Emotional Intelligence in Humanoid Robots: Social and Technical Applications

Article · September 2022
DOI: 10.36073/1512-0996-2022-3-166-178

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GEORGIAN TECHNICAL UNIVERSITY

ყოველკვარტალური გამოცემა
QUARTERLY PUBLICATION

Certificate
ICI Journals master Lists

ISSN 1512-0996
DOI:https://doi.org/10.36073/1512-0996

INDEX COPERNICUS
INTERNATIONAL

შრომები
WORKS

N3(525)

თბილისი – TBILISI
2022

Founded in 1924.
Published in quarterly editions.

Collection of Academic Works of Georgian Technical University is a multidisciplinary quarterly refereed periodical included in Index Copernicus International.

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ISSN 1512-0996
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UDC 004.8
SCOPUS CODE 3301
https://doi.org/10.36073/1512-0996-2022-3-166-178

Emotional Intelligence in Humanoid Robots: Social and Technical Applications

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Abstract. Main challenge in the human–robot interaction is to endow the robots with emotional intelligence making the interaction more genuine and natural. Main aspect in achieving this goal is the robot's capability to interpret human emotions. Destiny humanoid robot will be one of the most widely used agents in human-robot interaction. Destiny robot will be equipped with a module of facial expression recognition based on CNN (convolutional neural network) facial expression recognition model with high accuracy and capability. This module will be integrated into Destiny's SDK that will allow facial expression classification. Another approach is developing a tool for emotion recognition through vocal features, such as tone, timbre, pitch or loudness making it possible to acquire machine intelligence with emotional intelligence. This feature would be especially helpful for humans suffering from emotional disorders or from the inability to express emotions. The model can detect emotional signals in the human voice using CNN.

Keywords: actuators; artificial intelligence (AI); controllers; emotional intelligence; emotional recognition; robotics systems; smart home applications.

Introduction

Latest advancements in the field of Robotics and Artificial Intelligence clarified the integration and communication problems between humans and robots. Cohabitation of humans and robots require the consideration of the most important aspect of humans' lives: emotions and, relatively, emotional intelligence. Humanoid robots are the main creatures of recent robotics development and understanding human emotions is the key factor for deeper communication. The research aims to answer the core question of modern robotics: How does the development of emotional intelligence influence human-to-robot interactions? To answer this question the authors use quantitative and qualitative research methodologies; they present and analyze data to measure the main variables of the research question, use statistical analysis and case study methods. The main case study is developed on the robot humanoid robot Ryan and finds that empathy in a social robot can encourage users to have longer conversations and, therefore, develop deep interactions. Research also finds that human-to-robot interaction keeps people in a healthier state of mind, removes stress, increases longevity and happiness. Accordingly, mentioned findings are applicable to social life, modern robotics research and development, technical designing and AI-focused areas.

Clearly, using robots for human applications is not a novel idea, but driving social or emotionally-charged interactions with robots as the initiator is one so much so that, according to the research [3], advancements in robotics have arrived at a point where robots can effectively demonstrate *emotions*. Robotics as a field has garnered a lot of attention from enterprises, startups, and consumers alike. In fact, robots are being actively used across the spectrum—from retail and airports to hotels and restaurants. This futuristic field finds many takers (and understandably so). Here's what the data tells us:

- Industrial robots have been in active use, with the World Robotics 2021 Industrial Robots report claiming that around **3 million** industrial robots are operating in factories globally—an increase of 10%.
- Research further suggests that the robotics technology market size is poised to reach **$189 million by 2027.**
- In the healthcare sector, it was estimated that about **6,000 surgical robots** [2] performed a million operations globally in 2021. The robot healthcare market is predicted to be worth USD 6 billion.
- Another survey [2] predicts that *"The Global Robotics Market will reach USD 74.1 billion by 2026, registering a CAGR of 17.45%, during the period of 2021-2026, curbing the COVID-19 involved variety of the robot technologies like cleaning and robots of disinfection service."*
- Even in the food and medication delivery sectors, an ever-growing demand for home delivery led to an explosion in the use of robots for last-mile deliveries *at scale*.
- On the manufacturing side, investments in car production capacities, as well as modernization of industrial spaces, have driven the demand for robots.

Main Part

The Importance of Humanoid Robots

With developments in technology, improved capabilities, and the possibility of an ever-widening range of applications, humanoid robots are finally becoming commercially viable across a multitude of fields. From maintenance and companionship to inspection and disaster response, humanoid robots can effectively carry out multiple tasks. In terms of how humanoid robots work, they typically use voice analysis or computer vision to identify human emotions correctly.

The origins of humanoid robots date back to 1495 when Leonardo da Vinci sketched a plan for a ***humanoid robot,*** also known as Leonardo's Robot capable of standing, sitting, waving its arms, raising its visors, and moving its head while jaw opening or closing. The first British robot, Eric, was built by World War veteran Captain William Richards and aircraft engineer Alan Reffel in 1927. There are many such instances of robots at large. Needless to say, humanoid robots have come a long way.

Humanoid robots or human-like robots are no longer a figment of our imagination. According to research by Gartner, by 2022, 10% of personal devices will have emotion AI capabilities, either on-device or via cloud services, up from less than 1% in 2018.

Recent research [6] also indicates that the market for humanoid robots is all set to expand. As per estimates, this market is valued at $3.9 billion by 2023, growing at a staggering 52.1% compound annual growth rate (CAGR) between 2017 and 2023.

Considering that these robots can effectively mimic human interactions and emotions, they have become invaluable for customer-centric sectors such as retail, healthcare, entertainment, and nearly every other domain imaginable.

Development Possibilities of Emotional Intelligence for Humanoid Robots

While industrial robots are a widely-accepted phenomenon, socially-driven humanoid robots are less popular or rather commonplace. In other words, understanding the role of *emotions* within the human-robot dynamic remains unexplored.

This is probably because while a robot may be associated with productivity and efficiency, the word robot hardly conjures words such as feelings or emotions. Furthermore, it is a common belief that while artificial intelligence robots can process human emotions so as to provide personalized experiences, they cannot intuitively emote. This reality is now changing.

According to data [7], consumers present a higher degree of trustworthiness towards robots displaying positive emotions. Additionally, robots with emotions are preferred over a neutral counterpart [8]. This is primarily due to the direct correlation between human likeness and emotions. On the flip side, research indicates that humanoid robots that imperfectly resemble actual human characteristics could provoke negative emotional responses in observers.

Humanoid robots, powered by advanced technologies such as artificial intelligence and machine learning, are now being developed to successfully understand human social cues, from facial expressions to body language. A few interesting examples to consider include:

- Hilton Worldwide employs a service robot, Connie, as the concierge. Connie, a Watson-enabled robot concierge, can perform a multitude of tasks such as helping hotel guests figure out what to visit, where to dine, and how to find anything at the property.
- Japan's Kinosaki Onsen hot spring resort has employed an interactive humanoid robot, Pepper, to communicate with tourists in the information center and provide relevant information to them.
- Disney's female robot, Ursula, can sing, play music, dance as well as speak to her audiences at the Universal Studios.
- The Henn-na Hotel in Japan is fully staffed by robots and has employed anthropomorphic robots as front desk agents. An experimental study [10] was conducted by manipulating the smiling behavior of anthropomorphic robots at the hotel. It was found

that positive emotional displays led to a higher level of perceived service quality, interpersonal warmth, and customer satisfaction.

Case Study 1: How Instagram Data Helped Uncover How Emotional Robots Influenced the Potential Consumers' Affective Feelings

According to this study [11], the humanoid robot's voice appearance, voice, and facial expressions can positively or negatively affect customers during service encounters. By leveraging psychology, social sciences, cognitive science, artificial intelligence, design, engineering, computer science, and data science disciplines, human-robot interactions can become emotionally charged.

Granted that a robot's full display of emotional capacity remains to be unearthed, it can still display varying levels of emotional intelligence depending on the technologies used. In simpler words, the emotional impact between humans and robots cannot be disregarded.

The COVID-19 pandemic has left people feeling lonely, depressed, and socially isolated. According to experts, around 36% of respondents reported feeling lonely "frequently" or "almost all the time or all the time."[12]

The Questions:

- *Can humanoid robots bridge the gap and provide much-needed comfort as well as solace?*
- *Is it possible to confer robots with emotional intelligence?*
- *Can robots infer—and interpret—human emotions?*

The Answers:

While the technology might still be in the nascent stage, the pandemic has accelerated the relationship between humans and robots. According to research [13], developing a robot that is capable of expressing empathy in accordance with users' emotional states can help businesses. Researchers believe that robots can be endowed with human-like capabilities of observation, interpretation, and emotional expression [14]. This can be achieved keeping three touchpoints in mind:

1. Formalizing the robot's own emotional state.

This step involves embedding characteristic emotional traits into robots to enhance effectiveness and adaptiveness, as well as improve believability. As per data, over the years, robots are being designed factoring in key components for modeling emotions by:

- Defining neurocomputational models;
- Formalizing them in existing cognitive architectures;
- Adapting known cognitive models;
- Defining specialized affective architectures;

2. Focusing on the emotional expression of the humanoid robots.

In complex interaction scenarios (think: assistive, educational, or social robotics, for instance), the ability of a robot to demonstrate the right emotional expression can strongly (and positively) impact the resulting social conversation.

To achieve this, modalities such as facial expression, body posture, movement, voice, etc., are being studied and used to help robots to perceive and recognize emotional states in humans.

3. The ability of robots to infer the human emotional state.

For robots to infer and interpret human emotions, they need to first be able to interact with people. The design algorithms of today help classify the emotional states from different input modalities, such as facial expression, body language, voice, and physiological signals.

Case Study 2: How Integrating Artificial Emotional Intelligence in a Social Robot, Ryan, Boosted the Robot's Effectiveness in Engaging Older Adults

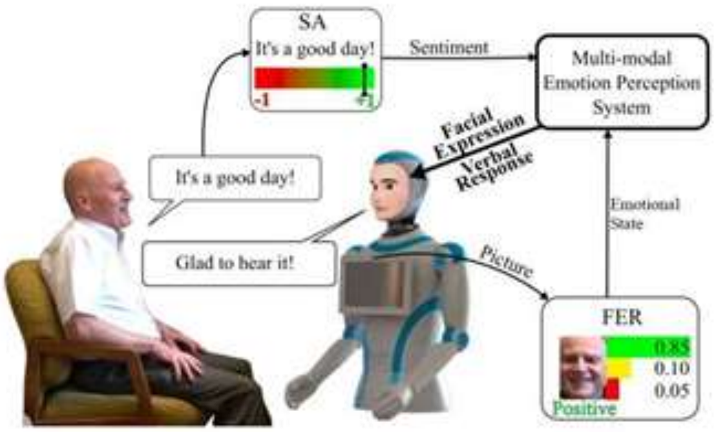

Fig.1 A multimodal emotion perception system

The central idea of this study was to use an emotionally intelligent robot to cater issues of loneliness and depression for elders. Ryan is a social robot able to assist older adults suffering from diseases like depression or dementia. In this study, two versions of Ryans were used – empathic and non-empathic – to interact with 10 older adults living in a senior care facility.

Here's a sneak-peek into the architecture of and its workings:

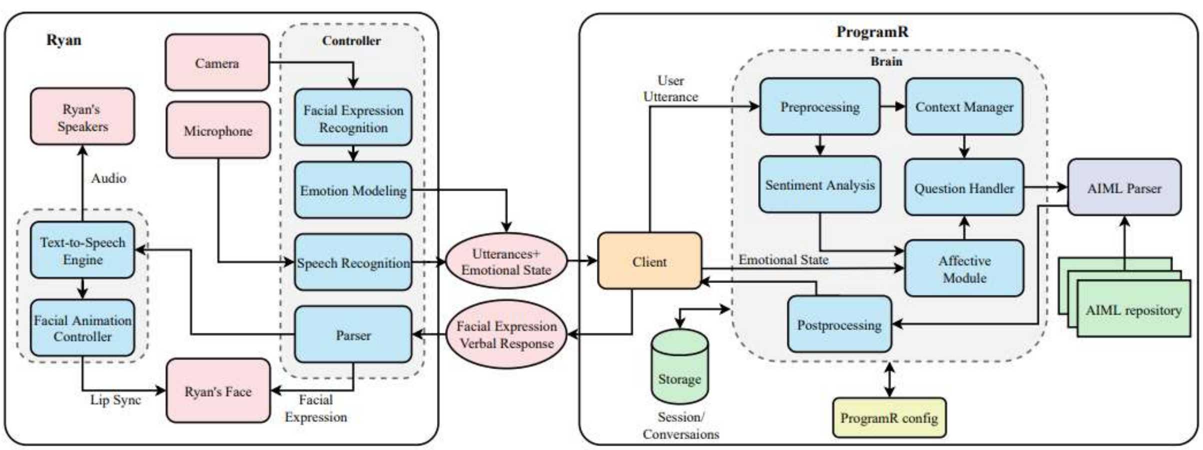

Fig.2. Ryan's software

The findings:

The empathic Ryan utilized a multimodal emotion recognition algorithm and emotion expression system, which includes modalities for emotion such as facial expression and speech sentiment to detects the users' emotional state and utilizes an affective dialogue manager to generate a response.

Here are users interacting with Ryan:

The non-empathic Ryan lacked facial expression and used scripted dialogues that did not influence the users' emotional state.

How Can Humanoid Robots Become Emotionally Intelligent?

It is the prevalence of Big Data that empowers researchers to transform unstructured datasets within these humanoid robots into meaningful and interpretable outcomes. Speaking in terms of how humanoid robots work, there are various technologies at play:

- **Natural language processing**. Humanoid robots can analyze emotions/feelings via natural language processing (think: sentiment analysis) when it comes to texts and facial recognition technology for pictures/videos. Furthermore, natural language processing helps:

- Detect the polarity of text-driven information;
- Provide value with respect to the customer's feelings for service robots;
- Uncover the users' affective states when conversing with robots;
- Optimize reactive emotions to improve human-robot interaction;

- **Facial recognition systems.** On the other hand, facial recognition systems, a popular method of biometric identification, help identify and analyze human faces based on digital images or videos. This technology is widely being used by companies to detect the emotions of users for the purpose of entertainment as well as security. Robots use face-tracking technology to not only maintain eye contact but also get people's attention and initiate conversation. In fact, humanoid robots are also being embedded with gaze tracking capabilities to be able to successfully understand where the human is looking at and establish eye contact. Using this as an invaluable clue, the humanoid robot can start a conversation with the human and mimic real-life conversational scenarios.

Facial Action Coding System (FACS)

Due to its scientific objectivity, FACS has become the most well-spread and popular system worldwide. It's a detailed, 500-page tutorial on how to read faces. It contains a detailed analysis of possible facial muscle movements, their combinations, and the nature of their performance. It aims to train a system to recognize different combinations at a different speed and with different degrees of manifestation (up to barely noticeable and very fast ones). The tutorial provides photo and video examples and practical exercises.

According to this FACS system, facial expressions are divided into three types:

- **Macro-expressions** are the daily routine expressions, usually obvious to all the sides of a communication act. They last between 0.5 and 4 seconds;
- **Micro-expressions** are short, less than 0.5 seconds, involuntary facial expressions appearing when a person is trying to hide or suppress the emotion. Micro-expressions cannot be consciously controlled;
- **Subtle expressions** are emotional responses to an event, environment, or another living being. Subtle expressions are not intensified and often mark the moment when a person starts feeling an emotion.

Table 1.

Emotion	Action units
Happiness	6+12
Sadness	1+4+15
Surprise	1+2+5B+26
Fear	1+2+4+5+7+20+26
Anger	4+5+7+23
Disgust	9+15+17
Contempt	R12A+R14A

Convolutional Neural Network for FACS recognition.

Input. VGG takes in a 224x224 pixel RGB image. For the ImageNet competition, the authors cropped out the center 224x224 patch in each image to keep the input image size consistent.

Convolutional Layers. The convolutional layers in VGG use a very small receptive field (3x3, the smallest possible size that still captures left/right and up/down). There are also 1x1 convolution filters which act as a linear transformation of the input, which is followed by a ReLU unit. The convolution stride is fixed to 1 pixel so that the spatial resolution is preserved after convolution.

Fully-Connected Layers. VGG has three fully-connected layers: the first two have 4096 channels each and the third has 1000 channels, 1 for each class.

Hidden Layers. All of VGG's hidden layers use ReLU (a huge innovation from AlexNet that cut training time). VGG does not generally use Local Response Normalization (LRN), as LRN increases memory consumption and training time with no particular increase in accuracy.

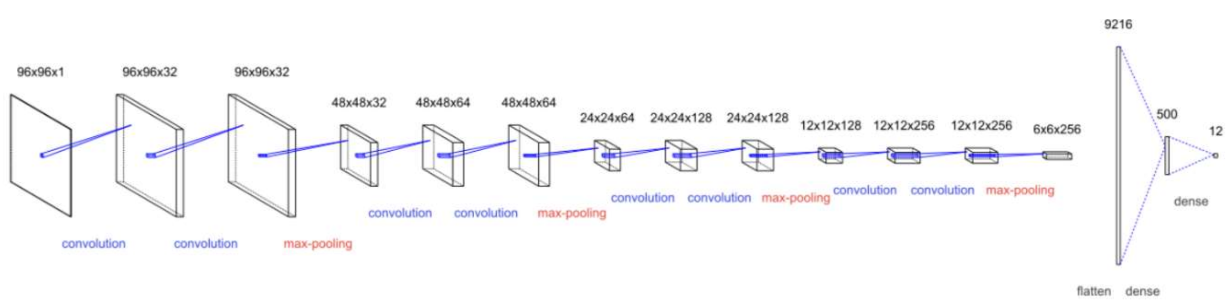

Fig. 3. VGG-16 Architecture

- **Artificial intelligence:** To top it off, improvements in artificial intelligence pave the way for cloud-based services such as the emotion/facial recognition application programming interfaces (APIs) that are provided by Microsoft, Google, and Amazon. For example, a Japanese railway company uses IBM Watson to analyze the customers' tone and emotions!

A Humanoid Robot Mechanisms

- **Sensors** – Sensors play a big role in understanding human emotions and amplifying the capabilities of humanoid robots. How? By allowing robots to perform key intellectual tasks that mirror those of their human counterparts. Note that different kinds of sensors can be used within humanoid robots, such as light sensors, contact sensors, proximity sensors, distance sensors, sound sensors, temperature sensors, pressure sensors, and tilt sensors. As an example, consider AISMO, which comprises a ground sensor on its lower torso, and which further includes:

- One **laser sensor** which detects the ground surface
- And **one infrared sensor,** which detects pairs of floor markings and helps it confirm the path navigation as per the planned map

- **Actuators** – In order to replicate a human's instinctive and dynamic actions, humanoid robots need actuators that can mimic the actions of muscles and joints and perform like them. Despite a different structure, humanoid robots can achieve human motion with rotary actuators.
- **Controller –** A controller is an integral part of a robot that is responsible for a variety of functions such as:

- Coordinating all aspects of the motion of the mechanical system in the robot
- Receiving input from the immediate environment via diverse sensors

At the core of a robot's controller lies a microprocessor that is linked with the input/output and monitoring device. Remember that the command issued by the controller is responsible for activating the motion control mechanism, which comprises different controllers, actuators, and amplifiers.

- **Electric motors (DC/AC)** – Quite simply, electric motors assist robots in engaging in rotational movements. Typically, electronically commutated DC motors are used for a lengthy life and optimized dynamics.
- **Power Supply –** The main fuel that powers a humanoid robot can be batteries with hydraulic, pneumatic, or solar power sources.
- **Artificial Intelligence –** 'Smart' robots are being powered by technological developments in artificial intelligence. AI helps replicate human processes such as the ability to learn, speak in a particular language, etc. In essence, AI is the superpower that makes humanoid robots more conversational, relatable, and interactive.

How Robot-Human Interactions Can Be Beneficial in Diverse Social Aspects

Lightening advancements in Artificial Intelligence, machine learning, hardware, robotics, and so on have helped the robots of today to evolve and recognize emotions and drive genuine, intuitive, as well as natural conversations with humans. Furthermore, Gartner predicts that more and more tech giants, as well as smaller startups, are investing in emotion AI for a good part of a decade.

However, the trouble lies on the consumer side. Humans are unable to genuinely connect with AI-powered technology because they are unable to visualize what they are interacting with. The solution lies in being able to develop a human-like interface.

So, the real question then becomes how advancements in AI-powered humanoid robots can help drive successful use-cases in people's everyday lives. The proof of the pudding lies in the diverse opportunities for applications of human-robot interactions across fields and sectors. Over the last two years, emotion AI has chartered newer territories.

Top 11 Applications of Humanoid Robots in Everyday Life

Social robots can multi-task for a variety of socially-driven applications:

- Social robots can take care of the elderly: Humanoid robots can communicate, offer personalized psychological therapy, and provide social stimulation when used strategically.
- Social robots can help the healthcare sector: As per data, humanoid robots will be mass-produced to be deployed in the healthcare sector as the pandemic wears on. For instance, a 'nurse bot' can remind patients to take their medication, they can converse with them every day to monitor the patient's wellbeing, and redirect them to doctors if need be. Disinfectant robots were widely used in 2020 to cater to the increased demands for cleanliness and hygiene.
- Social robots can assist in video gaming: By leveraging computer vision, the video game can successfully detect the myriad of emotions via facial expressions of the gamer and adapt to it.
- Social robots can drive accurate medical diagnosis: By making use of voice analysis technology, humanoid robots can assist doctors with the diagnosis of serious diseases such as depression as well as dementia.
- Humanoid robots can drive education: AI-powered learning humanoid robots can be used to adapt to the child's emotions. For example, if a child becomes annoyed with a task if it is too difficult, the robot automatically adapts the task to make it easier for the child.
- Humanoid robots can lend a helping hand to employees: The demand for employee safety solutions is on the rise. This is where humanoid robots can provide the necessary skills, knowledge, and resources to lower the stress as well as anxiety levels of employees, particularly for ones who are in demanding jobs.
- Humanoid robots can prevent fraud: An excellent example of this would be insurance companies wanting to use voice analysis. This can help detect whether a customer is telling the truth when submitting a claim or not. This type of emotional detection can save the company millions and prevent instances of fraud.
- Humanoid robots can make recruiting a breeze: AI-powered robots can conduct job interviews to understand the credibility of a candidate and assist the HR team in hiring quality talent.
- Humanoid robots can engage in intelligent routing: In the customer service space, humanoid robots will emerge as a must-have. Whether it's dealing with disgruntled customers or routing calls to the right, well-trained agent, a humanoid robot can drive all these tasks and interact with customers if the wait time is long.
- Humanoid robots can set the setting for a 'connected, smart' home: Humanoid robots can be trained to recognize the homeowner's mood and respond accordingly.
- Humanoid robots can help gain invaluable customer information in the ecommerce and retail sector:

Retailers are increasingly installing computer vision and emotion AI technology to collect key demographic information as well as data on the customer's moods as well as reactions.

Conclusion

With intense research in the humanoid robotics field, these futuristic, multi-tasking robots are finding applications across all industries and sectors. Forward-thinking countries such as the United States, Japan, South Korea, Canada, and the United Kingdom are driving increased robot adoption. It is safe to assume that there's continuous development to understand and simplify the interaction between robots and humans in the field of research. Research answered to the main research question: How does the development of emotional intelligence influence human-to-robot interactions? Used quantitative and qualitative methodologies and different structural cases studies, found the social applications of humanoid robots in peoples' everyday lives. Emotional intelligence is the key point where robots can develop meaningful relationship with humans: increase their happiness and longevity, reduce stress and the amount of routines, that is the area where tremendous positive effects are identified.

The takeaway: Despite all these examples, it is critical to note that there are several barriers to adoption. As mentioned earlier, the technology is still in its nascent stage. Moreover, trust issues around emotion AI technologies remain the biggest concern. As more and more people warm up to the idea of human-machine interactions, humanoid robots will become more and more commonplace. A transparent data management policy can help AI-driven organizations to gain their customers' loyalty and lay the foundation for a trustworthy relationship going forward.

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 ISSN 1512-0996