

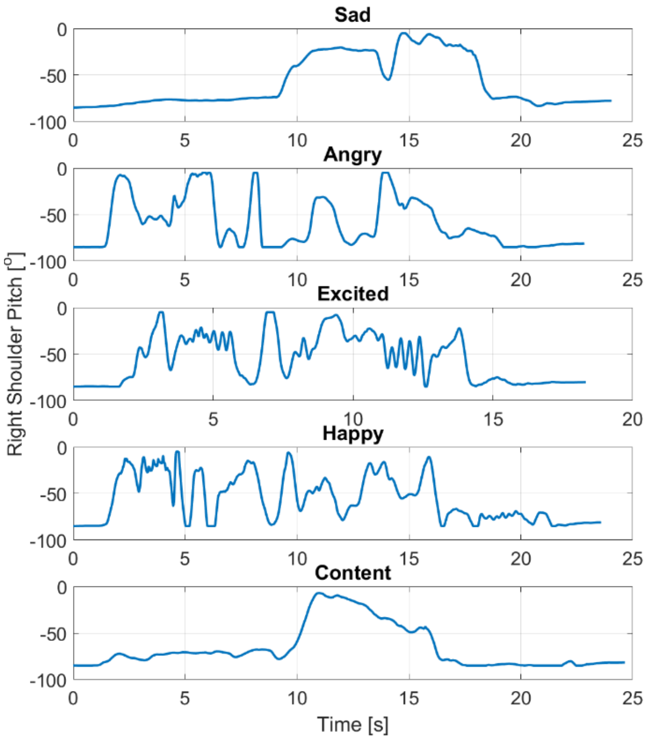

Fig. 2. Captured right shoulder pitch angle of actor

It can be observed from Fig. 2. that there are differences in motion dynamics for different type of mood. Motion dynamics is the lowest for sad mood, and the highest for happy emotional state. Determined max. absolute joints' speed are summarized in Tab. 1.

3.2 RobotThespian dynamic performance

Dynamic performance of RobotThespian are captured with step responses of 18 joints for four joint activation cases: initial to max. angle, max. to initial angle, initial to min. angle, min. to initial angle (Fig. 3. Blue and red lines represent desired and obtained joint angles, respectively. In order to have reliable joint measurements, absolute encoders are mounted directly on joints.

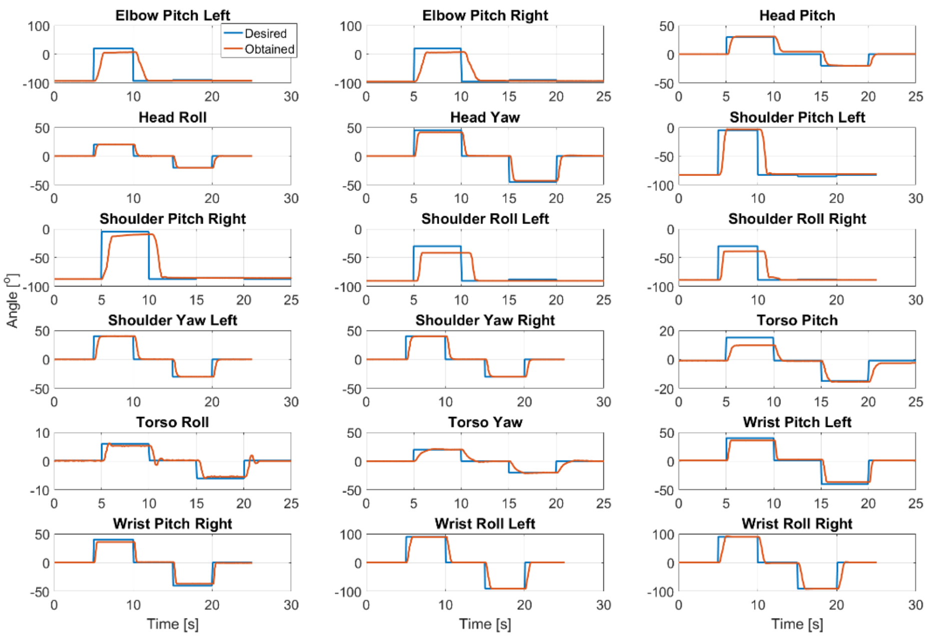

Fig. 3. Captured joint angle activation of RoboThespian

It can be seen from Fig. 3. that there are differences in joint dynamics, since RoboThespian has hybrid joints activation system. It combines pneumatic actuators and DC servo drives [18]. Maximum absolute joints' speed obtained for joints' activation from initial to maximum positions are listed in Tab. 1. in gray column.

3.3 Discussions

Ability of humanoid joints to perform the tasks regarding to some typical emotional states can be seen in Tab. 1, where are max. absolute joints' angle of robot $|v_R|_{max}$ (gray column) and actor $|v_A|_{max}$ listed. Bolded values of velocities represent robot capability to perform body movements.

Joint angle		$|v_R|_{max}$ [°/sec]	$|v_A|_{max}$ [°/sec]				
			Sad	Angry	Excited	Happy	Content
Head	P	120	**98**	**118**	151	169	123
	R	84	**48**	165	102	**71**	**34**
	Y	162	**128**	199	194	**135**	**77**
Torso	P	35	188	36	63	44	**35**
	R	25	28	33	52	56	**25**
	Y	35	97	**35**	82	81	**27**
Left Shoulder	P	257	**102**	**196**	**251**	292	**161**
	R	177	**113**	**134**	229	264	**131**
	Y	123	**89**	143	211	332	**115**

Right Shoulder	P	377	**75**	**231**	**165**	**323**	**172**
	R	253	**100**	**130**	**169**	272	**62**
	Y	148	**77**	163	194	743	**104**
Left Elbow	P	184	507	305	631	401	228
Right Elbow	P	225	234	281	294	837	274
Left Wrist	P	165	391	246	419	312	273
	R	226	657	**155**	379	575	**181**
Right Wrist	P	214	410	443	378	760	242
	R	256	**125**	**110**	273	1519	309

Tab. 1. Ability of humanoid joints to perform the tasks regarding to some typical emotional states: Joint angle (P-Pitch, R-Roll, Y-Yaw), measured absolute velocities of robot joints (gray fields), measured absolute max joints velocities of an actor for typical emotional states (bold stays for robot ability to perform motions captured by an actor: $|v_R|_{max} > |v_A|_{max}$).

Tab.1 clearly illustrates larger activity of the upper-body movements during the excited and happy scenarios in comparison to the sad and content scenarios. The robot could not achieve these movements regarding to its activation system, and consequently, emotional state on the robot will be non-real represented.

This analysis is very important before applying motions to the existing robot, or before design the new one. If the robot is not capable to realize tasks regarding emotional states, body movements should be slowed down. Afterwards, additional analysis has to be taken into account in order to determine whether robot performs body movements properly. These movements should be identified and recognized by humans.

4 Conclusions and Future work

This paper presents a basic analysis of humanoid ability to perform upper body movements regarding cognitive behavior. Experiments on real robot and human have been carried out, where maximum absolute velocity was taken as criteria for robot capabilities. Certainly, humanoid RoboThespian, besides limited joint's speed, has limited degrees of freedom compering to human, and consequently, it has difficulties in performing emotional body language. That will affect our perception of emotional state of the robot.

Recognition and critical recognition rates have to be found in order to find acceptable humanoid emotional body language. Facial expressions, voice and other effects acting together with body movements will improve recognition rates significantly. In such a way, even slower joints' movement will satisfy correctness of robot performing cognitive behavior.

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