Everyday robotics: robots as everyday objects

Frédéric Kaplan

Sony Computer Science Laboratory Paris
6 rue Amyot 75005 Paris
kaplan@csl.sony.fr / www.csl.sony.fr

Abstract

Why are we not living yet with robots? If robots are not common everyday objects, it is maybe because we have looked for robotic applications without considering with sufficient attention what could be the experience of interacting with a robot. This article introduces the idea of a *value profile*, a notion intended to capture the general evolution of our experience with different kinds of objects. After discussing value profiles of commonly used objects, it offers a rapid outline of the challenging issues that must be investigated concerning immediate, short-term and long-term experience with robots. Beyond science-fiction classical archetypes, the picture emerging from this analysis is the one of versatile everyday robots, autonomously developing in interaction with humans, communicating with one another, changing shape and body in order to be adapted to their various context of use. To become everyday objects, robots will not necessary have to be useful, but they will have to be at the origins of radically new forms of experiences.

1. Beyond science-fiction

Pencils, chairs, clothes, televisions, books… everyday objects that have, for a reason or another, found a niche in our homes among a multitude of possible competitors. Some have a clear function, others are versatile, or even useless. Some are attached with souvenirs, others do not evoke anything else than their function. Some have started to be useable after a long-term training, others have been straightforward to use since the beginning. Some help us to think about ourselves, others are mediators towards others. Some are precious. Some are cheap. Some are beautiful. Some are ugly. For which reasons, these objects have made it into our lives, among many others. What are our experiences cohabitating with them? What is their value for us?

This is the kind of questions one should ask in order to try to understand one of the intriguing paradox of our life-style evolution. In the 50s, in the 60s, in the 70s, many eloquent representations of our future life were showing an happy family of the XXIe century in an apartment literally full of robots: robot maids, robot companions, robot nanny, robot guards. Where are they? Why are we not living yet with robots?

Some might be tempted to explain the late arrival of robots in everyday life from a technological point of view. Building autonomous robots capable of navigating in an apartment has revealed to be a tricky issue and is still a partially unsolved problem. In contrast with industrial settings, our daily environments are extremely illadapted for robots. Every competency one would have expected a robot to have in the 50s (flexible communication with humans, dexterous movements, superior intelligence) have proved to be an extreme technological challenge. Some argue that robotics has taken a wrong technological route in the 60s by viewing a robot as a body controlled by a symbolic Artificial Intelligence program, and that it is only since the beginning of the 90s where basic principles of cybernetics have be rediscovered through behavior-based robotics that research was back on tracks. This "detour" would be the cause of the current lack of robots in everyday life (see Brooks 1999).

However, the discontinuous technological route of autonomous robotics in the last 50 years cannot explain everything. If robots are not yet part of our common everyday objects, it is maybe also because there has never been a sufficient effort to think what could *really* be the place of robots in our life. Many books were written, many colorful speculations were advanced but most of them were deeply rooted in the robot archetypes coming directly from science-fiction. The world of tomorrow was the one pictured in films and novels. Imagination of the engineer seemed to be trapped by these representations.

Figure 1: Everyday robotics in the 50s. Grey Walter, his wife, his daughter and their robot Elsie (Picture published in 1953 ©Philippe Constantin)

Few people ask whether it would actually be enjoyable to have science-fiction robots in our house? What would be our experience in cohabiting with such machines? In what sense, such experiences would enhance our life? These questions are important because they will eventually determine whether such robots will be used or not. In the world of design, this kind of questioning has been going on for a while. It has become increasingly clear that in order to create objects adapted to our daily life, understanding the experience of the user is a central issue (Norman 88). This implies, among other things, studying in detail the context of use associated with an object, the way an object "affords" certain actions, the way it finds its place as one element of the complex network of others objects. These are the underlying foundations that makes some objects, everyday objects.

To address in a relevant way the future of robots as everyday objects, a serious reflection must be initiated on the precise nature of potential *value* of a robot for its user. This means that instead of looking for a priori useful applications for robots in our daily life, it may be more important to think about our expectancies towards robots, about the kind of experiences that would make robot actually valuable as everyday objects and about the web of interrelations robots could bootstrap in everyday environments. Making progress in understanding both such expected and ecological values, will hopefully help us to draw a more accurate picture of our possible future life with robots.

This kind of design issues can only be tackled from a multidisciplinary perspective, through methodological experimental explorations using the tools of anthropology, psychology, ethology and sociology in addition to engineering methods. This article is not a review of the current state of the art in robotics (one could for instance refer to the articles in (Dautenhahn and te Boekhorst 2005)) but it is intended to provide an illustration of our approach to the design of everyday robots through a discussion of various prototypes and experiments conducted in our laboratory. In the next section, we first introduce the idea of a *value profile*, a notion intended to capture the general evolution of our experienced value with different kinds of objects. The value profiles of various commonly used objects are considered in order to guess what features are likely to determine particular types of experienced value. In section 3, we discuss in what sense robots are similar and different from common everyday object. Section 4 offers a rapid outline of the challenging issues that must be investigated concerning immediate, short-term and long-term experience with robots. Based on this analysis, the last section concludes on a more speculative view of our future life with robots.

2. Value profile of everyday objects

Experiences change the value of objects. In some cases, high expectancies are followed by disappointment. In others, unexpected qualities are discovered after a while. Time increase the historical value of some objects and make other obsolete. Such kind of evolution may be rapid. It takes only a few minutes to be excited or disappointed by an object. But it also involves long-term dynamics. In some cases, the same objects can continue to be used for many years.

One way to characterize how experienced value change with time is to introduce the notion of *value profiles*. A value profile is meant to capture in a single hypothetical curve the evolution of the experienced value of an object. Immediate value is characterized by the first minutes of interaction with the object. Short-term value corresponds to a time range that starts with the first days of usage and lasts for over a month. Eventually long term value is characteristic of the evolution over months and years. Value is evaluated through different means in each of these periods. In order to assess the multiple timescales that are typically characterizing our relationships with objects, value profiles can be plotted in some sort of logarithmic scale, where immediate, short term and long term evolution can be captured in a single curve.

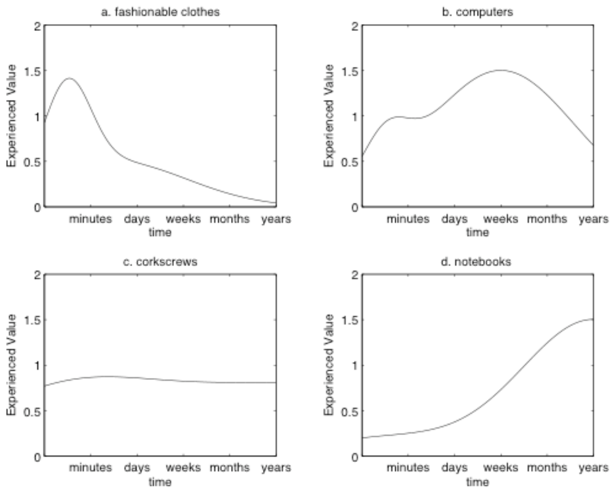

Figure 2: Hypothetical curves representing various value profiles for a fashionable clothe (a), a computer (b), a corkscrew (c) and a notebook (d).

Figure 2 presents four hypothetical examples of value profiles for different types of everyday objects: a fashionable clothe (a), a computer (b), a corkscrew (c) and a notebook (d). Immediate value of the fashionable item is high but progressively drops as it becomes less fashionable. Experienced value of the computer increase slowly because of the necessary training and adaptation of the user, reaches a peek when the user masters the technology and slowly becomes obsolete with new technological progresses. The value of a corkscrew reaches its optimum almost immediately as almost no training is required and stays at that level with very small risks of obsolescence or lassitude. Finally, the value of the notebook keeps increasing over time, as the user fills it with precious content.

Value profiles of such kinds could be drawn for any entities, living or artificial, with which we experience repeated interactions. What determines that a given object is likely to have a value profile of type *a*, *b*, *c* or *d*? In order to investigate this question, we have considered 40 everyday objects and tried to associate with each of them one of these four value profiles[1]. We have then considered 9 abstract features that could be used to characterize our experience with these objects. Here is the list of the dimensions chosen for this study

[1] The 40 objects include: an address book, an amulet, a board game, two books (a normal one and a favorite one), a cd player, a chair, a clock, two pieces of clothes (one fashionable and one attached with memory), a coffee-machine, a computer, a corkscrew, a fake jewel, a film on video, a gadget, glasses, a guitar, a key, a lamp, a mirror, a mobile phone, an organizer, a pencil, a photo album, a piano, a puzzle, a refrigerator, scissors, a table, a teddy bear, a telephone, a tv, a vaccum clear, a video games, video tapes, a washing machine, a watch, a webcam.

Versatility: How specialized is the object? Does it have a fixed, well-defined, closed functionality (e.g. a corkscrew)? Or is it intrinsically opened to various usages (e.g. a computer)? This factor is coded with two values: *close* or *open*.

Social orientation: Is the object targeted for individual usage (e.g. a mirror)? Or is it a mediator towards interindividual interactions (e.g. a phone). This factor is coded with two feature: social (*yes,no*) and individual (*yes,no*).

Network factor: Does the experienced value depends on the quantity of objects already present in the society? In some case, the more people use the object, the more it will be valuable for me to use it (e.g. a fax machine). In others, if too many people use the object, my experience with it will be less interesting (e.g. a Rolex). This factor is coded with three values: *negative, positive or neutral.*

Investment: Some objects need long-term investment in order to lead to an enjoyable usage (e.g. a piano), others are immediately intuitive to use (e.g. a lamp). Investment is coded in terms of the time necessary for an adult to master the object: *minutes, days, months*.

Historical capacity: Some objects are likely to be associated with souvenirs, or capable explicitly capturing parts or our life (e.g. a favorite pencil, preferred clothes, photos). Others offer no support for such memories. The historical capacity of objects can be coded with two values: *low* and *high*.

Personalization: Some objects can be explicitly customized (e.g. an organizer) or become adapt to their user (e.g. clothes). Others stay the same over time (e.g. a hammer). Personalization is coded with two values: possible or not-possible.

Control types: Interaction with objects can take various forms. Some objects are like extensions of ourselves (e.g. glasses) Some are more like autonomous entities with which we interact simply during short episodes (e.g. a washing machine). Some acts as a repository where we put things in order to fetch them later (e.g. a notebook). Some are content provider (e.g. a television). Some are essentially interactive entities which are not fully in our control but we which we have tightly coupled interaction (e.g. a video game). Control types are coded with five values: *extension, autonomy, repository, content-provider, interactive*.

Despite the fact that the details of coding was partly subjective, this method has permitted to structure our reflection on the different factors that play a role for determining the particular forms of value profile. Simple techniques of data mining revealed that most selective dimensions for determining the value profile are *historical capacity, social orientation, network effect and control type*. Analysis of the data show that: (1) profile *a* corresponds to objects with negative network effects requiring low investment, (2) profile *b* concerns mostly autonomous machines requiring some investment, beneficiating from positive network effects and that can be used both in a individual and social contexts (3) profile *c* corresponds to objects used as personal “extension” with specific closed functionality and with no possibility of customization and (4) profile *d* corresponds to objects with high historical capacity, versatile functionality and orientation towards social interaction.

If a robot was an everyday object, what would be its value profile? Will it look like the one of a fashionable item, instantaneously exciting but rapidly useless, a piece of advanced technology that requires training and slowly become obsolete, a corkscrew with very precise function that manages to stay interesting because it performs well its small job or a notebook that become increasingly valuable with time? To answer such questions we need first to see in what sense robots are similar and different from other everyday objects and then to understand the processes underlying immediate, short and long term experienced value in the case of robots.

3. Robots as everyday objects

What is a robot? Does it have to look like the zoomorphic creatures of science-fiction movies? Can some of our everyday objects can already been considered as robots? In what sense, a robot differs from most objects we interact daily? Answering these questions is of course a matter of definition. By definition, we will say that a robot is an object that possesses the three following properties: It is a *physical object* (P), it is functioning is an *autonomous* (A) and *situated* (S) manner.

A robot is therefore a physical (P) entity that perceives and acts in a physical environment. Unlike most everyday objects, a robot is programmed to have some form of autonomy (A). This means that such robots are not passive extension of ourselves. We may program them, give them instructions, in some cases train them, but we do not control them completely. Some machines that we use in daily life (e.g. washing machine, coffee machines) function also in an autonomous manner. However, by contrast with these devices, the environment (physical and social) perceived by a robot has a direct influence on its behavior (S). A robot is a situated physical entity, that constantly reacts to its environment and manipulates not only information but physical things (see Brooks 1999 for a longer discussion of the notion of grounding and situadedness).

These three characteristics are sufficient to distinguish robots from most everyday objects we interact with but they leave opened most of the other aspects we have discussed in the previous section. This is precisely what needs to be explored for the design of robots with particular value profiles.

If the main value of a robot is its rarity (which is a plausible scenario given the current small number of robots), the network factor is likely to be negative and the value evolution of a robot risks to be similar to profile *a*.

Being autonomous and socially situated, robots are likely to follow a *b* profile similar to the ones of computers. Experience should be enjoyable for a few months, but may decrease in the long term as the robot becomes obsolete. To ensure a sustained interest, a positive network effect (in which the experienced value increases with the number of robots used) would be a plus.

To reach long-term value, robots should follow either profile *c* or profile *d*. To follow a *c* profile, robots should be designed to stick to specific (unoccupied) niches where they would be optimally performing. On the contrary, to manage to have *d* profile, robots should be versatile and most importantly have an historical capacity. The current trends in robotics are exploring both ways. Some robots, like autonomous vacuum cleaners, offer a closed and specialized function. Others, like entertainment robots are opened to a large variety of usages ranging from playing games to providing contents. Both directions may be successful. However, it should be noted that robots shows important differences compared to typical profile *c* objects. Those objects are typically simple, not autonomous, not customizable and generally used to extend the user's possibility of action and perception. Their local optimality results from their simplicity and from the tight coupling with the user's needs. In the rest of this article, we will therefore investigate in further details under which conditions robots could lead an evolution of experienced value similar to a *d* profile.

4. Value profile of an everyday robot

Could we design robots that would lead to experiences enjoyable after a few minutes, more valuable after a few days and even richer after a few months? If such a machine could be designed, it would certainly find its place among long-terms everyday objects. But this is a challenging aim as evaluation criteria are different at every timescale. This section discusses each of these specific challenges based on research conducted in our laboratory.

4.1. Immediate experience

With robots, first impressions count. In a few minutes, any user will have made his or her first opinion about the object. We have conducted a series of preliminary studies about spontaneous reactions of infants and adults with particular prototypes of four-legged autonomous robots[1]. In these sessions, infants (10y old) have been regularly found to engage in some form of experimental test of the behavior of the robot (e.g. placing the ball near, then far from the robot to see its perceptual capabilities). On the contrary, adults were less keen to spontaneously interact with the robot, skipping this experimental phase to directly make comments about what their impressions about the machine. These investigations suggest that from an initial basis of natural expectancies, experience and culture are likely to change in an important manner our immediate reaction to robots.

Robots because they are autonomous, situated and physical artifacts tend to spontaneously foster interaction patterns that are usually characteristic of our experience with living animals. A crucial design issue is whether life-like design produces higher immediate experienced value or on the contrary introduces the machine in a misleading way. Human perception of automata has been a subject of reflection long before the arrival of the first robots. Life-like behavior can trigger interest or fascination, but can also be, in some cases, the source of some 'uncanny' feelings. Typically, this happens when the behavior or the appearance of the machine becomes very life-like and therefore violate our expectations about perceptual features that distinguish machines and animals. Freud was certainly one of first to put a word on this feeling. He calls it *unheimlich*, literally *was is not familiar* (Freud 1985). Paradoxically, it also means what was so intimate that it is now hidden and secret. This uncanny feeling may therefore result from the interplay between natural expectancies and experienced and cultural ones. More recently, this effect has been referred as the "uncanny valley" (Dautenhahn 2002)

Figure 3: Experimental studies of spontaneous interaction with a robot with children (top), with adults (bottom).

4.2. Short-term experience

How entertaining is an entertainment device? How much added value does a service robot offer? Short-term experience may greatly differ from immediate impression. It is in the first days of use that the performance of the robot is evaluated. Expected utility is matched with actual experience. Actual usage is compared with expected functionality. Interaction with the robot is enjoyable when actual function matches or is superior to expected functionality. So, as it is the case with most objects, the design should convey clear message about the type and context of usage of the robot. More importantly it should trigger the right kind of expectancies.

Some expectancies are based on our previous common interactions with machines and animals. Particular perceptual features (e.g. shape, movement) are associated with particular interactive experiences. Such associations result in specific schemata of interaction that are immediately triggered by particular feature of the object. Such schemata built up with experience and change with age. Other expectancies are based of particular views of

[1] All participants had never seen the robot before. The experimental sessions included five minutes of free interaction, filmed for later analysis. The participants were then asked to fill a questionnaire investigating their preconceptions about robots and relating them with their particular socio-cultural profile.

objects, machines and animals linked with a specific culture. They can be expected to different from one country to another. They result from cultural archetypes as pictured in novels and movies (Kaplan 2004) and more generally from philosophical views concerning human, animals and machines (Kaplan 2005).

We have extracted some simple design rules based on one-week experiments that were carried on in our laboratory for studying the short-term evolution of the interaction experiences with the same robot. One finding is that to publicize functionality overestimating the robot real competencies (e.g. speech understanding) is likely to lead to disappointing short-term experiences. It fosters immediate interaction but generate high expectancies that are rarely matched in practice. In a few days, users realized that the machine is behaving less "intelligently" then they though it was and they feel disappointed. Robots that provide a maximum information about what they can and cannot do ("transparent robots" Kaplan 2004) are more likely to lead to a positive short-term experience.

Another important aspect is linked with human-robot interaction and expectancies resulting from our experiences with humans and animals. Most everyday robots are likely to be mobile autonomous entities sharing the same environment then humans and interacting with them in some cases. Motion planning in such context must take into consideration several factors ranging for obstacle avoidance to the production of socially acceptable interaction schemata. For example, defining the appropriate distance a given robot should keep between itself and a human is already a rather complex problem. In the 60s, Edward Hall suggested in this theory of *proxemics*, that people maintain different degrees of personal distance forming concentric personal spaces (Hall 1966). In this line, service robots could expected to maintain themselves in what Hall referred as the *social space* (120-300 cm), entertainment devices would maybe be more effective if they are in present in the *private space* (45-120cm) and several prototypes of robots designed for affective experiences are likely to be more appropriate in *the intimate space* (<45cm) (Christensen and Pacchierotti 2005). But cultural expectations about theses spaces vary widely and context of interaction should also be considered.

These simple examples stress that designing successful everyday robots implies a fine-grained understanding of our expectancies. However, even if much more research needs to be conducted on short-term experiences, we believe the crucial issue lie in the capacity of robots to sustain rewarding long-term interactions.

4.3. Long-term experience

As suggested by our study on everyday objects, a key to sustain and increase the experienced value of robot is to endow it with an historical capacity. This is possible in various ways. First, the robot can act as a repository for our memories. Being an embodied entity sharing parts of our daily experiences, the value of such a robot could be to act as a "witness" of our life. However, progresses in ambient intelligence, wearable computing, smart clothes may offer many exciting opportunities for such applications and it is not sure that the robotic form is the most appropriate for this aim.

A way which we explore in the context of entertainment but that may reveal to be much more general is to consider robots capable of autonomous development and long-term learning. The richness of the behavior of such a robot increases with its developmental trajectory: what the robot has seen, what situations it has encountered, who it has interact with, etc. If previous interactions shape the robot's behavior in a distinctive way, entrainment dynamics between the user and its machine emerge. In such situations, the more the user interacts with the robot, the more the robot's behavior changes, leading through a positive feedback loop to continuously renewed forms of interactions with the machine. We believe understanding such self-reinforcing dynamics is the key for sustaining long-term intrinsically motivating interactions.

Creating autonomous developing robots capable of bootstrapping entraining dynamics with users is a challenging task. We have developed a collection of prototypes that represent first steps in this direction (Kaplan 2005). Some takes inspiration from animals training techniques, others from children's early language learning. More recently, we have considered models in which robots display some forms of "curiosity", being *motivated for learning* about their environment. Interestingly, this recent step may capture something important about what makes certain interactions enjoyable: Our results suggest that long-term entrainment dynamics emerge when *both* the robot and the user are intrinsically motivated for continuously exploring new forms of interactions.

Positive network effects are complementary dynamics permitting an increase of experienced value. In which conditions would an increase of the number of the robots result in an augmentation of personal experienced value of the machine? It could be argued that such dynamics could be in place if, in some way or an other, robots could benefit from the experiences of one another. To do so, they would need to find a way to communicate with each other. Several experiments with robots have successfully demonstrated how shared communication systems could be negotiated between autonomous embodied agents (Kaplan 2001). The robots have no direct access to the "meanings" used by the other robots, but they gradually bootstrap know-how for using communication conventions in order to have other robots performed particular actions. Some experiments showed that it is not even necessary to assume that robots share a prior repertoire of common concepts. Instead, they could build up their conceptual repertoire in a co-evolutionary process simultaneously with the construction of their communication system. These technologies permit new robotic applications where population of robots constructed shared communication systems without the need of a central coordinator. Moreover, several techniques currently under development do not assume that robots have exactly the same sensorimotor apparatus or control architecture. This means that populations of heterogeneous robots (e.g. different models of autonomous robots) can in some cases still manage to agree on an efficient communication system to interact with one another. Eventually, population of communicating robots are likely to foster indirectly social interaction between humans, another important feature for long-term interaction revealed by our study on everyday objects.

Several technologies under development permit to envision how robots could be endowed with historical capacity, positive network effects and act as social mediators between human. These are characteristic features of profile *d* objects. The next section explores this direction further by describing the emergence of everyday robots in the context of the progresses in ambient intelligence.

5. Perspective: Ubiquitous robotics

The picture of the everyday robot arising from our analysis is the one of versatile, evolving entity in recurrent interactions with humans and communicating with other robots. For robots to find a niche among the multitude of other everyday objects, they must offer a different added value. The robot's embodied and situated nature distinguishes it from other everyday objects. However, we have also acknowledged that its physical anchoring was not necessarily a positive aspect and could in some cases restrict its relevance of particular applications. In several contexts, technological innovation based on ambient intelligence seemed more promising.

A possible way out is to consider robots from a different perspective. For most robots, it is possible to separate a software part, in which adaptation and learning take place, from a hardware part, which remains the same. A robot can be seen as a software agent controlling a physical body. Therefore, using wireless network connections, a software agent can transfer itself between two physical bodies. The term *teleportation* can be used when the bodies are identical. When the software agent is transferred between two non-identical bodies (e.g. a personal robot and PDA), the term *metamorphosis* is maybe more appropriate. Using teleportation and metamorphosis, software agent controlling robots can manage to change body in order to find the most appropriate form for any given situation. A robot is not an easily transportable object compared to a PDA or a digital camera. Allowing software agents to "dock" into various kind of devices permits long term interaction with human as the software agent can follow the user even when he or she leaves home. From the point of the view of the agent's development, the number of learning situations increases consequently. Agents can learn through a variety of real world situated interaction, or even embodied in a virtual character inside a video game. Teleportation technologies permit to consider the possibility of the emergence of collective dynamics resulting in the interaction between a large number of software agents. By interacting not only with humans, but also with one another, shared convention systems can emerge adapted to both human-robot and robot-robot interactions.

Even if the first prototypes of systems based on these principles have already been tested (see Kaplan 2005 for a long elaboration of this scenario), this vision belongs for the moment to the domain of technological imagination. The imminence of the arrival of robots has been announced so often, that one should be careful in making prediction in that respect. Such evolution may happen, but in a way different from the scenario classically described. The robots of tomorrow don't have to be like the one imagined by science-fiction writers of the last century. If we are aware that it is experience that counts more that potential applications, that design has always to be thought in relation to contexts of use and that a lot can be learned from the complex ecology characterizing our interaction with everyday objects, we can be free to imagine other forms of future life in which we will cohabit with robots, or with entities that only vaguely resemble to what we used to call robots.

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