

# FUTURE REASONING MACHINES: MIND & BODY

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## ABSTRACT

In investing energy in developing reasoning machines of the future, one must abstract away from the specific solutions to specific problems and ask *what* are the fundamental research questions that should be addressed.

This paper aims to revisit some fundamental perspectives and promote new approaches to reasoning machines and their associated form and function. Core aspects are discussed, namely the one-mind-many-bodies metaphor as introduced in the Agent Chameleon work. Within this metaphor the agent's embodiment form may take many guises with the artificial mind or *agent* potentially exhibiting a nomadic existence opportunistically migrating between a myriad of instantiated embodiments.

We animate these concepts with reference to two case studies, illustrating how a machine can have fundamentally different capabilities than a human which allows us to exploit, rather than be constrained, by these important differences.

**Keywords:** Cybernetics, human machine interaction, robotics, agent systems, anthropomorphism, philosophy of cybernetics

## INTRODUCTION

Intelligent systems research has undertaken an arduous and evolving path over many decades all the while delivering, in approximately equal numbers, solutions to many problems whilst identifying further as yet unsolved problems. Core principles from many disciplines have influenced our perspectives on a system's function and form, none more so than the *one-mind-one-body* debate found in biological entities. Inevitably, our sources of inspiration come from what exists around us. Consequently not insignificant research energies have been invested in such projects as trying to realise a human-like robot, a system that encapsulates the one-mind-one-body concept. But to what extent should a machine's reference be sourced from such biological references as ourselves? Is the human-based approach to a singular mind-body paradigm the only tangible option? Indeed how ought we to manage our perceptions and interpretations of artificial entities that extend beyond this paradigm?

## THE ARTIFICIAL MIND

The relationship of the mind and body has been a psychological and philosophical problem for many years. From both philosophical and scientific theories, the mind-body relationship can be divided into two main categories: monistic and

dualistic. Firstly, monistic theories suggest that mind and body are not independent of one another. Behaviourists (including the likes of Aristotle, Hobbs and Hegel) hypothesised that mind was nothing more than a function of the body. Idealists, like Berkeley, Leibniz and Schopenhauer suggested that the body was just a mental representation. Spinoza proposed a theory of double-aspectism which postulates that mind and body are distinguishable but not inseparable.

Secondly, dualistic theories are of the view that mind is seen as distinct from the body and not made up of any physical substance. Some popular dualists include Descartes, Locke and James who belonged to a branch of dualism known as interactionism. Descartes, as an *interactive dualist*, believed that there was a distinction between the human mind (or soul) and the physical body, describing the mind as “[a] thing or substance whose whole essence or nature was only to think ... has no need of space nor of any material thing or body. ... This mind ... is entirely distinct from the body” [11]. He claims that a body without a soul would be an automaton, completely controlled by external stimuli, while a soul without a body would have consciousness but only of innate ideas, lacking any sensory impressions [17]. Interactionists believed that, although mind and body were of a very different nature, it was the interaction between the two that produced many aspects of human nature.

The prevailing view in cognitive science today is that the human mind consists of distinct faculties dedicated to a range of cognitive tasks: linguistic, social, practical, theoretical, abstract, spatial and emotional. Mental processes in humans are generally viewed as not being solely internally-represented symbol-manipulating algorithms, and thus the notion of a robot having a *mind* using the human mind as the frame of reference becomes an issue. Arguing against artificial system having a mind is similar to discussing whether the system simply operates at a level of syntax without semantics (i.e. a computer *acting* the role). Programs operating on a machine can be seen to be semantically blind, merely mimicking the grasp of meaning according to both the rule set employed and the data received. It does not *understand* the information; it merely has a methodology capable of dealing with it, a form of mapping between input and output. Searle [25] animates this stance in his Chinese Room Argument.

This paper argues against applying the term *mind* with respect to machines and makes the distinction between mind and the *artificial mind*. The term artificial mind refers to an artificial entity’s reasoning mechanism, independent of particular implementation technologies which has been developed for its interaction with both its physical and social environments. This undoubtedly includes our worlds and therefore its interaction with us. Machines with minds may arguably not exist, but the importance of AI is that machines with artificial minds can exist because as humans we tend to interpret the artificial entity according to our frame of reference. That is, we basically anthropomorphise and adopt the intentional stance [9]<sup>1</sup>.

## ROBOTICS AND AI

A predominant theme within AI research is to focus on the development of functional components and solutions to narrow problems, with limited abstraction and consideration of the broader objectives of AI.

Artificial intelligence was initially interpreted as an attempt to prove the *Physical-Symbol System Hypothesis* where “*formal symbol manipulation is both a necessary and sufficient mechanism for general intelligent behaviour*” [26]. Efforts to solve the AI problem that follow this hypothesis are now termed the *classical AI* approach. Simon maintained that the human cognitive system is basically a serial device.

When results were subjected to human interpretation, classical AI provided a rich source of control ideas. Problems arose when these control paradigms were applied to robotics, and in particular the control of mobile robots. The original theory that robots would simply provide the sensors and actuators for an artificial brain, when constructed, became seriously flawed.

The robot Shakey [23] provided a useful calibration for classical AI and its original idea of developing some form of artificial mind (effectively an artificial reasoning mechanism). While focused strategies to specific solutions are essential, they generally merely provide the mechanisms upon which more complete systems can be constructed. By reviewing achievements and failures to date within robotics and AI, an insight is acquired into the continued relevance and attainability of the grand challenge.

Problems arose with real-time performance and stability through, for example, sensor noise and demands of maintaining representational model validity. More elaborate models necessitated ever increasing computational effort that often

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<sup>1</sup> Consciousness is not discussed in this work although the ideas presented undoubtedly promote this discussion.

proved too cumbersome and not sufficiently responsive for real-world applications. It became apparent that understanding *system-environment* interaction was fundamental in achieving robust control for autonomous robots existing within a physical world.

This classical approach viewed mind as distinct from body and took a non-interactive dualistic approach. Early research in the field of Artificial Intelligence worked on developing artificial minds that were effectively disembodied with minimal interaction with any world (real or otherwise). However, this has a fundamental flaw, in that “*a program integrated in a computer with no visible appearance nor autonomous physical interaction with the real world has a more difficult time to be viewed as intelligent, whatever the power of its problem solving and the sophistication of its knowledge*”[28].

The inability of such classical AI systems to handle unconstrained interaction with the real world led to a search for new control architectures for autonomous robots. Recent research into embodiment, sociality and emotions are now approaching the problem from a new angle. This *New AI* has assumed a stance similar to double-aspectism. While mind and body are viewed by some as distinguished separate components they are not necessarily inseparable. A series of provocative papers by Brooks [6][7][8], argued that real world autonomous systems or embodied systems must be studied in dealing with the problems posed by classical approaches. While not a new concept, Brooks’ popularisation of the reactive approach served as a useful catalyst in looking for more embodied approaches to artificial cognition. Issues in real-time processing became very real, for example if the robot could not cope and it crashed into something. Only by direct interaction could the robot gain an understanding of the environment.

For either of the deliberative or reactive approaches, a robot requires a control architecture. This architecture determines how behaviour is generated based on signals from sensors and invoking motor responses. Reactive approaches which aggregate large numbers of simplistic non representational reasoners have led to *emergent “intelligent” behaviour* [5][21][18][22]. While founded in embodied robotics, these have not proved sufficient in order to achieve complex goals and suffers from issues of repeatability and the absence of a strong theoretical model. In contrast, deliberative architectures have displayed reflective reasoning capabilities but may lack the responsiveness and robustness demanded by real world applications.

Thagard defines a current central hypothesis of cognitive science, the Computational-Representational Understanding of Mind (CRUM): “*Thinking can best be understood in terms of representational structures in the mind and computational procedures that operate on those structures*” [30]. While there is much speculation regarding the validity of this statement, he continues by stating that this central hypothesis is general enough to encompass the current theories in cognitive science including connectionism. Interestingly, while strong embodiment, as discussed in for example, [6][30][15], continues to prevail as a necessary criteria for achieving stronger notions of intelligence in artificial systems, the fundamental mechanisms used in trying to build strongly embodied systems today are inherently symbolic in nature. The processes and control is achieved via symbolic computers. So, can embodied artificial cognitive processes be really achieved to the extent required to realise a strong notion of intelligence when our references for intelligence are based on natural systems? It’s like trying to make machines into natural entities, or inversely, to reduce natural systems to machines, an issue regularly discussed in AI.

Two diametrically contrasting issues arise:

- (1) If the reference for intelligence and the barometer for gauging degrees of intelligence is that of the human then anything less than a human in all capacities cannot succeed.
- (2) If the qualifier *artificial* is emphasised, then the process of comparison becomes more of an analogy, *with limitations*.

Proponents of *strong AI* believe that it is possible to duplicate human intelligence in artificial systems where the brain is seen as a kind of biological machine that can be explained and duplicated in an artificial form. This mechanistic view of the human mind argues that how people think, could be revealed through an understanding of the computational processes that govern brain characteristics and function. This would also provide an insight into how one may realise an artificially created intelligent system with emotions and consciousness.

In contrast, advocates of *weak AI* believe that human intelligence can only be simulated. An artificial system may only give the *illusion* of intelligence (i.e. the system exhibits those properties that are associated with being intelligent). In adopting this *weak AI* stance, artificial intelligence is an oxymoron.

Having briefly reviewed the AI and robotics journey to date, we wish to pause and consider the function of the reasoning machine, and associated possibilities in terms of divergent forms.

## FUNCTION OF THE MACHINE

What is the function of the ultimate reasoning machine? Our ability to invent something beyond our own capabilities becomes problematic. Could we understand any different, let alone invent it?

Robot success to date is based upon an ability to determine those tasks for which the robot is particularly apt. Examples include assembly, repetitive pick and place, hazardous substance manipulation, welding, and spray painting. Their role as a tool is clear and their function relies and exploits the properties of machines.

Given that machines have a fundamentally different capability set, to constrain it to our capabilities may not be appropriate. The issue becomes what *could* it do that exploits its inherent functionality? At a very basic level, are the human frames of reference of one-mind-one-body still valid in developing an reasoning machine's functional capabilities?

### Free the Mind

Like the rationalist tradition in philosophy (Descartes, Leibniz, Kant, Husserl) AI research holds that the mind is fundamentally rational, representational and rule-governed. Because of this, modern philosophers like Dreyfus [12] argue that AI research will fail because it falls prey to precisely the same issues that were directed against the rationalist tradition in philosophy. Furthermore, an animal mind is an aggregation of a vast number of highly parallel, asynchronous, analogue processes. In contrast, artificial intelligence to date is based on digital devices that in most cases such devices can only give the illusion of parallel, asynchronous behaviour, and, by its very nature, can only ever give an approximate illusion of (artificial) mind. So, maybe traditional philosophies of mind cannot be applied directly to intelligent digital entities but can only be used as analogy. Also, AI entities, on no matter what platform, whether a real robot or a virtual avatar for example, can be viewed as virtual entities where it is arguably impossible for the entity to know for certain whether their instantiated platform *is* a robot or an avatar. As current AI technology is based on digital devices, and as such all input/output and processing in an AI mind is through digital means, they do not necessarily require a fixed platform, just as long as the platforms, on which they are instantiated, support these computational entities.

It is important to note that this does not necessarily undermine the embodiment debate but rather embraces the context of the artificial entities existing through its body instantiation in a physical and social environment. While being physically and socially grounded is fundamental, the added dimension is that the form of its body can change.

While strong embodiment prevails as a grounding in aiming to achieve an artificial notion of intelligence in its true form, Descartes original proposal that mind is distinct from body rises again. By embracing functionality provided by mechanistic solutions ("telepathy" through wireless communication), the long standing notion of one-mind-one-body is challenged.

When applied to Artificial Intelligence, the general Cartesian model suggests that an agent has a distinct mind and body, but yet the mind relies upon the body and the body upon the mind in order for them both to operate successfully. It should be noted that distinctions between the physical instantiation of a body rather than using a virtual representation are often highlighted. It is argued that such physicality is viewed as a requirement for intelligent behaviour where its reference is our real and complex world. This is a different debate and the view adopted here is that the physical context is always present, whether the interaction is through robot actuators or VR interaction devices with users in the physical environment.

What if the one-mind-one-body approach is extended to accommodate a *one-mind-many-bodies* metaphor? Within such a context, agent's actions are potentially significantly enhanced:

- Firstly, there is no restriction upon the agent's embodiment form should take. Numerous guises may be adopted, for example that of a physical robot, or an avatar in virtual reality or a small 2D animated gif suitable for display on a PDA.
- Secondly, the artificial mind or *agent* could migrate between a myriad of instantiated embodiments akin to a ghost moving and possessing different bodies. The behaviour of the agent will be dictated not only by the agent's goals but also by the embodiment that the agent has adopted.

The choice of embodiment must, not only empower the agent, but maintain the agent's identity in the eyes of the user. This can be achieved in a number of different ways, including:

- Preserving key referential characteristics across the different instantiations, for example, the agent's colour scheme or eyes.
- Using transitions that maintain the presence of the agent throughout the transformation process.

The agent is thus unconstrained to any particular environment, physical or virtual. Opportunistic migration both between and within different environments, physical and virtual, should harvest the functional capabilities within each.

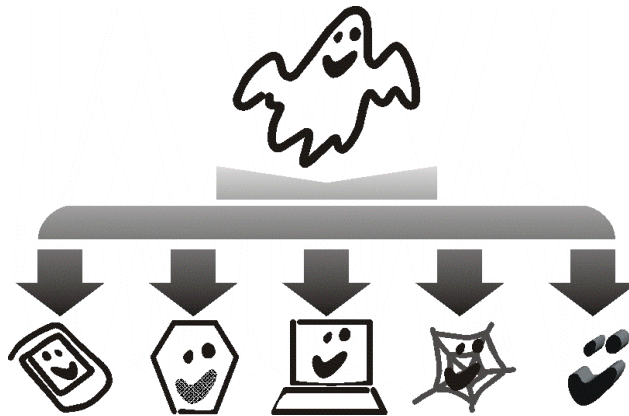
One important platform demonstrating this de-restriction from our frame of reference is an agent within a 3D virtual environment. Virtual Environments (VE) or Virtual Reality (VR) have a number of distinct advantages over other forms of real world instantiations (such as robotics). Within VR, the rules of the real world for instance, gravity need not necessarily apply. The agent form is likewise unconstrained, as it is capable of mutation in order to suit the task at hand, and may even choose to abandon one form of embodiment and adopt an entirely new one.

The objective is therefore to augment the artificial entity's functionality beyond our own frame of reference. The following case study demonstrates the one-mind-many-bodies metaphor.

### CASE STUDY: Agent Chameleons

The Agent Chameleons Project [13][24] strives to develop digital artificial minds that can seamlessly travel between and within physical and digital information spaces. Three key attributes of migration, mutation and evolution underpin this concept, and can be invoked in response to environmental change, ensuring the survival and longevity of the agent.

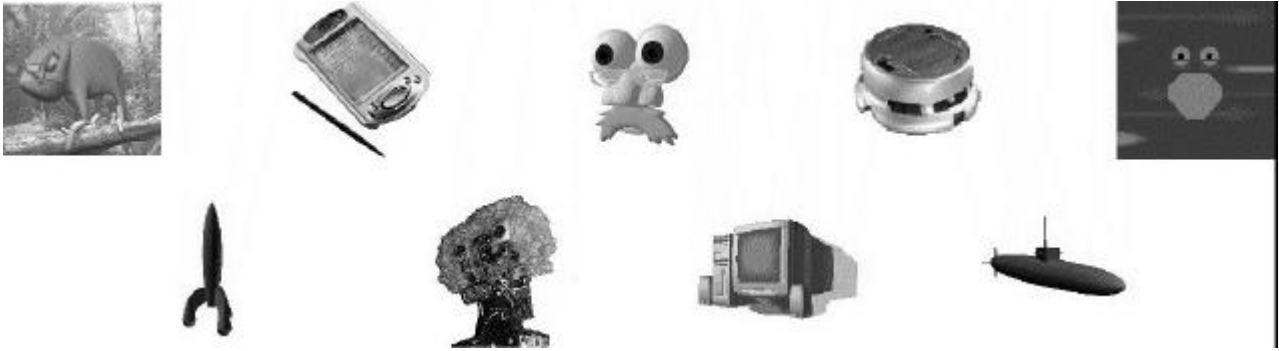
The traditional concepts of agent environment and its constraints are expanded through the use of agent migration. Agents are capable of mobility between embodiments in virtual environments (e.g. virtual avatar), embodiments in physical environments (e.g. robot), and software environments (e.g. OS desktops, PDA's) (see figure 1). Once instantiated in the world, the agent has knowledge of that world, and of its capabilities therein.



**Figure 1.** The Agent Chameleon spirit and its body instantiations: mobile devices (PDA), robot, PC, Web, and Virtual Reality respectively

Furthermore, the chosen embodiment of the agent must be capable of change, of agent mutation. This is particularly true in VR, where the agent is free of any constraints that exist in the real world. The agents must be capable of modifying their embodiment instantiation in response to the environmental and task specific events. For instance, in an outer space-like VR environment, the agent could adopt the persona of a rocket to allow it to fly, thereby facilitating human interpretation. The agent must exhibit the ability to dynamically select an appropriate form with associated functional portfolios. Additionally, the system must be extensible; it should be possible for the easy addition of new types of embodiment instantiations for different situations.

Crucially, this does not challenge the view that the mind and body remain dependent upon one another. Rather, the body is always present, and the reasoning of the agent is dependent upon that body. However, the form of that body is not constrained; the agent is capable of adjusting it, or adopting an entirely new one, to suit the task at hand. Each different embodiment instantiation fundamentally changes the viewing metaphor for that agent and its associated functional portfolio.



**Figure 2.** The current Agent Chameleon body instantiations as robots, VR avatars, entities on PC's and mobile devices

This work demonstrates how the traditional paradigm of one-mind-one-body can be extended beyond such a human-based reference to one-mind-many-bodies, thereby providing new core functionality for an artificial entity.

## FORM OF THE MACHINE

Conflicting arguments exist for and against the human form as a frame of reference for reasoning machines and these will continue to haunt robotics (see [14] for a discussion). The fundamental issue is how to achieve a balance between the function and form of the reasoning machine. Is the entity so strongly humanoid to the extent that we have the *replicant problem* as found in Philip K. Dick's famous novel: "Do Androids dream of electric sheep?" [10]. The functionality of the robot is then constrained by the human function and form. If aspects of the human form are used judiciously to facilitate human-robot social interaction (figure 3) [16], its capability set can diversify from our own and embrace inherently mechanistic capabilities and possibilities (e.g. vision beyond human visible spectrum, wireless communication, multi-actuator derived degrees of freedom, auditory enhancement).



**Figure 3.** Media Lab Europe's "JoeRobot" at the Flutterfugue performance with SmartLab and NYU CATLab in London 2002 (Photo courtesy of Brent Jones)

The influence of the appearance and the voice/speech of an entity on people's judgements of another's intelligence have been demonstrated in experimentation. The more attractive a person, the more it facilitates others to rate the person as having higher intelligence [1][3]. However, when given the chance to hear the person speak, people appear to rate the intelligence of the person more on verbal cues than on the person's attractiveness [3]. Exploring the impact of such hypotheses to HCI, Kiesler and Goetz [20] undertook experimentation with a number of robots to ascertain if

participants interacting with robots drew similar assessments of “intelligence”. The experiments were based on visual, audio and audiovisual interactions. Interestingly the results showed strong correlations with Alicke et al’s and Borkenau’s experiments with people-people judgements.

When we start to engage robots at a more complex level than our current interactions with washing machines, our propensity to anthropomorphise becomes inevitable. The important criterion is to seek a balance between people’s expectations and the machines capabilities [16].

The following case study explores our propensity to ascribe such notions as intelligence and emotions to machines.

### CASE STUDY: Emotion Machines

The work presented in [4] demonstrates the ease with which people are willing to ascribe human-like characteristics such as emotion and intelligence to small robots performing computationally simple behaviours. This effectively highlights how much “mind” one is willing to ascribe to an artificial entity with little or no explicit design decisions involved.

The first stage of the experimentation involved the design and implementation of seven independent behaviours on standard Khepera I robots (some equipped with the wireless communication module) as shown in figure 4. These were videotaped and a questionnaire was designed asking the observer to explain what the robots were doing, to pick three characteristics they would associate with the robots, and to grade these characteristics. Access to this questionnaire was distributed among a widely varied audience through Internet mailing lists. In the second stage, the same robots were dressed using coloured felt and given aesthetic “eyes” and the same behaviours were implemented. The same questionnaire was repeated.

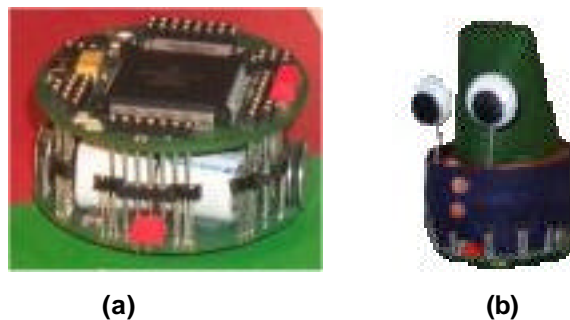


Figure 4. Experiments with Khepera I robots in (a) original form, and (b) in dressed form

The results indicated that in the first set of experiments, people were quite willing to see past the mechanistic exterior of robots and treat them as if they possessed some human-like qualities such as learning and interaction capabilities (none existed), and in the second experiment, stronger human-like features such as being alive and playful were reported.

This work raises the question of whether a system is required to be *inherently* intelligent or emotional in order for it to be *interpreted* as such. It is an orthogonal view of the pursuit of a system that one views as intelligent. An interesting aspect then arises. If the system can create the illusion of being intelligent and emotional, can it be maintained over time? Will its failing become apparent through our interaction with it?

It is important to recognise Schneiderman’s arguments against anthropomorphism [27], which state that people employing anthropomorphism compromise in the design, leading to issues of unpredictability and vagueness. The argument effectively distils down to a distinction as to whether one can maintain the function of the robot as a tool or not. When actuation and perception mechanisms are employed on the system to engage with its physical and social environment, the notion of the system remaining purely a tool becomes less manageable and consequently anthropomorphism is unavoidable. It’s how we manage the form and consequently anthropomorphism that becomes the important issue [16].

### THE FUTURE MACHINE

In the future, digital personal assistants will emerge to take advantage of the abstraction from a particular environment or platform. Autonomous reasoning empowers agents in deciding when to opportunistically migrate across different

platforms of varying capabilities. Three fundamental tenants that underpin this next generation of reasoning machine are now considered.

## Nomadic Agents

The Agent Chameleon work outlined previously, regarded the agent as an entity empowered with autonomy, human-computer interaction facilities, and a fundamental mobility. The embodiment instantiation thus merely becomes the container for a digital mind which opportunistically migrates between devices. The specifics of the hardware now reflect the capability set the autonomous mind.

Key technologies underpin such nomadic characteristics. These include white and yellow pages services for the location of people and services respectively. Agents would thus have access to directory services that permit access to publicly available resources and other agents. The agents would typically have a private directory for accessing resources specific to its owner and not publicly available. These agents would act as a proxy for the user in the real and virtual worlds, as well as allowing the user remote access to their devices and public resources. The presence of the agent moving through cyberspace, as the user moves through physical space, allows the associated user to be available at anytime through the agent and vice versa.

## Agent Evolution

Alas, all platforms are not created equal (e.g. varying memory, processing power, bandwidth, display characteristics). Consequently, these agents will have to be able to adapt to different conditions. Agents need to be able to evolve their very form. As they move from device to device they may necessarily have to shed some of their characteristics. This is analogous to exfoliation. Upon platforms that may not be able to handle an agent in its complete form, the agent would be able to reduce elements that are non-essential to its task at hand and scale down its capabilities. Alternatively, on platforms with minimal resources, the agent may merely send a minimally sufficient component of itself, which is required only for its current task, while the bulk of the agent can remain dormant and dismembered on the source device. Upon task completion, both parts would reintegrate and the agent would continue on its way. Furthermore, an agent may in certain circumstances wish to clone itself. Such circumstances may include those where it feels under threat, or under heavy resource demands. This elastic evolution would empower the agent with unforeseen versatility. The form of artificial evolution and adaptivity discussed is currently being developed within the Agent Chameleons framework [32]. These concepts resonate with initiatives such as IBM's *autonomic computing* [19] and that of Intel's *proactive computing* [31]. Central to such initiatives is software comprised of confederations of autonomous and social agents which are capable of such facilities as self-healing, self-protection, self-configuration and self-optimisation.

## Our Digital Friend

The current notion of the personal digital assistant is generally that of the physical device. The use of agents extends this notion beyond that of just the gadget to the concept of an autonomous intelligent digital assistant that is independent of any one physical device. These entities will effectively give any user their own personal assistant that will help with the information overload in daily life, assisting with personal communications and offer a generic interface to any number of devices. They will have the ability to react to the current needs of there user, and beyond this, grow and learn to anticipate future needs and requirements. Perhaps our vision can be best summed up by Luc Steels metaphor for what the robots of the future will be like: "*[it] is related to the age-old mythological concept of angels. Almost every culture has imagined persistent beings which help humans through their life. These beings are ascribed cognitive powers, often beyond those of humans, and are supposed to be able to perceive and act in the real world by materialising themselves in a bodily form at will.*" He goes on to detail how Angels may "*project the idea of someone protecting you, preventing you from making bad decisions or actions, empowering you, and defending you in places of influence*"[28]

## CONCLUSION

The demands on machines like robots have dramatically increased during the last decades. No doubt, the film industry has contributed greatly in moulding the imagery with which we associate the reasoning machine. Often it is presented as a friendly, hard-working and droll creature, such as R2D2 in Star Wars and the more human-like character of Data in

the Star Trek series. Creating an artificial being based on the blueprint of humans seems to be particularly compelling due, in part, to the basic effort of mankind to reproduce itself or even for the desire to be immortal. However, the film industry is not satisfied with presenting the bright side of machines. It also projects people's fears of machines into characters like The Terminator (MGM/UA, 1984), a nearly indestructible cyborg assassin.

This paper has sought to review and access our perceptions of reasoning machines. Within this paper we have reflected upon the mind-body debate and the monistic and dualistic standpoints. We have sought to extend the one-mind-one-body approach to accommodate a *one-mind-many-bodies* metaphor. Within this metaphor the agent's embodiment form may take many guises with the artificial mind or *agent* potentially exhibiting a nomadic existence opportunistically migrating between a myriad of instantiated embodiments.

The choice of embodiment must, not only empower the agent, but maintain the agent's identity in the eyes of the user. Central to this is the need to preserve key referential characteristics across the different instantiations.

We postulate a new generation of reasoning machines, which evolve and demonstrate autonomic characteristics. These machines are social [15], autonomous, intentional and are equipped with rudimentary self-healing, self-protection, self-configuration and self-optimisation capabilities.

While anthropomorphism in robotics raises issues about the taxonomic legitimacy of the classification *human*, and its sole association with ourselves, the question of whether machines will ever approach human capabilities persist. Technology is now providing robust solutions to the mechanistic problems that have constrained robot development thus far, thereby allowing robots to permeate all areas of society from work to leisure. The key is to take advantage of these reasoning machines and their capabilities rather than constrain them. We just keep in mind Asimov's Laws of Robotics [2], and remember where the OFF button is.

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## BIO's

### **Brian Duffy**

Brian Duffy's research aims to understand man-machine interaction from the perspective of socially capable robots situated in the Media Lab Europe's office environment. This seeks to research the fine line between observed and designed function and form. It is an exploration of the *illusion* of life and intelligence in artificial entities.

Brian's interest in designing and building social humanoid robots has developed from previous research at the Department of Computer Science at University College Dublin where he completed a doctoral thesis. Prior to this, Brian spent two years in artificial intelligence research and building robot prototypes at GMD's (now the Fraunhofer-Gesellschaft Institute) Autonomous Intelligent Systems Institute. Before moving to Germany in 1994, two years were spent at Institut National des Sciences Appliquées de Lyon in France working in the field of Distributed Artificial Intelligence and Multi-Agent Systems.

### **Gregory O'Hare**

Gregory O'Hare is Head of Department of Computer Science at University College Dublin (UCD). Prior to this he was a member of faculty at the University of Manchester Institute of Science and Technology (UMIST). He is director of the PRISM (Practice and Research in Intelligent Systems and Media) Laboratory within the Department of Computer Science. His research focuses upon Multi-Agent Systems (MAS) and Mobile and Ubiquitous Computing. He has published some 120 journal and conference papers in these areas together with two textbooks.

Gregory has secured some 6 million euro research funding for his research. He has acted as consultant for many national and international companies and organisations.

### **John Bradley**

John Bradley received his Bachelor Degree in Computer Science in 2002 from the University College Dublin (UCD), Ireland. From there he joined the Agent Chameleons project (a joint collaboration between the Computer Science Department UCD and the Anthropos Group in Media Lab Europe) as a PhD Student.

John's current research involves the self-adaptation of agents, as they migrate between heterogeneous platforms, driven by deliberative mechanisms. His other research interests include agent technologies, multi-agent systems, distributed artificial intelligence, agent migration, agent adaptation and robotics.

### **Alan Martin**

Alan Martin completed a Bachelor of Science Degree in Computer Science at University College Dublin, Ireland, and is now a PhD candidate there, working in collaboration with Media Lab Europe.

Alan's research interests include collaborative virtual environments, immersion, animated synthetic characters, agents and robotics.

### **Bianca Schoen**

Bianca Schön completed a Bachelor of Science Degree at the University of Applied Sciences in Darmstadt, Germany.

During her studies she gained experiences not only in economic enterprises like T-Systems debis Systemhaus GmbH in Darmstadt and the H.A.S.E GmbH in Hünfelden, but also in scientific institutes like the Fraunhofer Institut für Grafische Datenverarbeitung and the T-Systems Nova Technology Center, both situated in Darmstadt, Germany.

She is now a Ph.D. candidate at the University College Dublin, Ireland, where she is working in a collaboration project with Media Lab Europe.

Bianca's research interests include animated synthetic characters, artificial intelligence, agent technology, evolutionary- and genetic programming and evaluation methodologies.