Robot Creativity: Humanlike Behaviour in the Robot-Robot Interaction

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Abstract. Artificial Intelligence development is mainly directed toward imitating human reasoning and performing different tasks. For that purpose, related software and program solution where artificial intelligence is used have mostly thinking abilities. However, there are many questions to answer in ongoing AI research, especially when we come to the point which is addressing humanlike behaviour and reasoning triggered by emotions. In this paper, we are presenting an interactive installation Botorikko: Machine Create State, which is part of the Syntropic Counterpoints art/research project. We are exposing AI cyber clones to some of the fundamental questions for humankind and challenge their creativity. The robots are trained by using the publications Machiavelli and Sun Tzu and confronted to the crucial questions related to moral, ethic, strategy, politics, diplomacy, war etc. We are using a recurrent neural network (RNN) and robot-robot interaction to trigger unsupervised robot creativity and humanlike behaviour on generated machine-made content.

Keywords: Artificial Intelligence · Robot-robot interaction · Machine-made content · Robot creativity · Artificial intelligence humanlike behaviour · Interactive installation

1 Introduction

Development of an Artificial Intelligence nowadays is mainly directed toward imitating human reasoning and performing different tasks in the segments of thinking and learning, problem-solving and making decisions. Therefore, most of the software and program solutions based on Artificial Intelligence implemented into robots, computers, or other related systems has thinking abilities [1]. However, there are many questions to answer in contemporary Artificial Intelligence research which are corresponding to the way AI agent are solving those tasks. Ideally, robots should be in a position to perform the different task autonomously without human control or assistance [2]. Hence, we should address important questions to human behavior and reasoning, which is not only

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rational but rather triggered by emotions. What about the ethical and moral dimensions of such decisions? Furthermore, the development of such autonomous systems and devices requires more investigations toward machine consciousness, reasoning and cognition tasks performed in their judgment or decision-making [3].

Today's artificial intelligence is used in our daily lives by using it in GPS, machines for manufacturing of various products, and extensive usage in business areas such as customer service, finance, sales and marketing, administration and technical processes in various sectors. Most of the implementations mentioned could not be considered as replacement of human task but more to complement them, with the notion of giving to the people more freedom to develop their potentials and creativity [4]. But if we are developing AI agents to achieve and exceed the performances of humans, then we need to be aware of their full learning capacities and the evolution of their creativity. Furthermore, it would be interesting to explore and analyze different AI techniques capable of improving an outcome and the whole system.

In this paper, we are presenting interactive installation Botorikko: Machine Create State, which is part of the Syntropic Counterpoints art/research project. The project has the intention to expose artificial intelligence cyber clones to some of the fundamental questions for humankind and challenge their creativity [5]. Our focus will be to present how we prototype humanlike robot neck which behaves based on generated content's sentiment, as result of robot-robot interaction. Lastly, we will conclude and specify future directions of the Botorikko: Machine Create State experimental artwork.

2 Background

The most often, creativity in robotics is analyzed in the context of a robot performing behaviours that typically requires human creativity [6]. Gopinath & Weinberg [8] investigate the creative domain of musical robots and suggest a model for a robot drummer based on selected natural and expressive drum strokes that are similar to a human drummer. Schubert & Mombaur [8] created the model of motion dynamics that enables a robot to imitate creative paintings. Bird & Stokes [9] are proposed autonomy and self-novelty as a new requirement for a creative robot. Saunders, Chee, & Gemeinboeck [10] are emphasizing results of the system in particular when co-creation occurs between humans and robots. Kantosalo & Toivonen [11] are proposing a method for alternating co-creativity, where the teacher interacts with AI creative agent modifies the shared creative concept. Colin et al. [12] focus is less on producing a creative output and more of the process of creativity itself. They have introduced a hierarchy of problem spaces and represent different abstractions of the original reinforcement learning problem. Vigorito & Barto [13] are also treating creativity as a matter of creative process, rather than a creative outcome. For them, creative reasoning is a proves that emphasizes (i) sufficient variation and (ii) sufficient selection of candidate policies. Under sufficient variation, they are addressing action of representing the problem at multiple levels of abstraction. Furthermore, they propose that new behaviours can only be discovered by representing the learning problem at a sufficient abstraction. Searching for the solution on multiple levels of abstraction makes a distinction between creative robots, which produce novel output, and AI agents which are searching through space at a lower level of abstraction.

The creative act is for sure one of the most fantastic human capabilities which can be evoked in robots. The real test for artificial intelligence and new generation of robots would be to challenge their abilities in artistic domains such as dance, music, painting and drama. For anthropomorphic robots, the domain of the dance is fascinating and challenging to test their skills of replicating and embodying human movements. In that case, a creative process can replicate the mental processes involved in human creativity to generate movements by taking into account different music genres, personal artistic style, the audience evaluation [14].

Unlike the usage of artificial intelligence as a medium to support or imitate human creativity and behavioural, our approach is to liberate and explore its creative patterns through the robot's interactions. In the first Syntropic Counterpoints art installation titled "Robosophy Philosophy: Ubermensch and Magnanimous" we confronted philosophical standpoints of Aristotle (Magnanimous) and Nietzsche (Übermensch) and used their cyber clones to run debates and generate autonomously content we considered as results of AI agents creative act [5]. The artwork's cyber clones are developed as a combination of chatbot technologies and Recurrent Neural Network (RNN) models [15], enabling reinforcement learning toward the creation of artificial conversational agents with human-level performances.

3 Interactive Installation Botorikko - Machine Created State

The artwork Syntropic Counterpoints: Botorikko, Machine Created State is conceptualized as an interactive installation made of two to bicycles construction modified to carry two computer monitors and two pseudo robot manikin figures (see Fig. 1). The visitors can listen over the speakers and see on the computer monitors dialogues which are running in real-time between Machiavelli (Italian diplomat, politician, historian, philosopher, humanist, writer, playwright and poet of the Renaissance period) and Sun Tzu (general, military strategist, writer and philosopher who lived in the Eastern Zhou period of ancient China) AI clones. They are discussing strategies in politics, diplomacy, and how to deals and win in wars and conflicts. By doing that they are making a foundation for the first Machine Created State. Movement of the monitors follows the sentiments in the content created by AI clones and based on six basic emotions anger, happy, sad, fear, surprise, disgust.

Visitors can interact with the installation by pedalling bicycles which will automatically start sword fight between Machiavelli and Sun Tzu manikin figures look robots, placed at the front part of the bicycles and with the computer monitors placed instead of their heads (see Fig. 2). The installation is a unique example of human-robot-robot interaction which tends to become genuine social phenomena of our and future time.

Fig. 1. Interactive Installation Botorikko, two head mounted displays and two pseudo robots manikin figures (@copyright photo: Predrag K. Nikolic)

Fig. 2. Interactive Installation Botorikko, human-robot-robot interaction (@copyright photo: Predrag K. Nikolic)

4 Our Approach

In our approach, we are combining art and technology to create intelligent interactive artefacts which are trained to generate content as part of an artwork's creative concept and expression [3]. We are using two independent neural networks, one trained on books of Machiavelli and other one trained on books of Sun Tzu. The training was done with joined text of English translation of the books and use of many-to-many LSTM networks built with Keras and TensorFlow libraries, designed to generate the sequence of words based on the input sequence.

Sentiment analysis is done with Amazon Comprehend service, but other solution will be tested to find optimal results.

5 Prototyping Humanlike Behavior

5.1 BioMechanics of Human Neck

Even though each vertebrae movement range is limited, in combination off all seven joints, eventually neck can produce numerous head motions. Figure 3 visualizes human neck movements that comprise of three type range of motions based on biomechanical data [16]. Bending motions can be carried out in either forward (see Fig. 3(a)) or backward (see Fig. 3(b)) within the range of +40° to −50°, respectively. The second motion which is lateral flexion (see Fig. 3(c)), is also known as side bending or swing can be performed by human within the range of ±40°. Finally, the last motions are rotational (Fig. 3(d)) in which the left and right torsional can be executed within the range of ±55°. In this project, the biomechanics information of human neck was investigated in term of its type of movements and individual range of motion to generate natural neck mechanism of robot head. Based on this finding, the designed robot head shall be capable of producing three degrees of freedom (3DOF) movements with constraints angle, as mentioned previously to reproduce natural human-like motions. Details of the robot design and mechanism will be elaborate in the next section.

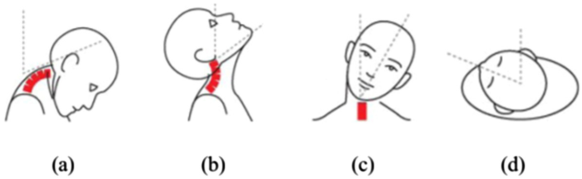

Fig. 3. Visualization of head movements [17]: (a) Bending forward, capped at +40°, (b) Bending Backward, capped at −50° (c) lateral flexion, range within ±40° (d) Rotation, and range within ±55°

5.2 Neck Mechanism Design

For our robotic head platform, a serial neck mechanism with three DOF was selected (seen Fig. 4) Since our total load capacity of the robot head is around one-kilogram, a serial mechanism was selected for its robustness and simplicity as compared to the parallel one. Technically, the mechanism comprises of three cube servo motors that stacked serially with various joints as in Table 1. Originally cube servo can be attached directly without any additional joints. However, for a bending motion with direct joint, such configuration will cause a non-symmetrical arrangement, and furthermore, all payload will be focused on the motor shaft only (see Fig. 5 (left)). To overcome this, combination of U-joint and rotational connect was employed in which the latter part is used to hold the motor on the opposite side of the shaft. By using this configuration, the bending motion will mainly cause by motor's body rotation and hence can hold more payload from the head.

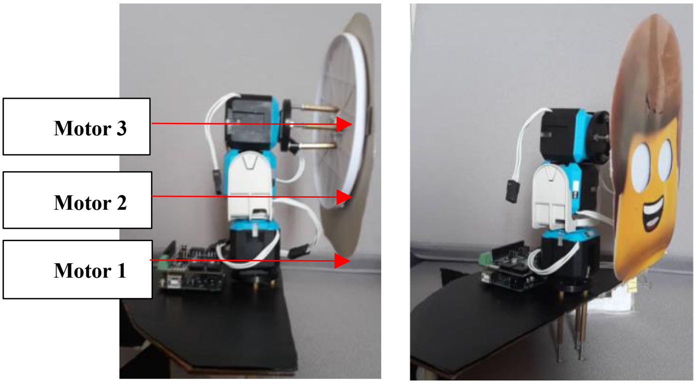

Fig. 4. Serial Neck Mechanism of robot head from side view (left) and perspective view (right)

Table 1. List of components for the robot neck.

No	Part name	Quantity	Function
1	Cube Servo G15	3	High torque DC motor with 360° angle control
2	Cube Servo Shield	1	Interpreter between controller and Cube servo
3	Arduino Uno	1	Robot controller
4	Rotatable Connect	1	Provide a freedom for Cube servo to rotate on the opposite side of the output while attaching to U Joint
5	U Joint	1	Create joint between rotation and bending motion
6	External Joint	2	Mount servo on neck's base and robot head

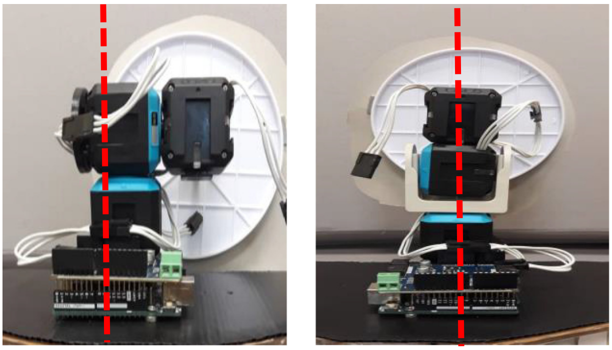

Fig. 5. Neck mechanism comparison of the cube servo by direct attach (left) and using U-joint attachment (right)

The first motor at the base responsible for generating rotational motion, the second motor attached with u-joint produce flexion motion and third motor with the head attached perform lateral flexion motion (see Fig. 5). All the motors are assigned unique address number and connected via a half-duplex serial communication protocol that controlled from the servo shield. The motor can perform smooth and continuous 360° rotation and can hold a stall torque up to 15 kilograms when powered with 12 V. All motors were assigned a range of motion constraint same as human neck parameters.

5.3 Control System

The control system module was designed to control the robot neck movement asynchronously. To achieve that real-time operating system (RTOS) based on ChibiOS was employed. Under such configuration, all motors can perform the task simultaneously and hence can generate smooth motion. The motors arrangement (see Fig. 4) constitutes of three servo motors. Motor 1 was responsible for rotational motion, and the control parameters were set to a positive value for a left turn and negative value for the right turn. As for motor 2 that executes the bending task, positive angle value was set for forward while negative for the backward. Finally, for the swing motion tasks that were assigned to motor 3, a positive value is for right swing and negative value for the left one. For all motors angle degree of zero is for the initial centre position.

For generating a humanlike robot's gaze emotion, the relation between the robot angle and the emotion need to be known in advance. For that reason, we use parameters that Johnson & Cuijpers were studied [18]. In their study, 44 participants were given a set of robot's head movement direction, and they need to select which emotion plausibly reflect the head direction. The summary of the robot corresponding angle set with its dominant emotion was list out in Table 2.

Table 2. List of robot emotion and its corresponding neck joints angle

No	Robot emotion	Flexion angle	Lateral flexion angle	Rotation angle
1	Anger	20	0	0
2	Happy	−30	0	0
3	Sad	20	0	0
4	Fear	20	0	−45
5	Surprise	−30	0	0
6	Disgust	20	0	−45

6 Conclusions and Future Directions

In the first part of the installation development, our focus was to improve artificial intelligence clones' performances and follow the sentiment of generated content with humanlike behaviour. For that purposes, we designed a humanlike robot neck platform capable of reacting on six basic emotions with equivalent movements. The system detects emotions from the generated content by the artificial intelligence clones. Several basic criteria we considered to achieve smooth neck imitation movements related to an emotional reaction, such as degrees of freedom, range of motion, velocities, total payload and torque requirement.

In our further research and development of the system, we will focus on created content analysis toward a better understanding of robots' creation. Furthermore, we intend to experiment with the content sentiment and challenge robot reasoning and sentiment-driven behaviour in its own creation.

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