INTRO TO ROBOTICS COMP20170
ASSIGNMENT 5: ESSAY
GROUP 4

INTRODUCTION:

This paper discusses the functionality and operation of the humanoid robot Pepper, made by Aldebaran United Robotics Group, its relevance to the fields of service, hospitality and healthcare, and its contributions to human-computer interaction. In this paper, Pepper's hardware and software capabilities are dissected, with a brief overview of its sensors, degrees of freedom, and general kinematics, along with its implemented algorithms for functionalities like navigation, facial and emotional recognition and intelligent speech. Furthermore, the role, ethics and future of sociable robots are conferred about in brief, giving us an inkling into the future of human and robot cohabitation.

ROLE, HARDWARE AND SOFTWARE INTRO:

Pepper is described on the Aldebaran website as "the world's first social humanoid robot, able to recognise faces and basic human emotions…optimised for human interactions…able to engage with people through conversation and his touch screen" (a, Aldebaran, no date, para. 1). It is about "4 feet tall, gets around on wheels, and has a tablet in the center of its chest." (Johnson, 2018, para. 2) . Made in conjunction with SoftBank Robotics in Japan, it sold out on initial release, and was popularly used in banks, airports and shops to greet and guide customers (Nichols, 2015). Its main role can be equated to a concierge, suited to interacting with clients, providing directions or recommendations, and doing other "soft service" related tasks, supported by the fact that it can not only recognise emotions, but emote itself. Equipped with a variety of interactive sensors, cameras, sound devices and LED's, it moves around using autonomous navigation with some degree of object and collision avoidance (b, Aldebaran, no date). Its base operating system is NAOqi (c, Aldebaran, no date), a proprietary Linux-based OS also used in NAO, the first robot Aldebaran worked on before Pepper (Nichols, 2015). NAOqi contains some well defined API's that control the robot's movement and behaviour, from avoiding objects to blinking and developing a dialog lexicon. Altogether, Pepper's software and hardware transforms it from a device with motors and parts to something that humans can emotively "read" and therefore attach to.

HARDWARE:

Going over its parts specifications (d, Aldebaran, no date), Pepper contains a lithium-ion battery that runs for about 12 hours, a 10inch touch display on its chest, 20 motors in different parts of its body, including its 3 wheels and several joints, and a variety of sensors and output devices, namely:
- 4 microphones and 2 loudspeakers at its head
- 2 2-D cameras and 1 3-D sensor at its head
- LED's at its eyes, ears and shoulders
- A gyro-sensor and accelerometer at its torso (the Inertial unit)
- 3 bumpers at its base
- 6 lasers at its base for front ground and surroundings evaluation
- 2 sonars at its base front and back
- 29 magnetic rotary encoders, using Hall-effect sensors for proprioception
- Touch sensors, 3 on its head and 2 on its hands

These sensors are used by its operating system's Extractors (e, Aldebaran, no date) to glean information about Pepper's environment, so that it can activate certain event listeners via external stimuli, to move its Autonomous Life State Machine from one state to the next. Certain states and event listeners start and stop corresponding Activities and Autonomous Abilities (f, Aldebaran, no date). More behaviours and animations can be added using Choreographe, a desktop application that provides a no-code drag and drop interface for Pepper's behaviours (g, Aldebaran, no date).

MOVEMENT:

Pepper has 20 degrees of freedom for natural movement (a, Aldebaran, no date). We can immediately see that rotational matrices prove essential for determining the range of motion for joint motion and movement. The technical specifications website explains that a frame is placed at a "fixed" joint closer to the torso, and roll, pitch and yaw rotations take place along the X,Y and Z axes (in that order) (n, Aldebaran, no date). Centers of Mass (CoM) are specified for each individual "body" part - these form the origin points for the coordinate systems of movement (o, Aldebaran, no date). Certain joints are linked together to form a "chain" for movement (eg. the joints of an arm). The very end joint is the effector, and its position is defined in relation to the last "fixed" joint in the chain (p, Aldebaran, no date). These relationships enable us to keep track of rotational matrices for inverse kinematics using Cartesian coordinates (q, Aldebaran, no date) , which is what the robot uses, along with angle interpolation (r, Aldebaran, no date), for its key motion methods in its API. For inverse kinematic methods, a Jacobian matrix with Cartesian coordinates is used, specifying the target position of the end effectors. A combination of these motion methods allow the robot to move from one saved "posture" to another in its predefined code, by computing "a path from its current posture to its target posture", with the postures saved as a set of floating points (s, Aldebaran, no date). The NAOqi API includes predefined postures such as "Crouch", "Sit", "Stand" and "LyingBack". This motion capacity also enables a list of idling motions in the API to be executed, such as "BackgroundMovement" and "ListeningMovement" (t, Aldebaran, no date). Thus, motion is implemented through listening to events or "Launch Triggers" in the environment using its sensors and extractors, and then starting an "Activity" like talking or moving somewhere specific, making the robot enter a "State" (u, Aldebaran, no date) . Each "Activity" has a set of motions or behaviours associated with it (v, Aldebaran, no date). A behaviour uses key controlled movements like joint positioning and walking in the ALMotion API (w, Aldebaran, no date).

NAVIGATION ALGORITHMS:

Besides Pepper's general movement, there are also some unique algorithms for reflexes implemented. Pepper's API includes general checks to avoid self-collision, so the movement of a part doesn't accidentally collide into another part (x, Aldebaran, no date). It is therefore always aware of its head and body. For external navigation, Pepper incorporates a version of VSLAM (visual simultaneous localisation and mapping) to gather environmental data and create a map of the environment (up to and longer than 200 meters) and points of interest (b, Aldebaran, no date). It is thus able to orient itself in its surroundings using its Visual Compass API (h, Aldebaran, no date), which "gives the current rotation angles of the robot compared to a given reference image along the Y and Z axis" by matching extracted key points from a current camera image with the saved and built environmental map. Pepper also uses its sensors actively to avoid collision with objects in its path when its navigateTo( ) method (or other navigation methods) are called (y, Aldebaran, no date). It uses holonomic path planning with a set of constraints (Suddrey , Jacobson, Ward, 2018), and then recalculates its path trajectory if it encounters an obstacle within its "security distance".

Lastly, Pepper’s API includes Push Recovery (z, Aldebaran, no date), which does its best to stabilise the robot if pushed, and a Fall Manager (aa, Aldebaran, no date), which protects the robot with its arms and “ragdolls” the robot by turning the “stiffness” off at the joints if it falls without stabilising, which it detects by its Center Of Mass changing. Aldebaran has gone on to make further hardware improvements, so that “..you can drop it from its own height 3000 times, and it will not break” (Nichols, 2015, quoting Rodolphe Gelin, para. 8). All of these functions encapsulate Pepper’s motion and navigation capabilities, allowing it to traverse a generally busy environment with lots of people or obstacles with quite a high degree of manoeuvring complexity.

ARTIFICIAL INTELLIGENCE - EMOTIONS AND SPEECH RECOGNITION:

Going over the NAOqi API, we can see some other key functionality besides movement and navigation modularised into packages. There are two key artificial intelligence features that Pepper’s encapsulates: emotion perception/presentation and speech recognition/responsiveness. The former is encapsulated in the People Perception, Core and Vision API’s, the latter in Interaction and Audio API’s (bb, Aldebaran, no date).

For emotional perception, Pepper uses facial recognition learning algorithms provided by Affectiva (Johnson, 2018). It uses its 3D camera to gauge if there are people in its “engagement zone” (cc, Aldebaran, no date). It can then use its Extractors in the Core API to “read” their faces to generate a set of numbers for their key features like their eyes, nose and mouth, stored in an array that functions as a faceprint (NEC, no date). These numbers can then be checked to generate things like a “Smile Index” as a float between 0 and 1, and various other facial expressions estmates, stored in an array of detection scores for 5 key emotions: neutral, happy, surprised, angry or sad (dd, Aldebaran, no date) - determined by having previously analysed a large dataset of other faces (Zijderveld , 2017) to learn how to generate faceprints, using a Convolutional Neural Network algorithm (Affectiva, no date). Other information is also stored, like estimations of a person’s age, gender and ethnicity (dd, Aldebaran, no date). The faceprints also help in recognising a person again. Using these estimates, it can trigger events to respond to the person’s emotions, like asking a question or offering a hug.

Meanwhile, its speech recognition features are implemented by technologies provided by NUANCE and Affectiva (ee, Aldebaran, no date), where it is initially fed a list of recognisable phrases, along with a grammar library. It then compares this to audio input, toggling a boolean value if speech is detected, and adding the recognised word to a key which stores phrases and the “confidence level” of the bot in recognising that phrase. Pepper contains dictionaries for 15 languages (a, Aldebaran, no date). Pepper also has “visual expressions” where the eyes turn navy blue while listening, and green when a phrase is understood (ff, Aldebaran, no date). The person’s voice also indicates to Pepper the person’s “excitement level” or the intensity of the emotion (i, Aldebaran, no date), which is used in conjunction with the feedback from the Vision API to create a more accurate picture of a person’s emotional level (Johnson, 2018). This is encapsulated in its Voice Emotion Analysis API (i, Aldebaran, no date), which stores the indicated emotion, as well as the emotional level, as numbers in an array. Both the visual and auditory processing methods show how Pepper emulates abstract concepts like emotions, by converting them into numerical data points.

ARTIFICIAL INTELLIGENCE - NATURAL RESPONSES:

As for its own moods, Pepper can determine this by combining a variety of factors such as its battery life, ambient environmental emotions, and if it’s faced by a person who is displaying a positive emotion etc. (gg, Aldebaran, no date). In this way, Pepper can synthesise information and respond accordingly in a human way. For example, Pepper contains pre-set “conversational skills” that extensively codify a set of conversational rules and concepts (hh, Aldebaran, no date) that make up Pepper’s lexicon and personality. Pepper can go so far as to prompt a person to chat with them using a conversation starter or “Proposal”. This, combined with the ALSpeakingMovement API (ii, Aldebaran, no date) that make Pepper’s conversational behaviour more natural. This natural and human-like characterisation is so embedded into Pepper’s ethos that SoftBank has explicit rules in how to program Pepper in a human-friendly way (How to Create a Great Experience with Pepper, no date) – expounding the facts that Pepper is a character, not just a robot, and that Pepper’s animation must not appear “non-human-like”.

USAGE:

All of these features make Pepper a robust first humanoid service robot, allowing it to fulfil roles in hospitality, healthcare, business services, and general signposting. Its capacity for the simulacrum of empathy means that it can be programmed to fulfil not just mechanical tasks, but more “human” activities like dancing, taking selfies, making a credit card pitch, or even performing Buddhist burial rites (Johnson, 2018). This means that Pepper can “interact with the unstructured spaces where humans live and work” (Nichols, 2015, para. 9), reinforced by “the powerful effect created when a humanoid accurately interprets the way a person feels and then exhibits contextually appropriate responses” (Nichols, 2015, para. 9), priming Pepper to engage in human-centric care roles like elderly care, assistive technology for children with learning disabilities or autism (E&T editorial staff, 2021), and translation aid roles for diverse crowds in airports (HMSHost, 2021). A combination of its well-designed responsive API and rounded, friendly and childlike visual hardware design makes Pepper have a high level of acceptance amongst and attachment from humans, especially in cultures used to assistive service technologies like Japan and Korea. However, in cultures where this is not the case, Pepper creates an “uncanny valley” sense leading to reduced engagement, as was the case with Pepper’s introduction in a grocery store in Scotland, which resulted in customers avoiding Pepper altogether (Nichols, 2018). However, even this experiment had an unlikely outcome of engagement with Pepper - "When we had to pack it up and put it back in the box," says a surprised Dr. Oliver Lemon, director of the Interaction Lab at Heriot-Watt, which programmed the robot, "one of them started crying” (Nichols, 2018, para. 14). This tells us that we can anthropomorphise Pepper in a lateral way when performing the same role, and that Pepper would flourish in the role of a co-bot, assisting alongside humans to make tasks easier rather than replacing them (Intel, no date) . Especially after COVID-19, Pepper’s usefulness was highlighted in a hospital reception role, welcoming patients, and taking their temperatures, to free up hospital staff to do more important tasks (I , Tyagi, 2021). So far, we have seen Pepper take up roles in airports (HMSHost, 2021), banks, government administration (II , Tyagi, 2021), schools and museums (Smithsonian Institution, 2018) - fulfilling Pepper's primary goal to “bond with people, giving them a positive, engaging experience” (How to Create a Great Experience with Pepper, no date, p. 15).

COMPARISON WITH OTHER HUMANOID ROBOTS:

Pepper is the natural next-case development of Aldebaran’s first robot project, NAO. NAO was better suited to being a programming and educational tool, due to its small size, and capacity to learn and share information (SoftBank Robotics America, no date), making it a good fit for the role of a personal teaching assistant in classrooms. Although NAO has 25 degrees of freedom compared to Pepper’s 20, its small battery life of an hour makes it unsuitable for extended use in customer settings for working shifts (j, Aldebaran, no date). The development of both NAO and Pepper paved way for Aldebaran's current project, Romeo, which is much larger at 4.5 feet and has significant improvements making it better suited to elderly and disabled care and household tasks. It is set to feature "a four-vertebra backbone, articulated feet, a partially soft torso, a composite leg exoskeleton, and a new kind of actuator that lets the robot control its limbs in a safer way" (Guizzo, 2010, para. 6), with 37 degrees of freedom, improved strength and consideration of force on its limbs (Guizzo, 2010). It would be able to do physical tasks, like opening a door or carrying out bags of garbage, that Pepper is currently unable to do. Preliminary introductions to retirement centres show that the elderly are able to attach to Romeo, finding it "cute" and 'interactive" (Nichols, 2015, quoting Rodolphe Gelin, para. 10). Thus, Pepper represents an important marker in the future of furthering humanoid robot development, in its interaction with customers, its testing of human-friendly intelligence modules, and its ability to accurately fulfil tasks over an extended timeframe, making it ideal for shift work in a customer friendly role - all undoubtedly essential for Romeo as well.

Its functionality can be compared to other robots currently on the market as well. Various generations of Honda's ASIMO robot, the first bipedal robot, perform similar functions. Designed primarily to showcase developments in robotic mobility, ASIMO is capable of recognising speech, gestures, people and environments, much like Pepper (Honda, no date). It has the additional capacity to run. With 57 degrees of freedom, ASIMO is about 4 feet, with around an hour's battery time (ASIMO by Honda, no date). However, since it was developed predominantly to showcase motion, it does not possess the expressive emotive intelligence Pepper contains, and therefore fulfils a very different role. ASIMO's production was stopped in 2018, as Honda pivoted to repurposing ASIMO's technology "for more practical use cases in nursing and road transport" (Deahl, 2015, para. 1).

Thus, Pepper's current role as an emotionally intelligent service robot is a unique one, combining various capabilities with analogues in other robots on the market, but fine-tuned in a unique way to allow for human interaction within the narrow constraints of its job focus. The data gathered from its current engagements with diverse audiences in a variety of fields also proves valuable in furthering human-robotics interactions, paving the way for better-performing robots in the future.

FUTURE OF HUMANOID ROBOTS:

While Pepper's usage might currently be limited, its presence highlights the possibility for robots to fill a gap in the human world - cohabitating with us and fulfilling not just technical roles, but abstract and emotional needs. Humanoid robots are "extensively being used for research and space exploration, personal assistance and care-giving, education and entertainment, search and rescue operations, manufacturing and maintenance, public relations, and most importantly healthcare sector" (Faisal et al, 2022, para. 8 or "2.2. Humanoid robots" para. 2). Most of these roles require not just complex task execution, but also the cognitive ability for us to relate to who we are interfacing with, and for the person, or robot, to relate back - often in a quick conversational setting to assure us of the "humanness" of what is in front of us. Already humanoid robots provide ways for the elderly and the learning impaired to take advantage of an encoded dictionary of social cues to stay socialised, improve mental health and feel a sense of community, while alleviating pressures on stretched social care systems (Booth, 2020). The humanoid robot and its functions mirrors our needs, and interestingly, encapsulates what is considered necessary to be represented as human - conversation, and the ability to respond to each other. As the technology to process and respond to more complex conversational prompts and need requests improves, the future of humanoid robots seems to be more imminently in our homes and our social circles - not as replacements for human interactions, but, as Pepper’s story reminds us, to aid, assist and add to a positive experience for humans.

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