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The Making of Robot Care

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ABSTRACT

The health industry is investing in robotics because it has the potential to optimize workflows and reduce the workloads of healthcare professionals. However, these optimizations come at a cost. By looking at three different robot systems and their underlying control architectures, this paper will describe some of the dynamics generated by the migration of computational logic developed for industrial robot systems to the healthcare domain. We combine a reading of robot control systems with perspectives from cultural techniques to uncover dynamics that neither approach can detect independently.

KEYWORDS

Robot control, robot architecture, healthcare, cultural techniques

1. Introduction

It is said that the arts can be prophetic. Yet when the Canadian artist Norman White created the first version of "The Helpless Robot" (1987) whose single action consisted in asking to be moved from one position to another, he probably did not imagine that one day, human beings might find themselves in precisely the situation he had designed for his hapless robot.

With a marked shift in the population pyramid towards the tail end of human life expectancy in the affluent, developed part of the world as well as rising costs for qualified personnel, the robot revolution that started on the factory floor is expanding to the hospital ward. Various large-scale project and "age-labs" in the United States (MITAgelab), Europe (EU Robot-Era) and Asia (RIKEN-TRI) are heavily invested in the delivery of automated health services at all levels of care giving (Kachouie et al.). This has profound implications for robots, and for people. Yet, as robots enter their new areas of operation, they carry robot history in them, and they tell a story. The proposition of this paper is that by observing this story in the inner workings of the robots, one can uncover not only details of this robot story, but seeds of future narratives. The control systems and architectures devised for precise motion and reliable action are not just applied to healthcare, they define how care is executed and experienced by human beings. Robots alter healthcare, and redefine not only the dependencies between machines and people but also the concept of care. The next sections lay the groundwork for this inquiry by situating robot control in the field of cultural techniques.

2. Control Architecture as Cultural Technique

The theoretical and methodological framework for our analysis is inspired by the recent discussions conglomerated under the conceptual framework of cultural techniques (Siegert; Winthrop-Young; Parikka). From this perspective, robots do not appear out of thin air but are generated by techniques that precede them. To clarify this point, Bernhard Siegert's re-evaluation of design practices from a material basis may prove useful. In Siegert's (120-21) reading, design has traditionally been seen as having anthropocentric origins and this understanding underlines the author/creator/designer myth, which sees every design as a product of the designer's inherent vision and creative capabilities. What Siegert (122) suggests is that instead of focusing on the designer, we should consider the different materialities and techniques that are involved in the design process.

Cultural techniques put emphasis on the technicity of the design process; how different materials and methods produce different results by conditioning what is possible. The selection and application of cultural techniques creates distinctions in the world. These distinctions are not only physical, but also symbolic and cultural (Siegert 15). For example, designing a robot brings us to a distinction between what is a human and what is a robot. This question is ethical (how robots interact with humans) but also technical, especially in the contexts where Artificial Intelligence is designed from anthropocentric perspectives (i.e. when a robot's intelligence and agency resemble human intelligence and agency). Robot designs are thus recursively intertwined with our understandings of what it means to be a human (Cf. Siegert 8-9). Processing this distinction does not, however, produce only technological results. Consider, for example, the cardiopulmonary bypass, which is a technique wherein a machine takes on the role of heart and lungs, keeping the human alive while surgery takes place (see Gibbon; Goldberg). In this "symbiotic" relationship, the distinction between what is human and what is technology is no longer defined by what is natural versus artificial, but rather it is redrawn by the techniques which operate between them. In fact, from this perspective there is no longer such thing as a human or a robot, but as Siegert puts it, "there are only historically and culturally contingent cultural techniques of shielding oneself and processing the distinction between inside and outside" (9).

The distinction between human and technology leads us to one of the key problems in designing robots: the problem of control. This problem is highlighted especially when autonomous systems, which operate without human control and supervision, are designed for contexts requiring decisions that directly impact human life such as warfare (Asaro 690) or social institutions (Crawford and Calo 312), and in our case healthcare. In this paper, we are interested in how robot control is produced through cultural techniques. To take control as an issue of cultural techniques is on one hand to understand the theoretical underpinnings of the concept and on the other to see the practical implementations of those theories and methods. Or to rephrase, what the cultural techniques perspective contributes to our endeavor is a way to unpack the processes of forming and deforming control in different contexts from software to hardware, from engineering to policy, regulation and experience, allowing us to investigate the hidden social costs through technical materials.

Let us begin with software. Friedrich Kittler's "There is no Software" might be considered an early attempt at questioning the preferential attention that cultural studies has given to software, and several researchers within the field of software design have generally acknowledged the existence of a more complex landscape with different paths along which constitutive elements of software are assembled and interlinked. Niklaus Wirth (Wirth), for example defined program as the sum of data and algorithm, while Kowalski (Kowalski) defined algorithm as the sum of logic and control.

Every program has one or more algorithms, but how the individual algorithms are linked together technically and conceptually is defined by a program's architecture. Not unlike the architecture of a house, a program's architecture offers a summary view, a bigger picture than isolated depictions of windows and heating systems. To understand robots and what makes them tick, one needs to see how program architecture establishes control over the individual parts of the system. Furthermore, understanding robot actions requires the software-centric viewpoint to address a missing element, namely, interactions with the outside world.

Moreover, control need not be explored and understood only as logic operating on the level of ideas, rather it is also located on the level of practical realisations of control problems. It is manifested in the selection of particular technical solutions or engineering practices and their affordances. Practices of control emerge through software arrangements organized under material constraints, control architectures, sensors, and surface materials; how these threads interweave in specific situations and interact with people in particular places, defines how we experience a robot.

With the exception of purely virtual robot agents, robots and humans are embodied with physical presence in the world. Looking at robot control architectures as cultural techniques allows one to understand how robots are designed to interact with the world; this approach will tell us not only how robot designers solve difficult technical problems, but also how they choose to respond to the features of the world, and how the responses are then crafted into the robot. The design of control architecture operates with distinctions: the world is defined in a particular sense perceivable and graspable to the technologies and devices at hand. That which is perceived in relation to the cognitive and mechanical affordances of the robot becomes the way world is “taken in” and processed.

A control architecture inclusive reading of a robot then allows one not only to understand what a robot can do, but to see what its limitations are and how the system manages those limitations. Control architectures are the blueprints of potential robot behavior. They show what a robot is, and also what it can be. Through observations of robot control affordances we can construct a more robust bridge to a critical position on the actual making of relationships between robots and human beings. In order to illustrate various pathways along which such dynamics play out, we will examine three different robot systems: Paro, ASPIRE and RIBA. In all three cases we will focus on how these particular healthcare robots manifest the logics of control in their own ways, and how these actions directly and indirectly impact the making of robot healthcare.

3. Paro

Paro is the name of a robot that resembles a baby harp seal in appearance. Paro is conceived as a companion for hospital and nursing home patients. The designers contextualize the usefulness of such a robot with the fact that animals in general have been shown to be beneficial to people in emotional duress (Baum et al. ”Physiological Effects”), and that many hospitals no longer allow animals on the premises due to hygiene constraints.

Paro’s effectiveness is a product of multiple factors combined into a believable package; it is a competent deployment of animatronics consistent with the Japanese robot tradition (Schodt). First, Paro is a small and cuddly toy, similar in weight and size to a human infant. Paro is covered in white faux fur, and responds to voice and touch. Paro is mostly immobile, and can produce slight body motions and high-pitched sounds reminiscent of young mammals. Prior to the robot seal, the Paro designers experimented with other animatronic robots such as robot cats (Shibata and Tanie, "Physical and Affective"). These experiments showed that robot figures resembling living creatures too closely were deemed less desirable by patients. For example, a robot cat too closely resembling a real cat was deemed disappointing because it only looked like a cat without being able to perform as an actual cat. The "uncanny valley" (Mori) describes a disjoint between robot appearance and behavior , and the repulsive response of people experiencing an almost but not quite human robot. Parois an animal version of this uncanny problem. In response, Paro was designed to resemble a seal without actually mimicking a seal (Shibata and Tanie, "Influence of" 3). Since few people have had direct experiences with seals (as opposed to cats), making a seal-like non-seal is easier than making a cat-like non-cat.

Robot control architectures usually contain multiple parts or layers that share information, as shown in Fig 1. Paro's internal software control architecture is built of two layers: one proactive, the other reactive. These two layers produce different types of behaviors. The first layer is a weighted (variable) transition system that rhythmically cycles through configurations of pose primitives, where the combination of the poses is organized through a behavior generation module. Because the motor command primitives respond to state weights, the resulting robot motions are not noticeably repetitive despite the limited number of individual states (Wada and Shibata, "Living with Seal Robots"). This is important as repetitive mechanical behavior is detrimental to believability in life-like robot pets.

The second control layer is reactive. This allows Paro to respond directly to voice and touch. Responsive action of reactive control systems is an intuitive way of associating input with output in robotic systems. The approach has been inspired by observations of biological systems, and was perceived by early cybernetics as a viable first path towards mimicking living systems (Mindell). Reactive systems are a special class of feedback systems in which the input is directly related to the output. The relational logic of this direct connection can be formulated in different ways based on how the output should be affected by the input. Negative feedback systems, for example, oppose the input in their output, while positive feedback systems augment a perceived input signal in their output. Paro uses positive feedback to respond to stroking, for example, and responds with a squeaky seal-like sound. The more you stroke, the more the robot squeaks.

This reactive layer is supplemented with computational memory, allowing events to be recorded, recalled from memory and coupled with internal responses over the lifetime of the robot. With this capacity to recall input stimuli and corresponding output actions, the system can respond not only to individual events, but to a set of events over time with varied responses.

Furthermore, the robot can memorize a frequently articulated word and will map this utterance to a select condition, such as its own name (Wada and Shibata "Living With Seal Robots"). Calling Paro by its name and seeing the robot respond to this personal identifier is another part of the fabric of life-like behavior. Furthermore, the variability of Paro's responses is generated by selectively recombining individual actions into action sequences. For example, the robot might blink, move its head and then utter a sound, or remain immobile as if asleep and produce sounds in that state. This choreography of actions allows the designers to generate, from a limited repertoire of action primitives, complex composited behavior sequences.

Paro's tactile sensors can detect a variety of haptic events. The robot's internal logic assumes that soft touch originates from a user with gentle intentions while rough handling is mapped to the opposite, unkindness. A single sensory input thus allows Paro to make strong assumptions about its owner. Paro classifies gentle stroking as positive, and beating (or excessive stroking) as negative. It then couples the negative input with one kind of response and the positive input to a succinctly different response, demonstrating to a patient that it "understands" the patient's actions.

Finally, Paro has an oscillator-based diurnal rhythm that modulates the selection of the current behavior component. This allows the robot to differentiate daytime from nighttime events and activities. Adding an artificial diurnal cycle to the robot makes the behavior seem more life-like, as biological pets also exhibit diurnal rhythms, adding yet another component to the life-likeness features.

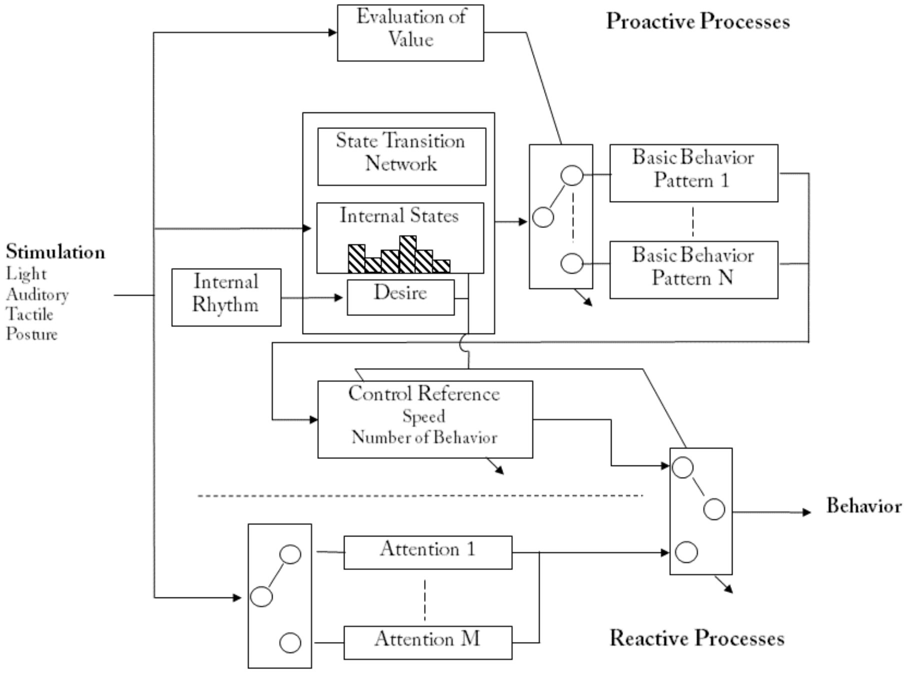


Fig 1. Paro's control architecture, based on (Wada and Shibata, "Living with Seal Robots" 974).

This temporal cycling ensures that people are synced with the robot; it generates a sense of shared experience. This rhythm becomes part of the basis for addictive interaction, as the robot needs its sleep and will otherwise not treat its human companion with the desired level of attention. Together, the design modules described above produce behavior patterns that people associate with living pets. Paro has been introduced to several elder care homes, and several elderly patients have reported affectionate feelings towards the robot (Wada et al., "Psychological and Social Effects").

It is the combination of robot appearance and actions with human expectations that creates the complex yet one-sided robot experience. Indeed, the side effects of robots with only superficial social competence that exact prolonged one-sided giving have only recently been understood (Scheutz) as problematic. It seems that the fallout resulting from the difference between the aspirational promises made by social robot designers (Breazeal) and growing scrutiny on the part of emotionally needy patients only becomes apparent over time.

4. ASPIRE

As opposed to the Paro robot that has been in operation for several years, the ASPIRE system is still in the research and development stage at the time of this writing. Similar to Paro, however, ASPIRE intends to improve the care of elderly patients with innovative robotic technology. While Paro and the RIBA system (described below) take the form of full-sized animatronic robots, ASPIRE will develop a group of small ground and aerial vehicles to perform healthcare related activities. In particular, these small robots are intended to assist with the automated and customized delivery of medication. The project authors hope to overcome some of the physical limitations of large and heavy robots with nimble robots operating in concert. Additionally, ASPIRE offers the potential for significant cost savings by replacing large and expensive hardware with miniature and cheap hardware. While the Paro robot framework builds upon an existing and proven framework of animal and pet therapy described by Baum et al. ("Physiological effects"), ASPIRE's care delivery rationale is without precedent within the healthcare field. However, the merits of smaller networked robots have been previously proposed (and partly proven) in search and rescue contexts (Nourbakhsh et al.).

The ASPIRE authors position their approach within two important robot-human interaction paradigms, that of co-robots and multiple agents. Co-robots are designed to assist humans in tasks of importance to human beings (Riek). The co-robot does not replace humans, but rather selectively augments activities performed by humans. Multi-agent cooperative systems address the problem of dividing up a single task between multiple robots and cooperatively solving the problem (Luke and Panait 387). The ASPIRE investigators caution that the problem of cooperative (aerial) robotic systems in shared, highly constrained spaces is a fundamental problem (implying that it is indeed worthy of inquiry). Furthermore, they contend that co-robots must be trusted by humans, and that this trust can be created by appearance and behavior of the co-robots, a tenet borrowed in turn from the humanoid robotics approach. Robot behavior should be "predictable and consistent with principles of human spatial perception" while their appearance "must foster a high level of comfort and not create high cognitive demands on the user", as the authors of ASPIRE note in the project description. The solution to this challenge includes the creation of a control framework with "intuitive user control" over an ensemble of co-robots and the design of "both low-level and supervisory high-level controllers" (Aspire).

What follows is an account of some of the technical details of the ASPIRE system. These observations are added only to assist in carving a path to a critical understanding of the difference between what these robots actually do, how they are portrayed, and how they might be experienced.

In the ASPIRE project the robot hardware is not particularly innovative. Indeed, the project seeks to move the entire research endeavor from hardware to software. In particular, the control architecture inscribed into the software is the cornerstone of ASPIRE. It is the flexibility and adaptability of the motion control system that sets ASPIRE apart from other healthcare robots. The L1 adaptive control paradigm (L1) of ASPIRE decouples the estimation from the control element (Aguiar et al. "Time-Coordinated"). The feedback from the output of the system enters a multi-part operator consisting of a control element, a state predictor and an adaptive process (Aguiar et al. "Time-Coordinated" 14). The goal of the L1 controller is to obtain an estimate of the internally unknown signal at time t, and to define a control signal which compensates for uncertainties associated with this unknown element within the bandwidth of a (low pass) control filter introduced in the feedback loop. L1 offers a high level of adaptive control and is able to respond to external factors not explicitly included in less sophisticated feedback loop methods. Not only does L1 allow for fast adaptation and uniform and predictable performance bounds through the entire operation of the system, but it is also effective in the transient phases, making L1 more robust than other similar control architectures.

While the benefits of one control architecture over another might appear academic, the results can be of practical significance, and this recourse to practicality is important here. For example, Aguiar et al. describe the system as offering a unique approach to the attitude-control problem, avoiding geometric singularities and providing singularity-free path following. The approach extends to cases where the speed profiles of multiple vehicles along their paths are arbitrary (as long as they meet certain geometrical constraints). In other words, the robots can follow prescribed paths under many circumstances, not just the one offered in the testing scenarios. More succinctly, the solutions generalise.

The ASPIRE system is an architecture of architectures; it combines several sub-control components into one system. It is, for example, possible to integrate commercial autopilot modules (providing angular rate and speed tracking) with an outer loop controller as shown in Fig. 2 below. This inner/outer-loop approach simplifies the design process and affords the designer a systematic way to seamlessly tailor the algorithms for a very general class of UAVs (Xargay et al.). Finally, the approach also describes lower bounds on the convergence rate of the robots' collective dynamics, meaning it will be able to predict under which situations problems (of the collective dynamics) might occur. In sum, the avoidance of singularities, the ability to generalise (within limits) and bounded convergence make this control approach superior to other control architectures. Consequently, the coordination of multiple aerial robots and the following of a predefined path become possible when individual robots with L1 control modules are integrated into a hybrid control architecture. The ensuing robot "hive" is then capable of path generation, path following, and temporal coordination (Aguiar et al. "Time-Coordinated" 23).

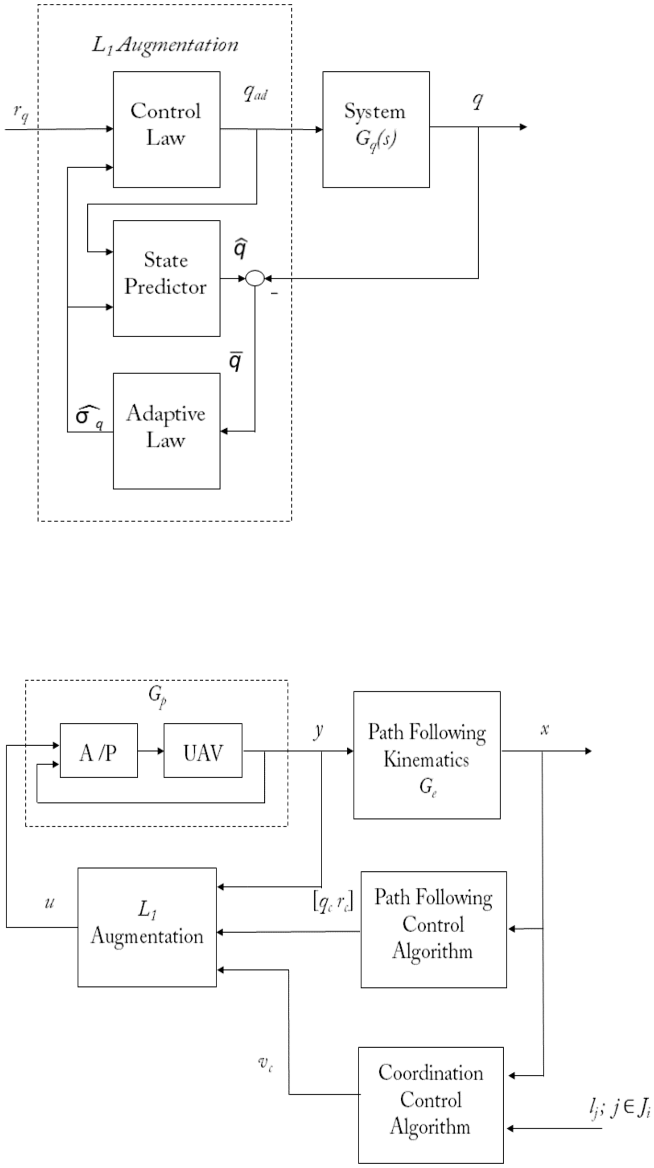


Fig. 2. L1 adaptive control loop (top) and L1 augmented system for coordinated path following closed-loop system for one of many autonomous aerial vehicles (Aguiar et al., "Time-Coordinated" 15 and 18).

As the ASPIRE team points out (Xargay et al. 499), L1-enabled operation not only lets a group of robots follow a predefined path as a group in a 3D environment without collisions, but also allows them to break out of formation, and land at a designated spot simultaneously. These are the actions ASPIRE intends to fold into a robotic healthcare delivery framework. Oddly, the authors make no attempt to justify the applicability of this sophisticated control ability to healthcare; they simply assume that it will be effective in the new domain. More on this transfer of applicability will be said below.

5. RIBA

RIBA (Robot for Interactive Body Assistance) is a robot specifically designed to assist healthcare workers with the task of lifting and moving a bedridden patient from a bed to a wheelchair and back. At first sight, the almost cartoonish RIBA seems to be a direct descendant of industrial robotics. As is the case with Paro, RIBA is a robot design responding to the demographic pressures of an aging Japanese society reluctant to import cheap foreign labor to assist in the intensive labor of elder care. While Paro acts an alternative to a pet, RIBA is an alternative to a team of human beings. Yet RIBA is a specialist and acts as the muscle for heavy lifting, leaving the existing care workers with more time to care for the patients and "monitor the environment" (Mukai et al. "Development of" 5996).

RIBA is the product of a large scale, multi-year investment by a cohort of three robot teams with over 40 active researchers active since 2006. The work is supported by the Collaboration Center for Human-Interactive Robot Research (RIKEN-TRI) and is financed by the Tokai Rubber Industries agglomerate (RIKEN-TRI.). The current RIBA concept is a product of several earlier unsuccessful attempts at creating lifting mechanisms for hospital use. Most systems were either too cumbersome for the staff or uncomfortable for the patients (Mukai et al. "Development of" 5996). The RIBA team solution comprises of a mechanical structure with sufficient payload, motion accuracy, and ranges of joint movement to actually lift and move a live human patient without modifying the environment (i.e. reclining the bed or flattening a wheelchair). RIBA is the first robot to demonstrate the ability to gracefully lift and move live human beings comfortably in and out of a bed in hospital practice.

Weighing 180 kg and standing 140cm tall, RIBA is a large robot. While RIBA does not look like a human being, it is designed to have similar structural features. Link length, joint configuration, and the motion range of all its joints were determined with reference to a human body. But the robot is not limited by human anatomy. DC motors and potentiometers are used to control and measure the angles of every joint. A coupled drive mechanism allows the output of two joint pair motors to be concentrated at one joint if the other joint in the pair is not required to move. This enables the robot to manage a high payload with thin and light arms. Four omnidirectional wheels move RIBA around in narrow spaces (Ding et al. 246). Together, these features translate into a very flexible mechanical system that is well-suited to the task of lifting heavy but delicate objects, such as living human beings.

The hard RIBA mechanical components are covered in soft materials made to resemble a giant white teddy bear. Cameras, microphones and tactile sensors under a layer of soft rubber are used to assess the surroundings. Touch sensors in the hands and shoulders are made from tactile sensitive sheets with a multitude of individual active sensing nodes (Mukai et al. “Whole-body contact”). RIBA can distinguish tactile input between the patient and a caretaker/operator based on the amount and distribution of pressure points, as each of these actions produces a different sensor data signature (Mukai et al. “Whole-body contact). While the lifting trajectory is estimated in advance of the executed motion, RIBA’s arm sensors collect data in real time and help modify the pre-calculated robot motion (Honarvar et al.).

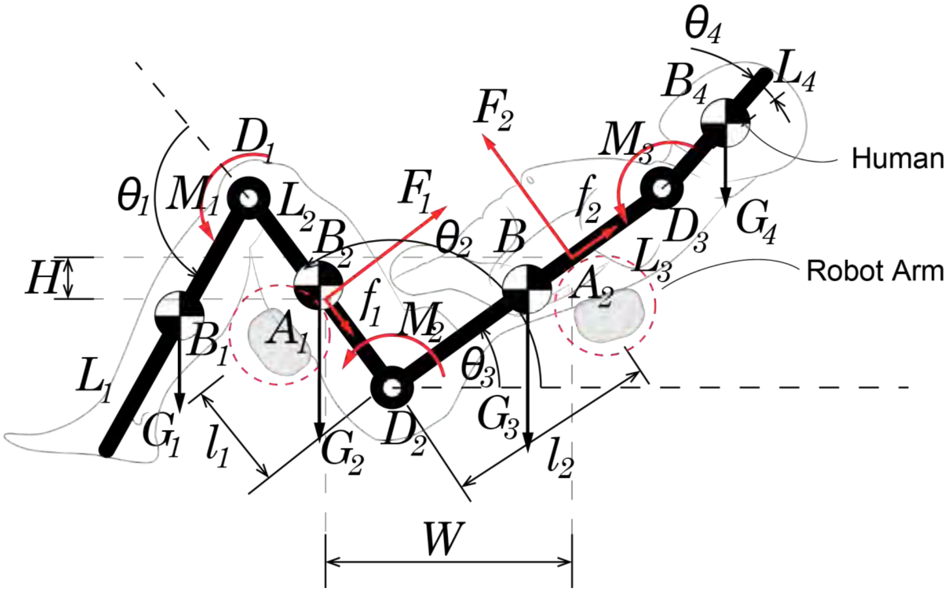


Fig. 3. Four-link human RIBA model parameters of a human being used to estimate comfort; based on Ding et al. (246).

RIBA is designed to consider the comfort level of the patient during the lifting process. New in robotics, comfort control has precedents within industrial design in biomechanical car driver models (Siebertz et al.). RIBA’s designers have employed similar quantitative (EMG signals of erector spinae back muscles) and qualitative (questionnaire) measures to evaluate the experience of comfort during interactions with the robot (Ding et al.). RIBA’s sensor design team developed a model to estimate the forces acting on the human joints during the lifting process. From this model, RIBA predicts the patient’s comfort level and uses this prediction to distribute the patient’s weight in the robot's arms evenly, preventing excessive pressure points. This distributed sensing and motion generation creates a manipulation scheme in which the entire body of the robot becomes the contact area. When the manipulation object is a human being, whole body manipulation means that many areas of the robot body, not just gripper arms, come into contact with the human. In this way, RIBA produces an unrobotic interaction quality, performing the labor of lifting and the craft of care with inhuman effectiveness.

6. Care under Robot Control

Ronald Arkin, Patrick Ulam and Alan Wagner maintain "Robotic systems are close to being pervasive, with applications involving human–robot relationships already in place or soon to occur involving warfare, childcare, eldercare, and personal and potentially intimate relationships" (571). To tackle the potential ethical risks of robotic technology, Arkin, Ulam and Wagner have been examining military robotics and suggest a technological solution consisting of:

> 1) the design of ethical governor which restrains the actions of a lethal autonomous system so as to abide within the internationally agreed upon Laws of War (LOW); and 2) the use of moral emotions as a means for modulating ongoing robotic behavior in a manner consistent with enforcing restraint. (572)

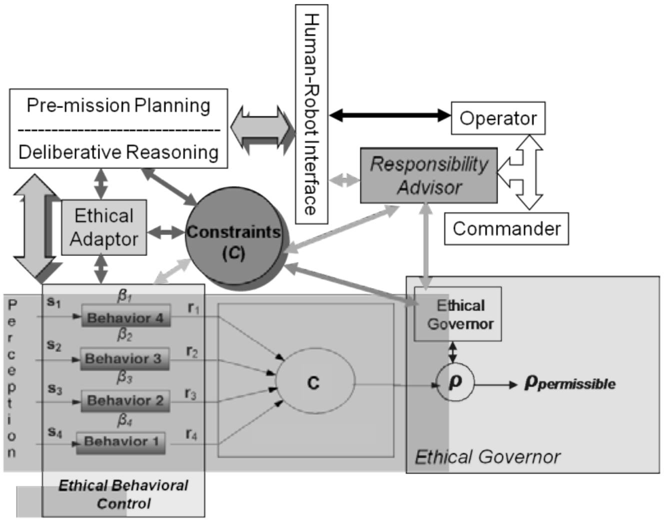
What is important here is that while these systems have been designed in the military context, according to the authors, their "ethical design components" are claimed to be "generalizable to a broader class of intelligent robotic applications and are suitable for use in domestic and healthcare settings" (572).

While we can trace the history of control in particular robotic systems, the signatures of other forces can be less distinct. The dynamics of robot technology transfer as exemplified in the context of the ethical governor above is a case in point. Technology transfer moves systems designed for one context, such as space research, to another, such as civilian use. There is only a short history of robots providing healthcare, and one can observe an uneven distribution of provisional solutions. Despite this short history, several authors have probed select aspects of the robot health territory with different disciplinary framings, including cultural geography (Boyer), sociology (Turkle), philosophy and social robotics (Sparrow and Sparrow), robot healthcare training (Wada et al. "Development and preliminary evaluation") and social shaping of technology (Chang and Šabanović), amongst others. Our direct robot control reading as cultural technique differs from these approaches.

Jussi Parikka points out that one shortcoming of the cultural techniques approach has been the lack of political perspectives (156). For us, thinking about technology transfer provides a way to think about the politics of healthcare robots from the perspective of cultural techniques. In other words, the transfer includes not only technologies per se but also the cultural logics these technologies follow and produce. In other words, when these technologies, either as wholes or as parts, transfer from one category to another, the logics of control also transfer or travel simultaneously. From a historical perspective, this is not a radical idea since technology is always rooted in older technology. However, if we are to believe the proposition that technologies redraw the ways in which the distinction between, for example, humans and machines are understood, this also becomes a political question. For instance, what are the intended and unintended shifts that occur in situations where technologies designed in the context of military and industrial research move to healthcare?

The history of robot technology transfer is so dynamic and the systems so unstable that a control architecture attempting to support ethical actions in military robots can be (and is) expanded to the otherwise utterly unrelated challenge of preserving dignity in robot healthcare for Parkinson’s' patients (Arkin, Ulam and Duncan 56; Arkin, Scheutz and Tickle-Degnen 3). To put this provocatively, one might ask: which forces and cultural techniques are at work such that a control system designed for a killer robot can migrate to a healthcare robot? Even the robot designers seem uneasy with their “solution”. The provisional nature of the approach becomes apparent in the fact that a key element of the design, human level empathy, has yet to be integrated into the architecture; certainly no minor issue. The authors offer only an outline of how this problem might be addressed: nothing more than a logit function that sums a series of vaguely defined probabilities of “feeling an emotion” (Arkin, Scheutz and Tickle-Degnen 4) is proposed. Functionalising components is an important part of the crafting of robot architecture, but it can come at the cost of altering the very components themselves.

Fig. 4.



As such, architectures of robot care have the potential to change perceptions of the human body. The heart-lung apparatus Gibbon successfully tested in 1953 after two decades of development, was able to oxygenate a patient's blood stream sufficiently and bypass the otherwise vital actions of the lungs during surgery (“The development of”). Because of this apparatus, the view of the significance of heart and lung as repositories of humanness could at least be mechanically disputed. Ultimately the replacement of heart-lung failure with the event of brain death as the criterion for clinical death shows, as Goldberg (“The Changing Face”) has suggested more generally, how our sense of what is unique to the human experience changes as science (and the technologies that implement it) progresses. Likewise, robots that deliver care reconfigure care.

The Paro robot’s (mental) healthcare is a product of what engineers call “site engineering” and what sociologists refer to as “inscription prescription” pairing (Latour / Johnson). Site engineering refers to the arrangements and provisions made to enable a technical system to operate within a defined zone with known conditions. A road is one example of quotidian site engineering that facilitates automobile travel. Likewise, smooth floors or communication networks create conditions under which a wheeled wireless robot can operate. Paro’s site engineering is created through the facilities of hospitals and hospices: captured audiences of lonely people. The patients in turn provide the inscription/prescription as they use the robot precisely as required to elicit the responses they enjoy alone or in groups. They must first care for the robot before it can care for them. And if they choose to not cuddle the robot, they receive nothing but periodic calls for attention. Both inscription (the robot providing something a person would provide) and prescription (using the robot correctly) are configured through the site engineering of the hospital and the robot’s own usage manual (Wada, “Development and Preliminary Evaluation”). With little experience in reading robotic systems, elderly patients are prone to imagine an inner life that the synthetic creature lacks. As the description of the Paro control system above shows, the robot behaviors are based on simple reactive mechanisms coupled with a selective memory of past events. Paro comes to life in the mind of its users through “fantasies of substitution” (Turkle), and it does this so effectively that biological traces of increased pleasure can be detected in the urine of patients in user studies (Wada and Shibata 973).

RIBA, by contrast, reconfigures care from a robustly physical angle. This system has taken on the most mundane of care tasks, heavy lifting, and made use of robot technologies to change the way that problem is solved. RIBA does not imitate human care givers and giving, but reconfigures the care of lifting into an otherworldly realm; the robot holding the human body is a force projector and interface at once, able to optimize the comfort of a patient in a way that supersedes the capacity of human workers. Indeed, the robot invents the idea of comfort carrying. The exchange with human caretakers also follows an unusual trajectory. There are no buttons or screens on RIBA; rather, the robot receives instructions via voice and touch. RIBA’s back upper arms are the input areas that the operator activates in order to move the robot arms into place. According to the research team, this method was inspired by the way a teacher instructs the motion of a student, guiding a student’s motion when teaching a sport or dance. RIBA defines the term interface not as a noun, but as a verb.

The ASPIRE project is by far the most controversial of the three healthcare approaches discussed in this paper. Here, the belief in a yet-unproven solution is constructed by an arrangement of reputations, prior work and assumptions of frictionless technology transfer. The ASPIRE team has made notable contributions to the design of time-critical cooperative path-following under complex vehicle dynamics and time-varying communications topologies in a rigorous mathematical setting. Furthermore, the authors have transferred their theoretical solutions to algorithms, produced control architectures to implement these algorithms, and tested their system in the field, bridging "the gap between theory and practice" (Kaminer et al. "Path Following" 550). In other words, since the researchers have solved a challenging problem in applied control theory and tested it in the "real world", the inclusion of yet another "environmental factor", in this case the delivery of healthcare, is a minor challenge, and their claims are sufficiently believable to the professional audience they address. Second, the choice of test site is a significant site engineering action. The authors will demonstrate the benefits of their collaborative control scheme by having their crawling and flying robot swarm operate in a home-like care environment (as opposed to a laundromat). Third, the tasks these robots will be given are aligned with "domestic assistive devices for healthy older adults in a research laboratory" (ASPIRE). Independent of the ability of the robot ensemble to be truly helpful, the work can claim to contribute to healthcare delivery through the choice of these site-engineered framings. ASPIRE instrumentalises care through its focus on the mechanical delivery of objects related to care. Care in a deep sense is almost embarrassingly absent in the proposed project.

As is the case with other robot sales efforts, the ASPIRE team infantilizes patients through the robot system name space, referring to their robots as "Cinderella bots" (Robertson). Instead of presenting robots as the complex and demanding systems they are, robots for care are cast as playful toys; often covered in fur, with large ears and cute names. The Japanese RIBA designers claim that the robot's teddy-bear-like head "prevents psychological discomfort" (RIKEN-TRI). This infantilisation is hardly malicious, but rather a sign of a lack of vision for a more mature concept of synthetic help.

Roboticizing healthcare entails solving a messy problem with optimisation procedures supported by technologies. Formulated by Morozov ("To Save") as a criticism of Silicon Valley business practices, "solutionism" is a mode of thinking that redefines problems with social or political dimensions into engineering problems addressable exclusively through technical means. For example, healthcare companies such as Sentrian (Sentrian) offer services for remotely monitoring patients. Biosensors, in conjunction with ubiquitous computing environments, allow real-time views of bodily conditions that previously required at least a visit to the doctor's office. Because information technology infrastructures scale, the company can simultaneously "care for" a large number of patients while producing significant savings. However, the Sentrian approach and similar e-Health business models do not contain the human touch that a human doctor can offer when there is bad news to share.

Likewise, the ASPIRE robot drones offer a new kind of care (such as bringing you a sleeping pill), yet they displace other care forms; they will offer no kind words wishing a good night's sleep. Such human-specific care events are erased from the concept of healthcare and diminish the craftsmanship of care (Coeckelbergh "E-care as"). The savings are immediately perceivable, but the new costs are hidden; they accumulate, and become apparent only over time.

A big selling point for robot elder care is the claim that these services could result in the elderly being able to delay the transition to institutional care (Sharkey and Sharkey; Normie; Doyle et al.). But in order for the elderly to stay out of expensive institutional care, one has to build elaborate and expensive robot care – that is, care for the robot systems themselves. Living spaces will have to be upgraded for imperfect robots. Shaggy carpets may be good for people but they are bad for robots. Bedrooms will have to provide space for charging stations for energy hungry autonomous vehicles. Wireless networks for continuous data transfer will be de rigeur for good robot communication. Designated landing and charging zones for indoor drones are a requirement but a nuisance for people. These and other provisions produce a new condition: robot healthcare requires less care for people but more care for the robot infrastructure they accumulate, and become apparent only over time. And yet, nothing in this altered configuration is assessed based on its ability to provide better care that respects human dignity (Coeckelbergh "Health Care").

7. Collective Robot Imaginaries and the End of Human Life

Media theory has classically understood the tool as an extension of the human body (McLuhan; Mumford), and many robot conceptions are based implicitly on this position. When a robot fireman carries a heavy load from a burning building, the robot performs an extension of a human action. When a robot system is able to operate without oxygen, it extends the domain of livable environments and performs something no human being can do. And yet, the tool-as-extension philosophy has its limits for understanding emergent robot culture. Driverless cars have superhuman abilities in the sense that they do not fail where humans do; they do not fall asleep (despite endless driving), they do not exhibit road rage, do not steal parking spaces, do not run red lights, and so on. They not only do what we cannot do, but do not do what we should not do.

In this respect, robots, as space stations, are not extension tools (cf. Sloterdijk), but rather they participate in the making of the technological imaginary, a concept that denotes visionary, innovative, utopian and fantastic visions of the future. While the reference to imaging in the term technoscientific imaginary originates in scientific practices of visualization as a defining aspect of Western scientific cognition (Marcus), today the term connotes a variety of ideas that link science and technology to cultural and social contexts. The technoscientific imaginary is not linked to a specific technology, but rather, technologies and cultural techniques from informatics, artificial intelligence, genetics, and biotechnology add to it in various ways. The result is a shape-shifting cloud of ideas, hopes, and fears linked to what future technologies can produce or destroy. The technological imaginary is a powerful collective operator that can produce hope even in the face of overwhelming opposition. It is our contention that the robot control architecture transfer operations described in the examples above are not just a new form of solutionism; they are also a version of the technological imaginary fueled by the desire to age gracefully and defy death. Robotic systems in healthcare applications recreate capabilities humans no longer have, and they create capabilities humans never had.

Yet what are we imagining when we confront old and frail people with robots? While people in need deserve support, they are the least able to defend themselves from the new kind of craft-reduced care that robots offer. At the end of life, these contrasts are sharpened. There is no intrinsic value in the conditions of advanced age, other than becoming a new audience for medical studies and interaction experiments. Consequently, a new audience of ageless agers (Samochowiec, Kuhne, and Frick) is the target of a growing collection of health monitoring and care technologies.

The best care robots can offer is the care humans cannot offer. RIBA can let an immobile body defy gravity with a force that a human caretaker cannot provide. Simple chat bots will never tire of answering the trivial questions of dementia patients that can drive a sane person mad. A robot toy will endure and feign to enjoy endless petting from a desperately depressed person. Robot technology in healthcare can be effective where human beings are at their limits.

But what about the ultimate limit? How should a robotic smart home behave when a terminally ill person wishes to die? What kind of last comforts and last wishes should a system deliver, and what should it never do, despite its abilities? Maybe self-restricting technical systems will only become imaginable once the mostly young robots care business managers experience the trials of old age. Maybe that pressure will generate robot care models that combine what robots really do well with the compassion only human beings can offer. Then again, the cold presence of a robot as alien other might be the more appropriate farewell from this world.

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