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Guido and *Am I Robot?* A Case Study of Two Robotic Artworks Operating in Public Spaces

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Abstract
This article is a case study of two artworks that were commissioned for and exhibited in art venues in 2016 and 2017. The first artwork, *Guido the Robot Guide*, guided the visitors to an art-science exhibition, presenting the exhibits with a robot's perspective. *Guido* was the result of a collaboration between artists and engineers. The concept was an irreverent robot guide that could switch transparently from autonomous mode to operator control, allowing for seamless natural interaction. We examine how the project unfolded, its successes and limitations. Following on *Guido*, the lead artist developed the robotic installation *Am I Robot?* where the idea of a hybrid autonomous/remote-manual mode was implemented fully in a non-utilitarian machine that was exhibited in several art galleries. The article provides a concise contextualisation and details technical and design aspects as well as observations of visitors' interactions with the artworks. We evaluate the hybrid system's potential for creative robotics applications and identify directions for future research.

Keywords
Robotic Art
Robot Guide
Collaborative Robotics
Dynamc Robot Autonomy
Telepresence
HRI
Robot-human Interface

Introduction

What is a robotic artwork? As some readers may not be familiar with the term, it is important to begin by stating clearly what type of robotic systems belong to the category. Traditional media such as painting or sculpture are just some of the means used by contemporary artists, whose practice can be expressed through many different media. In a similar way to how video art was invented by artists who, in the 1960s, chose to make art with television sets and video cameras, robotic art is made by artists who choose robots as their medium. The artworks thus produced often comment on the relation of humans and technology, providing metaphors, unfolding speculative scenarios or exploring technical possibilities in a non-scientific or commercial manner. The practice of artists working with robots has sometimes been described as creative robotics, "a transdisciplinary practice that builds on the history of robotic and cybernetic art to explore human-robot configurations from a critical, socio-cultural perspective. It brings together concepts and methods from experimental arts and engineering, performance and the social sciences" (Gemeinboeck, 2017). This artistic integration of robotics and computer science started in the 1950s. Notable examples include Nicolas Schöffer's *Cysp1*, (from Cy-bernetic and Sp-atiodynamic) a mobile sculpture that responded to sound and light (1956), Nam June Paik's *K456* remote-controlled flimsy humanoid (1964), Edward Ihnatowicz's *Senster* (1970) a large scale pneumatically driven beast that moved its long neck towards visitors, as well as Stelarc's cyborg-like *Third Hand* (1980).

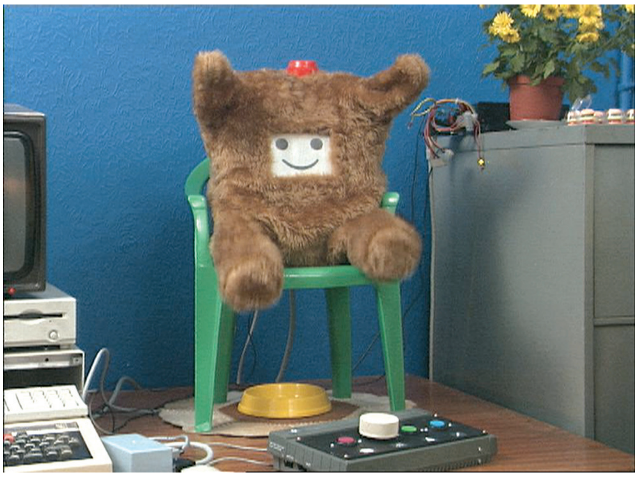

Figure 1. The Fluffy Tamagotchi, video still, P. Granjon, 1998

Paul Granjon, the lead artist for both artworks discussed here, has been making robots for live performances and exhibitions in galleries and museums since the mid 1990s. Self-taught in coding and hardware, he makes simple programmed machines that aim at provoking in the audience a reflection on what he often refers to as the co-evolution of humans and machines (Granjon, 2013). For example one of his first working robots was the *Fluffy Tamagotchi* (1998) [Figure 1], a teddy bear-sized noisy and messy robot that claimed to bring back the physicality of pets to the sterile interactive toy. The robots he made since continue to raise questions about our needs and uses for robots and other contemporary technologies while exploring in a practical manner some of the possibilities offered by these technologies. We will examine two robotic artworks operating in public spaces : *Guido the Robot Guide* (2015), a museum guide robot created in collaboration with a team of artists and engineers, and *Am I Robot?* (2016) an art installation featuring a talking mobile robot.

Museum guide robots have been tested in real guiding situation since the late 1990s. Some of them are wheeled platforms fitted with more or less expressive "faces", for example *Rhino* (Burgard W. et al, 1999), *Minerva* (Thrun et al., 1999) and more recently *FROG* (Karreman et al., 2015). Humanoid robot guides are also tested such as

Robotinho (Faber et al., 2009), *TT2* [7], *ASIMO* (Falconer, 2013). A common design of existing robot guides is a centaur-like set-up, where a full size humanoid, with or without legs, is mounted on a motorised base as seen in *Hermes* (Bischof et al., 2002), the working version of *Robotinho* and *TT2*. The guide robots mentioned above operate autonomously for both navigation and audience interaction. They are all research robots and are presently not active in galleries and museums on a full time basis, if at all.

There are cases of autonomous mobile robotic artworks sharing space and interacting with members of the public, unburdened by the task-based function of being a museum guide or another utilitarian function. Examples include Max Dean and Rafaello d'Andrea's *The Table* (1984), a mobile table interfering with visitors motions, Simon Penny's *Petit Mal* (Penny, 1997), an awkwardly balanced machine that visitors could approach for playful interaction, Maria Velonaki's *Fish Bird* (Rye et al., 2005), a pair of graceful wheelchair robots that dropped poetic notes on the floor while engaging in motion with visitors, Kacie Kinzer's *Tweenbots* (Kinzer, 2011) that were left free in Central Park, depending on the public's good will to reach their destination, as well as Carsten Holler's *Two Roaming Beds (Grey)* (Kennedy, 2015) that visitors could book for a night in the Hayward Gallery in London. All the examples above provide situations where humans and robots can share a space and interact in real time in a playful and/or exploratory fashion.

Interest in physical implementations of AI is widespread among the general public, as evidenced by the commercial success and the abundance of films, graphic novels and novels featuring intelligent machines. Celebrity robot expert Rodney Brooks has identified "a mismatch between what is popularly believed about AI and robotics, and what the reality is for the next few decades" (Brooks, 2017). Both the artworks described in the article recognise this gap and the lack of an even remotely satisfactory general artificial intelligence, the intelligence of "autonomous agents that operate much like beings in the world" (Brooks, 2017). To address the issue, both artworks use a concealed (*Guido*) or semi-concealed (*Am I Robot?*) hybrid autonomous/remote-manual mode that makes use of human intelligence in a basic implementation of collaborative robotics.

Concealed remote-control can be traced back to Baron Von Kempelen's *Mechanical Turk* automata (1770), a seemingly autonomous chess playing humanoid that was in fact operated by a short person hidden under the chess board. *The Wonderful Wizard of Oz* (Baum, 1900) is a concealed host, monitoring and affecting Dorothy and her friends' environment. Closer to us, children taking part in MIT's Personal Robots Lab experiments with cute *Dragonbots* are actually interacting with hidden researchers who control the robots' speech and motion. The set-up is semi-concealed as, after the experiment, the researchers "show [the children] the teleoperation interface for remote-controlling the robot. All the kids try their hand at triggering the robot's facial expressions" (Kory-Westlund, 2017).

The growing field of collaborative robotics provides numerous examples of approaches to partial autonomy, for example with the notion of dynamic robotic autonomy explored by Schemerhorn and Scheutz, where the sharing of a given task between the robot and the human operator varies according to the complexity of the task and the abilities of the robot and of the human. Their experiments in human-robot collaborative tasks demonstrated that subjects "accepted robot autonomy and seemed to prefer it [to non autonomous mode], even going so far as to ignore instances of disobedience and attribute greater cooperativeness to the autonomy mode" (Schemehorn et al., 2009). A related approach to dynamic autonomy is coactive design, "a way of characterizing an approach to the design of HRI that takes interdependence as the central organizing principle among people and robots working together in joint activity" (Johnson et al., 2014). In both cases the system aims at optimising the output of a robot-human team by dynamically allocating tasks to the human and/or the robot according to their strengths and weaknesses.

In the field of robotic museum guides, the collaborative approach has been explored by a transdisciplinary team in the Politecnico de Milano with a robot guide called *Virgil* (2015) that combines a human museum guide and a telepresent robot. *Virgil* possesses navigation and obstacle avoidance algorithms that operate jointly with the museum guide's commands. The authors' "new robotic service implements the concept of human-robot collaboration [...]. Conversely to many robotic solution applied in museums [...] the storytelling activity continues to be entrusted to the museum guide and a robot assumes the role of a remote collaborator, which explore the areas inaccessible for people." (Lupetti et al., 2015).

Guido the Robot Guide was commissioned as an artwork for a science-art exhibition in Luxemburg. Granjon's brief was to lead the creation, in collaboration with team of engineering and fine-art students, of a mobile robot that would guide the public through parts of the exhibition. The concept was to provide information on the artworks from the imagined perspective of an intelligent robot with an irreverent sense of humour. Unlike the robot guides mentioned above, *Guido* did not use machine vision or speech recognition. The artist's intention was that, operating by default as an autonomous machine with pre-programmed paths and speeches, the robot's voice and aspects of its motion and navigation could be over-ridden by a professional human museum guide at the touch of a button. This hybrid autonomous/remote manual mode was intended to provide the robot with a flexible, knowledgeable and responsive presence, akin to that of a human guide. A full account of the project is provided below.

Some aspects of *Guido*'s concept were developed further in another robotic artwork by Granjon called *Am I Robot?* (2016). The *Am I Robot?* installation features two parts: a mobile robot called *Combover Jo* and a semi-concealed control room. *Combover Jo* is let loose in the exhibition space, moving freely among visitors and static exhibits. Unlike *Guido*, *Combover Jo* has no utilitarian function, no job. It cruises at a leisurely speed, pronounces randomly selected sentences and navigates around obstacles and visitors. At times, the visitors can engage in complex conversations as well as interactive motions with the robot where for example the robot follows a specific individual or responds to verbal commands. This intelligent behaviour occurs when some visitors have discovered the control room and realised that they can control *Combover Jo*'s motion and speech. Other visitors might not be aware of the existence of a control room and assume that the robot is intelligent, until they, in turn, find the controls and have a go at driving the robot if they wish.

Am I Robot? relies on the playful dimension of the interaction and on the unfolding of the manual control trick to question visitors' assumptions about the current state of AI and robotics. The mismatch between most people's expectations and actual possibilities of contemporary robotic systems is significant, as was confirmed when observing *Combover Jo* moving among visitors: although incredulous about the insight of the robot ("How does it know my name?!!" was a comment heard several times), a majority of individuals did not question the autonomy of the robot. The hybrid autonomous/remote manual mode is an effective way to not disappoint audiences' science-fiction-fed expectations, yet the control room operation offers a playful reminder that artificial general intelligence is not available yet and that HI (human intelligence) still has the upper hand.

In its current state the *Am I Robot?* installation offers a simple and effective system for implementing experimental HRI in real situations. The basic structure of the system provides a clear platform for observing public engagement and for testing different relational scenarii in research or commercial contexts. Future developments, discussed below, will likely imply a more advanced autonomous mode integrating aspects of Levillain and Zibetti's concept of "behavioural objects" (Levillain et al., 2017) and a co-active mode (Johnson et al., 2014) instead of the simple remote-controlled manual mode.

1. Results

Guido the Robot Guide

In 2013, Clément Minighetti and Marie Noëlle Farcy, curators at the MUDAM Museum in Luxemburg, started to work on an ambitious exhibition project titled *Eppur Si Muove* — and yet it moves — amous sentence attributed to Galileo. The show was going to pair science and technology artefacts from the collection of Musée des Arts et Métiers in Paris with contemporary artworks exploring scientific or technological aspects related to the artefact. In 2014 the curators commissioned Granjon to develop a robot guide for the exhibition, in collaboration with engineering, fine-art and business students from the ARTEM Alliance of higher education institutions in nearby Nancy, France (http://www.alliance-artem.fr/). The MUDAM curators had contacted the ARTEM alliance and it had been agreed that the robot guide development would be run as an ARTEM project in 2014-15. Granjon's role as lead artist for the project was to design the overall objectives for the robot, its personality, liaise with the engineering team, led by Patrick Hénaff, for hardware and interface design aspects, and to supervise the deployment of the robot in the museum. Granjon proposed that the robot was to present the exhibits from a robotic perspective, with a slight superiority complex and a deadpan sense of humour.

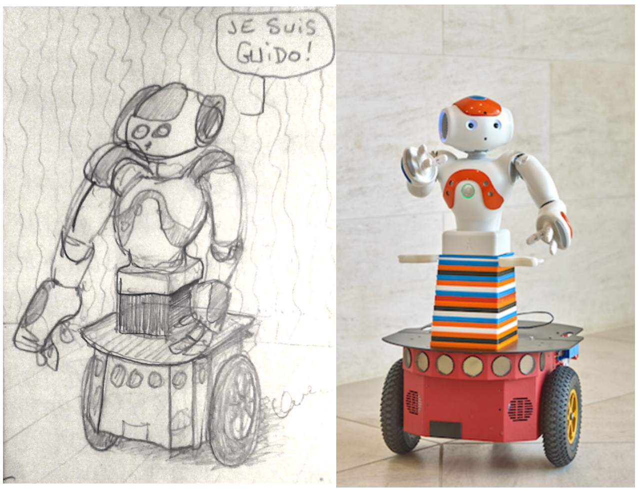

Figure 2. ***a.*** *Original sketch for Guido, Granjon 2015*
b.*Guido the Robot Guide in MUDAM Museum, P. Granjon 2016*

The budget did not allow for the fabrication of a bespoke machine. The Computer Science department at l'Ecole des Mines de Nancy owned several *Nao* robots and two Pioneer wheeled platforms that they agreed to lend for the duration of the project. After assessing the *Nao's* walking capabilities, it was quickly established that the robot's speed and balance were not sufficient for robust delivery of guided tours. Two of the lab's *Naos* were torsos, identical in specifications and looks to full *Naos* but deprived of legs. The team tested mounting one of these on the Pioneer platform and decided that *Guido* would be built on that model. The centaur design [Figure 2b] combines the robustness and precision of a differential drive wheeled robot with the appeal of *Nao*'s cute humanoid features and access to its built-in social robot capabilities such as speech, speech recognition, touch sensors, realistic humanoid motions and prehensile hands. Granjon decided to call the robot *Guido*, a friendly name that refers to its job in the museum.

The engineers' main interest in the project was to program a mobile platform for pre-determined navigation task using odometry to access a series of via-points, while being able to deviate from and return to its route if an obstacle blocked it. They were also keen to devise a

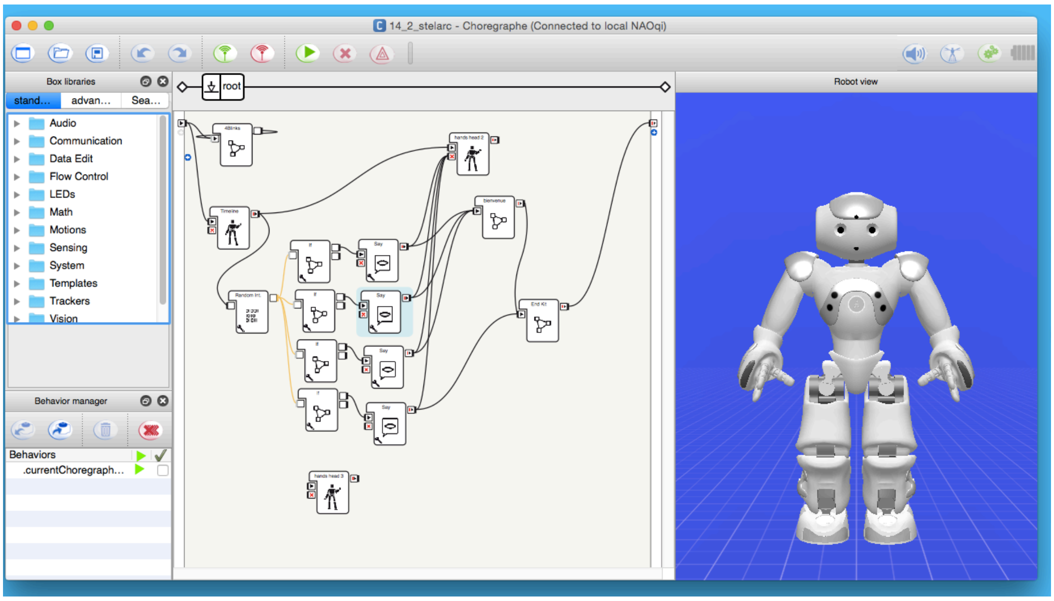

Figure 3. Aldebaran Choregraphe programming environment screen shot

robust integration of the Pioneer base and the *Nao* torso.

The fine-art students started to experiment with scripting monologues and matching gestures for the robot using the Aldebaran's Choregraphe visual programming application [Fig. 3]. Some of the test scripts written by the students contained verbal interaction with the public, the robot branching in one or other behaviour depending on the response. The *Nao's* speech recognition system quickly showed its limits, achieving a recognition rate of less than 20% for simple words like yes and no in a reasonably quiet office environment. We decided to use this feature sparingly in the final design, given that the robot would have to be deployed in large rooms with the visitors standing at a distance of one or more meters from the robot. Due to other commitments, all fine-art students but one did not follow the project until the end. The remaining student Alix Désaubliaux and her tutor Maxime Marion became very apt at programming the *Nao* with Choregraphe and custom scripts [Fig. 8]. They contributed significantly to the timely delivery of *Guido*. In agreement with the curators it was decided that *Guido* would speak French, one of the three official languages spoken in Luxemburg. As *Nao's* makers Aldebaran are based in Paris, French was *Nao's* first language. The robot's speech synthesizer is apt at producing a clear and melodious child-like French voice.

Granjon worked with the curators to make a selection of 17 exhibits from two connected spaces of the *Eppur Si Muove* exhibition. The two spaces were located on the same level, separated by a 20 meters long hallway, and all the floors were made of smooth stone very suitable for the robot's wheeled motion and odometric navigation. The robot was programmed to follow a series of via points that led it from artwork to artwork. It stopped and delivered a scripted comment in front of each artwork. A set of custom gestures was programmed for each artwork and for several interstitial behaviours. One of these behaviours was a Tourette function where the robot would briefly interrupt its current action and gently swear. Another was a walking-like arm motion and a musical clockwork sound when the robot travels between two exhibits. The detailed content of the visit is not within the scope of this article, but we provide two examples of scripts—one for a technological artefact, the other for a contemporary artwork —so as to give the reader a clearer idea of the guide's robotic perspective and of the familiar relation the robot was attempting to create with the human public. The first speech comments on a vintage car battery: "The following example is a Tudor lead-acid battery made in 1947 for automobiles. We can see that the quality of machine food is improving rapidly. This is not yet of cordon bleu standard, but it smells quite good electrically speaking, even if the old lead acid technology is a bit like baked beans: rather heavy and emitting lots of gas. Personally I prefer lithium ion, much more energetic and sooo tasty!". The second example was related to the *Tool Bones* sculptures by Damian Ortega (2013), a set of traditionally cast bronze objects combining features of human bones and common tools such as hammer or pickaxe: "Well, I went a little too far earlier when I spoke about you humans as an obsolete species. An alternative exists which has already begun: a future where human and machine merge and become a hybrid entity called cyborg. These intriguing objects made by Damian Ortega evoke a likely alternative to the obsolescence of homo-sapiens, a deep bio-technological mutation where the tool integrates with the skeleton. Your children or grand children might benefit of this new potential, living in harmony with my future cybernetic fellows".

The original idea was that after *Guido* delivered its speech on a given exhibit, it would answer visitors' questions. This would be done by switching to remote-manual mode, a human operator temporarily and transparently becoming *Guido*'s ears eyes and brain. A basic function was created that provided a joystick for over-riding the autonomous navigation and a keyboard interface for speech input. This version was sufficiently developed for testing and for planning improvements but not enough for use during visits. We will analyse the subsequent shortcomings on the robot's potential to engage with the public in the discussion section of the article. *Guido* delivered a couple of public visits a week in MUDAM between July 2015 and January 2016 [Fig. 4]. It was then returned to the Ecole des Mines de Nancy where it was painted white and made into a dancing robot called *Minoid*.

Figure 4. Guido and young visitors during a guided tour, P. Hénaff, MUDAM 2015

Am I Robot? robotic art installation

In October 2015 Granjon started work on a new commission for a robotic art installation. He had been invited to contribute to a new exhibition curated by Clare Gannaway in Manchester Art Gallery (UK), titled *The Imitation Game*. According to the gallery's website "*The Imitation Game* was an exhibition by eight international contemporary artists who explored the theme of machines and the imitation of life. [..] With a title inspired by Alan Turing's *Turing Test*, devised to test a computer's ability to imitate human thought, introduced in an article while he was working at The University of Manchester, *The Imitation Game* included three new commissions and works never before seen in the UK." [22].

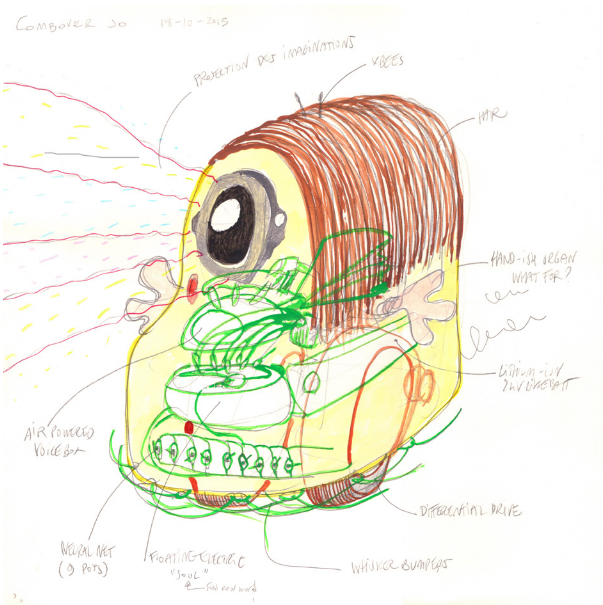

Figure 5. First visualisation sketch for the Am I Robot? robot Combover Jo, P.Granjon 2015

Granjon's project was to push further the concept of a hybrid autonomous/remote-manual system touched upon in *Guido*. He imagined a non-utilitarian non-humanoid mobile robot that would roam on the gallery floor [Fig.5]. The robot would be able to talk, navigate and display several behaviours autonomously. It would also be at times remotely controlled without a noticeable change in voice or motion. The curator found the idea interesting and Granjon was given the green light to build the installation that he called *Am I Robot?,* turning the title of Isaac Asimov's famous collection of robot stories *I, Robot* (Asimov, 1950) into a question that gave an indication of the robot's partial autonomy. The exhibition occupied two levels of the building. The robot was allocated a large roaming area on the first floor while the control room was installed on the second floor. The control room was not advertised or sign-posted as such. It was installed inside a specially built cubicle that visitors could freely access [Fig. 6c]. Most visitors would have already visited the first floor and seen the robot prior to entering the control room. In the room they found two monitors, speakers, a joystick, a microphone and a keyboard [Fig 6b]. One of the monitors displayed a live video feed from the robot while the other showed text that could be inputted through the keyboard or the microphone. The speaker played live sound captured by the robot's on-board microphone.

The robot itself [Fig. 6a], like *Guido*, was based on a differential drive platform. Unlike *Guido*, it was built from scratch in a manner more similar to Granjon's usual method where a "low-level, empowering methodology [is] based on a first hand understanding of principles at work in the electronical-mechanical objects I build" (Granjon, 2007). Significanlty less complex in software and in hardware than *Guido*, the robot's body was built from a Beseler Vu-Lyte 2 epidiascope (1956), a distant ancestor to the data projectors now used in education environments, providing a bulk slighlty smaller than an R2D2 unit. The robot was not given a face but had two three-fingered hands and a mock combover of brown electrical cable running across its top. This last feature provided the robot's name: *Combover Jo.* The motorised hands originally fitted on the robot were removed in the final version of the robot due to catching walls and fixtures, leaving the robot without any humanoid characteristic but the lens of the epidiascope turned into a sort of eye with a circle of green

Figure 6. clockwise from top: a- Combover Jo robot version 1 (Manchester), photo credit Michael Pollard b- Am I Robot? control room controls, P. Granjon c- Am I Robot? Control room outside, P. Granjon.

LEDs. The robot's non-threatening, almost comical appearance aims at putting the visitor at ease, removing apprehension, fear or uncanny valley-related unease. *Combover Jo*'s top speed is approximately 0.5 m/s. In autonomous mode it avoids obstacles, including visitors and pronounce randomly one of 200 pre-programmed sentences at irregular intervals. It speaks English or Spanish with a distinctly robotic voice that is neither male nor female. The sentences range from humorous greetings such as "Hello Dude", "Hello Dudette" to deeper existential reflections like "Where is my soul?" or "I was not born". Green coloured stripes on the floor mark the limits of the robot's domain. A colour sensor fitted under its base triggers a u-turn manoeuvre when it detects green. Detection of a red floor area activates the robot's dream state, where it will stop when close to an obstacle and project through its eye-lens a short pre-recorded video sequence, presented in the exhibition catalogue as a "robot dream" (Furber et al., 2016). The dreams feature non-narrative edits of technology and science footage combined with images of nature. As soon as a visitor touches the joystick in the control room, *Combover Jo* switches to manual mode. Text typed or dictated in the control room is transmitted to the robot and pronounced in the same voice and tone as the pre-programmed sentences. The robot moves under joystick command with an overriding avoidance manoeuvre taking over when it is too close to an obstacle while moving. When the robot is not moving while under manual control, visitors can get to touching distance.

Am I Robot? has been exhibited in three different exhibitions at time of writing, with a significant upgrade installed for the last showing. In all cases three main types of interaction with the robot were observed:

- No interaction, the visitors avoids or ignores the robot and continues on their initial destination
- Attempt to interact physically, for example by standing in the way of the robot or dancing.
- Talk to the robot.

The last two types interactions do not last more than approximately one minute when the robot is in autonomous mode (unless the visitor is a child). When in telepresent mode, the interaction becomes much more involved and complex. When the visitor in the control room has mastered the controls, *Combover Jo* becomes really responsive. It can comment on a visitor’s clothing or even, when the driver knows the person in front of the robot, call them by their name or ask knowing questions. It can also follow or avoid specific members of the public or perform basic dances. More than half of the visitors observed assume that, when in tele-operated mode, the robot is autonomous and driven by an AI program. Children tend to question less than adults the personal knowledge the robot might demonstrate and enjoy playing and conversing with it. Some adults will react incredulously (“How does it know my name?!”) but still not suspect that another human is behind the intelligent behaviour of the robot until they enter the control room or another visitor informs them about its existence [Fig 7b]. In the control room, visitors tend to behave like tricksters [Fig 7a], giggling and prompting each other to enter text that will trigger optimum response from *Combover Jo*’s current interlocutor. Other visitors who might not suspect another human to be in control when the robot simply greets them become suspicious when it starts to show too much knowledge, humour or general intelligence.

*Figure 7. **a.** visitors in Am I Robot? control room. **b.** Combover Jo version 2 (Hull) and visitors in the gallery space. Photos credit Tom Curran*

Figure 8. ***a.*** *Alix Desaubliaux and Maxime Marion working with Naos in Ecole des Mines de Nancy, 2015.* ***b.*** *Mehdi Adjaoue and Romain Schumers with two Guidos in MUDAM, 2015. All P.Granjon*

2.Discussion

Guido

The navigation and spatial accuracy of the robot were very good, *Guido* succeeded in positioning itself by the artworks for script delivery with an approximately 20 cm precision, even if it had encountered obstacles on the way. The integration of the *Nao* torso with the Pioneer P3DX base was also very functional and robust, with seamless communication between the two units.

During the preparation of the *Guido* project, the MUDAM Museum guides expressed a semi-serious concern about the future of their jobs: would visitors prefer the robot guide's visits to the ones they were paid to deliver. After seven months of robot visits they were fully reassured: a common response from visitors was that after an initial peak of interest due to the unusual nature of their guide, they realised its limitations, the rigid nature of its performance and lost interest. This had been anticipated by Granjon whose response was to imagine a robot with a hybrid autonomous/remote manual mode manned by a trained operator. The rationale behind the decision to implement a hybrid system was motivated by two main factors:

- The budget, timescale (8 months), and workforce available for delivering a fully functional robot guide were tight.
- More crucially, the natural interaction that was sought to achieve required a level of general artificial intelligence significantly superior to any system presently available, including all the guide robots mentioned above. Even Honda's famous *ASIMO* was not up to the task. In 2013, "to test the robot in real-world conditions, Honda set up *ASIMO* as a tour guide at Japan's National Museum of Emerging Science and Innovation. The company want[ed] to see if the robot c[ould] autonomously interact with visitors, answering questions and explaining things" (Falconer, 2013). *ASIMO* repeatedly failed to recognise visitors' raised hand motions and relied on tablet input to overcome the difficulties of real-time speech recognition in actual museum conditions.

Despite the engineering team's efforts, *Guido*'s complete hybrid mode was never delivered due to two main reasons:

- The budget was not sufficient for training and paying the wages of a professional museum guide who would have supervised all the visits throughout the exhibition. This person would have had a key role, ready to switch to remote manual mode anytime a visitor had a question, or when he/she would have spotted a good moment for snapping off the recorded script and comment, for example if someone's phone was ringing or if a child had a robotic toy.

- The speech input function, that would have allowed the responsivity required for a full conversation level of interaction with *Guido*, was never implemented.

In their work with the human guide-controlled telepresent robot *Virgil* mentioned above, Lupetti et al. state that "keeping the storytelling activity performed by the museum guide is fundamental due to the fact that only a human can provide the interpretative aspect. The interpretation [...] is the process in which the museum guide can create links between the visitor culture and the heritage contents. This process allows visitors to develop an empathic relationship with both the museum guide and the cultural heritage itself." (Lupetti, 2015). Similarly Granjon places a crucial emphasis on the role of the human in the loop as a factor of empathy with the robot. He favors a collaborative approach where the robot is given space and time to operate in full autonomy while a human operator monitors the activity and can take over aspects of the interaction when the robot is not able to deliver a convincing behaviour. Granjon sees variations on this approach, at least for the present and mid-term prospects of general artificial intelligence, to be the only available tool for answering the audience's expectations for a truly engaging robot.

Am I Robot?

The conclusions drawn from the *Guido* project strongly informed the conceptual and design decisions for the *Am I Robot?* installation. Most importantly, *Am I Robot?* delivers a fully functional hybrid mode. In addition, *Combover Jo*'s non-humanoid design and the lack of a utilitarian role are intended to reduce the amount of pre-conceived opinions regarding the robot's role or intelligence. Levillain and Zibetti examined several non-humanoid, non-utilitarian robots in their research on behavioural objects, artifacts with life-like interactive behaviours made possible by techno-scientific developments, shifting away from the status of simple objects. They posit that "the appearance of a humanlike robot prompts attributions of the capacity to feel and sense. This kind of assumption may conflict with the actual behavior of the robot, which is often not as sophisticated as its appearance" (Levillain et al., 2017). *Combover Jo*'s lack of humanoid or zoomorphic features does not generate the same level of assumptions (although several visitors have enquired about its ability to hoover, drawing parallels with a cleaning robot). The absence of a clearly defined function produces a similar effect: as *Combover Jo* is not presented as a guide or a receptionist, visitors do not assume that the robot will deliver a set behaviour inspired from a human guide or receptionist. Such a behaviour would most likely be inferior in presence, interaction and engagement compared to a human professional, which would leave the visitor dissatisfied as was apparent in the *Guido* project.

The notion of behavioural object can be applied further to *Am I Robot?* Levillain and Zibetti state that, "unlike the social robot, behavioral objects are not specifically conceived to serve, help, or cooperate with humans. Although they can sometimes mimic human social behavior, they are not designed to engage a user with humanlike social skills, or features such as gestures, posture, body and facial traits that organize the social interaction" (ibid.) Behavioural objects can be used for exploring aspects of HRI, especially playful and explorative interactions, that would be more difficult to access with task-oriented anthropomorphic social robots. In the same way as a humanoid robot elicits a specific set of expectations, a social robot will also be expected to behave in a helpful, utilitarian and benign way. Granjon examined the limitations imposed on the exploration of the true potential of machinic life — a notion explored by Johnston as the capability of a machine "to alter itself

Figure 9. Visitors socialising with Combover Jo during the States of Play exhibition, Hull UK, 2017. a: photo credit Tom Curran. b: P. Granjon

and to respond dynamically to unknown situations" (Johnston, 2010) — by constraining social robots to a benign role. He suggests a creative robotics approach to non-benign experimental robots where "non-benign [...] does not stand for malign, but instead aims to define an area where a wide range of autonomous behaviours are possible, covering a full gamut of possibilities which may include aggressive as well as friendly traits." (Granjon, 2017). The notions of behavioural object and of non-benign robot share the characteristic of not being designed for serving human needs, allowing exploration of speculative HRI scenarii not subjected to utilitarian, commercial or scientific constraints.

In that manner, *Combover Jo*'s non-utilitarian and non-humanoid characteristics, combined with a robust, safe, human-friendly design and an absence of instructions not to touch or get too close to the robot aim to lay the foundation for an open human-robot relationship. Granjon's observations of visitors' interaction with the robot confirm that in many cases a natural interaction occurred, especially with children but also with adults. Largely perceived as a friendly creature, *Combover Jo*'s unassuming presence is a simple but effective way to engage humans. The semi-concealed control room trick is not a lie, as visitors are implicitly invited to discover the controls. The trick operates instead on two levels:

- It allows the emulation of an intelligent robot (of the future?), capable of initiative, humour, conversation, and moods.
- The robot's disclosed reliance on HI for delivering an intelligent presence raises questions about the capabilities of general artificial intelligence in comparison to humans'.

Directions for future research

There is no plan at this stage to continue research and development of a museum guide robot. After the initial exhibition in Manchester, the *Am I Robot?* installation was shown in the Oriel Mostyn Art Gallery in Llandudno UK and in the *States of Play* exhibition organised by the British Craft Council in Hull UK. It was included in *Prototipoak*, a creative robotics exhibition in Azkuna Zentroa Arts Center in Bilbao Spain in summer 2018. Public interest in and engagement with the installation motivates further development of non-utilitarian collaborative robotic artworks. Two main aspects need to be addressed in future projects:

- improving the quality of the autonomous mode by integrating machine vision aspects such as people detection and face recognition, basic speech recognition, and more importantly a learning function that would allow the robot to generate new behaviours from past experience. The learning function would include a curiosity factor inspired by Kaplan's work with *Aibo* robot dogs [31]. The autonomous mode could be further improved by studying visitors' reactions to various programmed behaviours following on Levillain and Zibetti's concept of behavioural objects.
- develop a more complex and integrated collaborative mode instead of the current basic tele-operation. More functions could remain shared between the robot and the human. Some of these functions would be influenced by the learning engine of the robot, acting as a sort of personality that could be only partially over-ridden by the human. This advanced collaborative option would implement aspects of the co-active approach described by Johnson et al., where the robot and the human operate as interdependent team partners.

3.Materials and Methods

Guido

Hardware

Guido was based on a standard *Pioneer P3-DX* differential drive mobile base on which a *Nao* T14 torso was attached. The torso was raised with a stack of perspex slabs so as to bring Guido's head to a height of approximately 60 cm. Communication between the base and the *Nao* was effected by an on-board NUC computer connected with an ethernet cable. The Pioneer base was fitted with two 12 V lead acid batteries that were also used to power the NUC and an on-board Wifi unit. The base was connected to the NUC by USB. The *Nao* torso was powered by its own built-in battery. An emergency stop button mounted on the platform could interrupt the supply of power to the motors. At times an amplified speaker and an external microphone were used to amplify Guido's voice. We also experimented telepresence with a Wifi camera installed at the front of the Pioneer base. Built-in ultrasound sensors and bumpers on the P3-DX, combined with on-board odometric hardware were used for navigation and obstacle detection.

Software

The Pioneer mobile base embeds the Aria operating system that allows real-time execution of low-level programs for control and management of sensors. It was programmed with the Aria API. The program integrated specificities of the robot's field of operation such as the percent of wheel slip on the stone floor, calibration of the magnetometer according to the ambient magnetic field as well as the maximal and minimal values of emergency acceleration and de-acceleration. The *Nao* torso runs Gentoo Linux from a built-in computer located in the robot's head. The two robots have been integrated into the framework ROS (Robotic Operating system) running on Linux Ubuntu 12.04, installed on an on-board NUC PC [Fig. 10]. ROS allows communication and exchange of informations between several communicant objects in a robotic project. Here it allowed to build the control architecture of Guido by creating software links between the Nao (using Aldebaran's Nao-dedicated programming environment NaoQI2+ and the Pioneer P3DX (using its specific layer ROSAria) and the remote monitoring computer through the Wifi network. All the programs of the control architecture are coded in C++. An algorithm based on Braitenberg's vehicles was used for a fluid obstacle avoidance. The voice and gestures of the *Nao* torso were programmed with Aldebaran's Choregraphe. Choregraphe uses a visual timeline and drag and drop function boxes that also give access to C-like scripting. Pre-scripted functions can be called sequentially or in response to sensor inputs or Wifi commands.

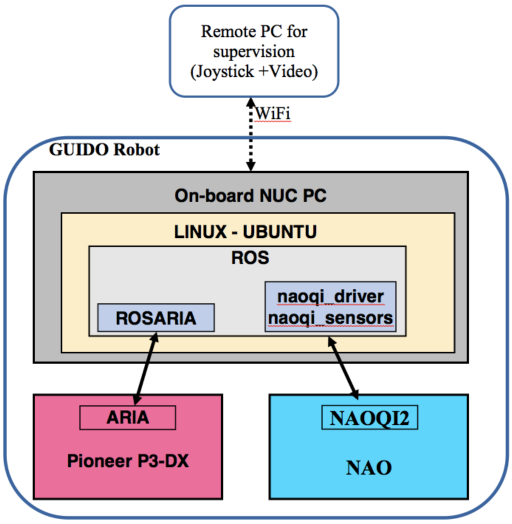

Figure 10. Guido's software architecture

Am I Robot?

Hardware

Combover Jo's body is based on the shell of an *ITM Vu-Lyte II* epidiascope, sprayed metallic purple. The shell is mounted on a bespoke aluminum platform. Two DOGA 12 V 60 W motors provide up to 80 rpm to the 20 cm diameter polyurethane scooter wheels. Two free spinning caster wheels support the front of the robot. Power is provided by a 12 V 16 aH Lithium Ion battery connected to an 8 V, a 5 V and a 3 V low drop voltage regulators. An Arduino Mega microcontroller [32] runs the main program that deals with navigation in autonomous and remote-controlled states as well as state monitoring and selection. Another Arduino Mega controls the Parallax Emic 2 text to speech synthesizer and the dream function's on-board Pico PK-120 pocket video projector. An Arduino Nano connected to the main Arduino Mega is dedicated to reading data from the floor colour detecting sensor. Three HS-04 ultrasound sensors and a front bumper are used for obstacle detection. The eye-lens cavity carries a circular array of 24 ws2812 addressable RGB LEDs and the video projector. A motor can move the lens forth and back but this function is not implemented in the current version. A Sony camera module connected to a Tramtec 2.4 GHz dedicated encoded transmitter provide video monitoring to the control room. A Sennheiser wireless microphone and transmitter provide the audio monitoring. Combover Jo's voice comes from a front-mounted speaker connected to a 12 V 20 W mono audio module that amplifies the speech synthesizer's output. Two Zigbee modules receive data from the control room: one for the joystick and one for the ASCII speech stream.

In the control room, processing is done by an Apple Mac Mini. An AKG dynamic table microphone connected to a compact 4 way USB audio mixer is used to collect the user's speech input. The base of the microphone was modified with addition of a push button, a reed relay and an Arduino Uno. The Arduino Uno controls the reed relay that cuts speech input after a set duration so as not to overload the speech to text software (see below). The Arduino also reads keystrokes from a modified PS2 keyboard used to input typed speech. The Mac Mini's keyboard is concealed, used only by staff to start and stop the installation at opening and closing times. Dedicating a keyboard solely to the speech input function is a fool-proof way of preventing unwanted user interference. Such interference happened in the first version of the installation that operated from a Chrome web interface in kiosk mode with a single keyboard. A small audio amplifier and a speaker are used for audio monitoring the on-board microphone. From the control room, several connections lead to a shelf located in the same room as the robot. The shelf carries an xBee module connected to the Mac Mini for speech transmission, an Arduino Mega connected to the Joystick and to the other xBee module for the transmission of manual navigation data, the Sennheiser audio receiver and the Tramtec video receiver. The transmission range from shelf to robot is variable depending on walls and other obstructions, averaging at 25 meters approximately for a robust video signal, and significantly more for the xBee modules' text and joystick data transmission. We observed no interference between the xBee modules and the video system or with the local Wifi network, that all operated at 2.4 GHz.

Software

Combover Jo runs on standard Arduino code, using several timers to monitor and actuate its different functions. The Mac Mini in the control room runs an application written in Xojo to manage text input from the microphone and from the PS2 keyboard. The keyboard strokes are decoded by the Arduino Uno in the base of the microphone, sent serially to the Xojo app that displays the text on the monitor. Text is sent to Combover Jo's text to speech unit either if the user presses return or if the input exceeds a set number of characters. If the user pushes the button on the microphone base, speech input is prioritised and treated by the Dictation speech recognition application built-in Mac OS X 10.10. The speech recognition software used in the first installation of *Am I Robot?* was running CMU Sphinx on a Linux machine, but this proved too inaccurate for reliable public use. The Apple Dictation and Xojo solution is very robust and approximately 80% accurate. It deals well with ambient noise and different accents. The timing device that cuts microphone input after 20 seconds was implemented to avoid overloading Dictation. Prior to that patch, the software was constantly trying to process microphone input while the user kept the button depressed and eventually crashed if the user kept the button pressed for too long. The time limit relay resolved the problem. The increased accuracy and ease of use of the speech input combined with software updates to navigation and to the dream mode brought the second iteration of *Am I Robot?* to a robust professional exhibition standard.

Conclusions

Observations of both *Guido* and *Am I Robot?* artworks in action confirm that some humans are ready to embrace friendly robots as agents, at least in the context of art exhibitions. Presently the current state of general artificial intelligence robotics is not matching humans' expectation for a robot agent, a gap that generates frustration and lack of engagement from the visitors. The collaborative robotics approach, of which several examples are mentioned above, is an effective way to overcome this expectation gap as well as being a solution for exploring speculative HRI scenarii and future human-machine cooperative systems. Granjon's ongoing interest in exploring the co-evolution of humans and machines is underlined by a belief in the importance of cultivating innate cognitive and physical human abilities. Playing a transparent trick on the viewers, who might be lead to believe they are interacting with an autonomous intelligent machine when in fact they are in contact with another human intelligence, aims to provide a playful counterpoint to the false expectations fed by science-fiction movies and non-specialist media.

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