Roball – An Autonomous Toy-Rolling Robot

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Abstract

A mobile robot toy must be designed to be appealing to children, to create interesting and meaningful interactions, and to be capable of facing the wide variety of situations that can be experienced, all at a reasonable cost. In this paper we present Roball, a rolling robot. Children are used to play with ball-shaped objects, making Roball implicitly appealing. A special characteristic of the design is that the physical structure of the robot, its dynamics and its control are all taken into consideration to create interactions particular to Roball. In addition, its spherical shape gives Roball robustness in facing all kind of obstacles, surfaces, and interplay situations. This paper describes the robot and observations made of children who played with Roball. The use of Roball as an educational tool for helping autistic children is also discussed.

Introduction

In the 1980s, processing was the major concern and led to the personal computer revolution. In the 1990s, access was the primary focus, causing the WWW/Internet revolution (Saffo 1997). The concept of interaction also grew in importance during this period, creating interesting and appealing ways of exchanging information between computers and users. The current trend for the next decade is that interaction (not just for Internet but with electronic devices that operate in the physical world) will be the primary focus, using sensors as the key technology to create "smartifacts" (Saffo 1997).

Interaction is surely one concept of great importance for the toy industry, and commercial interest for interactive toys is actually expanding rapidly. The physical appearance of toys is still essential in making it appealing to children, but now interaction is also important and can be done in various and novel ways: speech, sounds, facial expression, visual cues and movement. The Tamagotchi in 1997 created a new market for virtual pets children have to nurture, followed a year later by the Furby doll, a furry head creature. AIBO, the robot-dog from Sony and part of the MUTANT project (Fujita, Kitano, & Kageyama 1998), was also introduced on the market. Other projects are also oriented around the robotic pet concept (like Tama-a of Omron, Robokitten of ATR or R100 of NEC). The complexity and obviously the costs of these products depend on the ways the toy can interact with the child. For example, the Furby doll is 35$US and can talk and respond to sounds and touch, using one motor and a gearing mechanism to control the different moving parts. AIBO however, equipped with lots of motors, a camera, a powerful microprocessor and various sensors, can move by itself in the environment and is sold for about 3000$US.

The growing emphasis on interaction is not the only reason why there is a good chance that mobile robots may first be used for entertainment purposes in our homes. For instance, vacuuming is one task that has been the motivation of many robotists for a long time, but still robot vacuuming systems are not yet something common in households. One reason may be that for such task-oriented robots to be widely used, they have to accomplish the task with precision and effectiveness, doing as good or better than humans. While technological development and research are still required to reach this level of optimality, developing a robot that has to interact in interesting ways with one or many users is a much more reasonable goal to achieve. A child will tolerate that his or her robotic toy sometimes stumble or fall for some reasons: this will just be part of the game. The variety of situations that a mobile robot would encounter in a household environment also presents important challenges for the research community, with great marketing opportunities.

Children like to play with a lot of things, and so many different types of robotic toys can be imagined. The goal is to design a robot that is appealing to the child and capable of facing the variety of situations that can be experienced during interplay and in a household environment, all at a reasonable cost. Toward achieving this goal, we have designed a spherical toy robot we named Roball. In this paper, we present how Roball is able to operate in real world environments and create interesting and meaningful interactions with children. The paper is organized as follows. First, the general characteristics of Roball are described. The following section explains briefly the principles of the software architectural methodology used for programming Roball, followed by the description of the mechanisms implemented to control the robot. Observations made of children who played with Roball are then presented. The use of Roball as a pedagogical tool for helping autistic children is also addressed.

Roball, the Rolling Robot

Designing an autonomous mobile robot to operate in unmodified environments, i.e., environments that have not been specifically engineered for the robot, is a very challenging problem. In a household environment for instance, dynamic, unpredictable and very diverse situations occur constantly. Research involving the design of software control architectures (Arkin 1998) and approaches to make mobile robots navigate, learn and plan their actions in the world put a lot of emphasis on these issues. One primary concern then is to have the necessary processing power to implement the algorithms required for the robot. However, in doing so, other aspects of the robot are sometimes forgotten: its structure, its shape, its dimension, its weight, etc., will all influence the situations the robot will experience. Also, the objects (other toys, shoes, clothes, etc.), obstacles (walls, couch, table, chairs, stairs, etc.), operating surfaces (wooden floor, ceramic, shaggy carpets, etc.) and entities (dog, cat, people, etc.) that the robot can encounter in a household environment are very diversified. A wheeled robot may flip over or on the side; a tall walking robot may trip on something and accidentally fall on somebody; or a heavy robot may cause a lot of damage falling down the stairs. While these situations may not always be avoidable, integrating physical, electrical and software considerations is very important in designing robots that are well prepared to handle the situations that arise in a household environment.

These considerations are even truer for toy robots. Children are extremely hard on their toys: they grab them, throw them, kick them, put them in places they should not be in, etc. Electronic products are easily affected by these conditions. High tech toys would usually cost more because of the additional processing, electrical and mechanical components required to create sophisticated interactions with the child, and parents will think twice before paying more money for something that might get damaged more easily. Indicating the age range is one way of preventing misuse of a toy by younger children, assuming that older children will carefully use the toy. However, it is not a foolproof solution because once the toy is out of store, there are no guarantees that it will be properly used or that a child will respect the age restriction. For example, we have personally witnessed a one year old boy getting his hands on a Furby doll and rapidly damaging the doll. The damage would have been even worst (and costly) on AIBO.

So, a toy robot must be appropriately designed to handle the variety of situations that arise in a household environment, and be extremely robust while still be appealing to children. The design we have come up with is to encapsulate the robot inside a sphere, and use it to make the robot move around in the environment. This simple idea has the following advantages:

Figure 1: First prototype of Roball.

- The sphere protects the robot's circuitry against shocks, dirt and other things that high tech products are sensitive to. No assumptions on the child age or on the way the toy must be handled are then necessary.
- A spherical shape allows the robot to face all kind of obstacles, surfaces and interplay situations. A rolling ball usually follow the path of least resistance. It has less chances of getting stuck on top of an object or in between the legs of a chair. In contrast, a wheeled robot may see its caster wheel work very poorly on a carpet, or the robot may overturn when trying to move over a boot for example.
- Children are used to play with ball-shaped objects, making the robot implicitly appealing. Kicking is to be expected, more so than with another kinds of toy robot, making robustness even more important. But contrary to an usual ball, Roball will not necessarily stay in a corner once the child is done playing with it, and it can behave in different ways when the child is too hard with the robot.

Our first prototype, built in 1998, is shown in Figure 1. The mechanism differs from other round-shaped robots like Gyrover (Xu *et al.* 1998) in that it can rotate on all of its external surface, and not on a wheel. This prototype was built using a 68HC11 microcontroller board, a plastic sphere and components com-

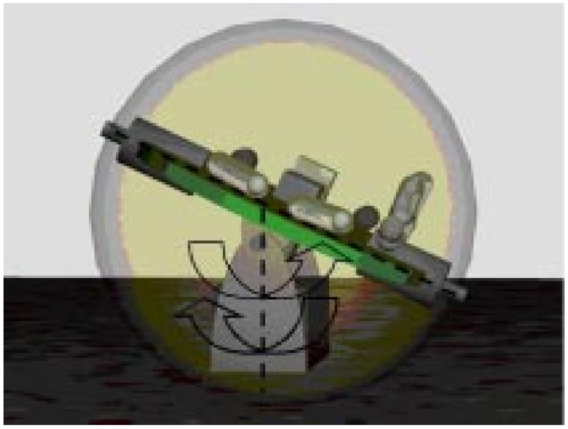

Figure 2: Roball's propulsion and steering mechanisms.

monly available in robotic supplies. Roball is 6 inches in diameter and weighs about 4 pounds. The overall cost of material used was less than 100$US. Figure 2 illustrates the propulsion mechanism of the robot. Two motors attached to the extremities of the sphere are used to make the robot move. The battery is supported by a servo-motor and is used for steering. Tilt sensors are used to detect the horizontal and vertical inclinations of the internal plateau supporting the microcontroller.

After having built our first prototype of Roball, we found other designs of spherical robots. The Solar Ball Kit commercialized by Images Company Inc. is a spherical robot that uses solar energy in its first version. In the second version, when light is detected a battery is activated and the robot moves. The BEAM MiniBall is also a rotating robot that has a similar behavior. The Orbot rollerbot is a rolling sphere robot teleoperated using a TV remote control. Toy Biz Inc. (Arad, Pitrone, & Jeffray 1996) also has a patent on a self-propelled toy ball which plays musical tunes and generates sound effects. Once energized, the electronics of the ball operate to propel the ball and simultaneously activate an integrated circuit sound effects chip which plays a musical tune. When the ball bumps into something, the propulsion mechanism is disengaged and the circuit then plays a randomly selected pre-programmed sound effect. Thereafter, the propelling mechanism is again activated and the ball resumes playing the musical tune. Roball significantly differs from these products by using a microcontroller and sensors to make the toy navigate autonomously in the environment and interact in various ways with the child, as explained in the following sections.

Software Architectural Methodology

Once the structure and the processing components of Roball assembled, we needed to design the software to control the robot. The approach used to control the robot must include efficient software mechanisms for sensing its environment, for low-level control of the robot's actuators, and also for managing the goals of the robot and create interesting interactions with the child. Following the guidelines of a software architectural methodology is then important. It also facilitates the design by starting with simple mechanisms and adding new capabilities (like learning for example) in future developments.

The architectural methodology used is designed with the primary objective of combining various properties associated with "intelligence", like reactivity, planning, deliberation and motivation, while still preserving their underlying principles (Michaud, Lachiver, & Dinh 1996; Michaud 1999). This architecture can be categorized as a hybrid deliberative/reactive robotic architecture built around the behavior-based paradigm (Arkin 1998). The basic idea is to have behavior-producing modules (also called behaviors) control the actuators according to sensory data and the state of the robot, and dynamically change the selection of the behaviors over time. The selection of behaviors is done according to environmental states, the goals of the robot and reasoning done about the world.

As shown in Figure 3, the architecture has three abstraction levels. Behaviors are the agent's skills for responding to the situations encountered in the environment. These behaviors all run in parallel and their resulting commands are combined using an arbitration mechanism (which can be priority based, motor schemas, fuzzy logic or other methods (Arkin 1998)) to generate the control actions (or commands) of the agent.

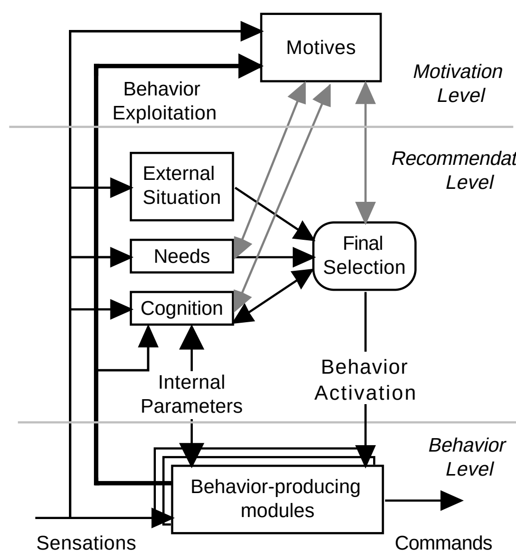

Figure 3: General framework of the architecture.

Based on this repertoire of behaviors, the other modules of the architecture are responsible for changing the selection of behaviors and to reconfigure them according to the agent's goals and the situations it encounters in the world. The novelty of this architectural methodology compared to others is that it proposes a different method for behavior coordination at the *Recommendation Level*. Three modules are used to formulate, in parallel, behavior recommendations from different monitoring conditions. The generic names chosen for these modules only try to characterize the conditions they monitor and their effects on the agent. The *External Situation* module evaluates sensory information to affect behavior selection. The *Needs* module selects behaviors based on the motives of the agent, possibly correlating them with perceived events. The third recommendation module, called *Cognition*, exploits or acquires knowledge about the environment to plan or to prepare the use of behaviors. This knowledge may be influenced by perceived conditions in the world, by motives or by the intentions of the agent. Different kinds of knowledge can be incorporated in this module according to what can be useful for the agent, like a topological map of the environment (Michaud, Lachiver, & Dinh 1996) or an 'interaction model' for dynamic and nonstationary environments (Michaud & Matarić 1998). Cognitive recommendations can also be influenced by information coming from behaviors by the *Internal Parameters* link, as they can reconfigure specific behaviors using the same link. These three modules recommend the activation or the inhibition of behaviors by using a *desirability* measure and an *undesirability* measure for each behavior. These measures make it possible to prevent possible conflicts when recommending behaviors, which may occur from the parallel and independent evaluation of these three recommendation modules or from different rules in the same recommendation module. The actual activation of behaviors, i.e., *Behavior Activation*, is determined by the *Final Selection* module, based on these measures.

The third level of the architecture is the *Motivation Level* made of the *Motives* module. The *Motives* module is used to monitor the agent's goals and to coordinate the proper working of the other modules. The word 'motive' was chosen because it refers to something that prompts an agent to act in a certain way. Methods to manage motivations or even emotions (Breazeal 1998; Maes 1990) can be implemented in this module. Motives can be influenced by the environment (from sensed conditions), the intentions of the agent (derived from behavior recommendations and activation), knowledge about the world (managed by the *Cognition* module) and by observing the effective use of the behaviors. This last influence is related to the link called *Behavior Exploitation*, which refers to the use of behaviors. This is different than *Behavior Activation* in the sense that an **active behavior** is allowed to participate to the control of the agent, and it is said to be **exploited** if it is actually used to control the agent (by reacting to the sensations using the control rules of the behavior). An activated behavior is not exploited when it is not releasing commands that affect the actions of the agent.

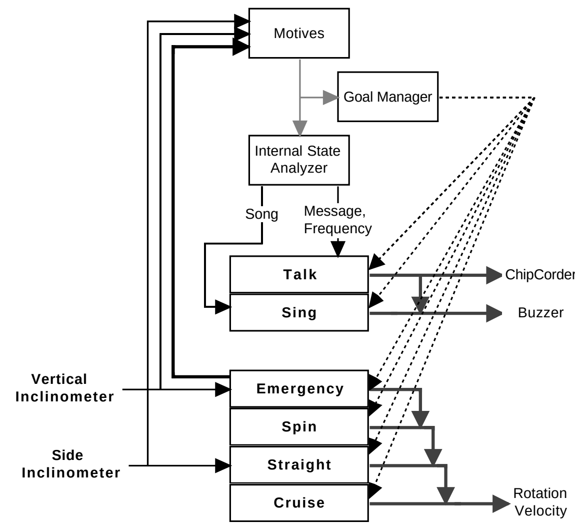

Figure 4: Decision modules used to control Roball.

Observing the exploitation of behaviors over time can serve as an abstraction of its interactions within the environment (Michaud & Matarić 1998). Finally, motives can also affect behavior activation by influencing directly the *Final Selection* module when it may be necessary.

Approach Used to Control Roball

The use of the modules of this architecture and their procedures are determined according to the agent's capabilities and purpose. As a first implementation for Roball, our goal was to design simple mechanisms to make the robot move in the world and interact with the child in two ways: by vocal messages and by the movements of the robot. Only four of the six modules of the architectural methodology are then necessary: the *External Situation* module is not required, and since only one module issue behavior recommendations the *Final Selection* module is not required. In future works, these modules can be easily added to improve the capabilities of Roball. The *Needs* module is named the *Goal Manager* module to clarify its purpose in this implementation. In addition, the *Internal State Analyzer* module is associated with a kind of *Cognition* module that does not issue behavior recommendations but interacts with behaviors using the *Internal Parameters* link.

As shown in Figure 4, four behaviors are used to control the velocity and the direction of Roball, using Subsumption (Brooks 1986) as the arbitration mechanism. These behaviors are, in order of priority: *Emergency*, used when the robot comes in contact with an object; *Spin*, to make it turn in circle; *Straight* to make Roball go straight in one direction; and *Cruise* to make it move forward. To generate vocal messages using a simple device, we use an ISD ChipCorder[1], a single chip device for voice recording and playback. Specific messages are memorized in EEPROM and are addressable by the microcontroller of Roball. A behavior named *Talk* is responsible for generating the proper message at a specified frequency using the ChipCorder, and *Sing* plays songs using a simple buzzer.

Behaviors are implemented as individual processes that get activated or destroyed according to the goals of the robot. These goals are managed using motives. In this implementation, a motive is a variable that has an energy level and an activation level, both ranging from 0 to 100% (Michaud & Vu 1999). The energy level can be influenced by various factors: sensory conditions, the use of behaviors associated with the motive, activation of other motives and cycle time (for cyclic occurrences). The energy level is computed by the equation $E_m = \sum_{j=1}^{n} w_j \cdot f_j$, where f represents n influencing factors, weighted by w, affecting the motive. The activation level of motives is used to determine the recommendation of behaviors by the *Goal Manager* module, and is derived from the energy level using a mapping function. The general state of Roball is determined by the *Goal Manager* module using three motives:

- *Hungry*. This motive verifies that the battery voltage level is greater than a preset threshold. If not, the *Cruise* behavior is deactivated to make the robot stop, and Roball asks to be recharged.
- *Distress*. This motive examines the frequent use of the *Emergency* behavior (using a *Behavior Exploitation* link), which is a sign that Roball is having trouble moving freely. Every time the *Emergency* behavior is used, Roball apologizes for having hit the object. If *Emergency* is used frequently in a short period of time, Roball asks for help and the behavior *Spin* is activated to try to move the robot out of trouble.
- *Awake*. This motive is used to simulate sleeping periods during which Roball is not playing with the child. When *Awake* is not activated, all behaviors are deactivated. Otherwise, Roball is allowed to move and to interact with the child. Coming back from sleep, the robot says hello and plays a short song. Roball stays awake longer when no distress situations are experienced or when the robot is not moving a lot.

When awake, Roball is programmed to wander around in the environment until it decides to rest, based on the motive called *Resting*. This motive deactivates the *Cruise* behavior, stopping the robot for a certain period of time (determined randomly). During resting, the robot is allowed to interact with the child in one of three ways: Roball can ask to be spun, to be shaken or to receive a small push to start moving again. Three motives, *Spinning*, *Shaking* and *Pushing* respectively, are used to monitor these requests and the response from the child. For example, if the child shakes Roball when it asks to be spun, then the robot tells the child to stop. When spinning is requested, Roball can indicate that it feels dizzy or that it wants to get another spin, depending on how it was spun. Spinning is detected by a particular state of the tilt sensors, which occurs only when the robot is being spun. When spinning, a message expressing excitement is generated. If a response is given to a request for spinning, shaking or pushing in a reasonable amount of time, then Roball thanks the child. This action is monitored by a motive named *Happy*. If the child does not respond to the request, then a motive named *Bored* gets activated and the robot tells the child that it is getting bored. When the energy level of *Resting* drops to zero, these interactions stop and Roball starts to move again. For the pushing request, the *Resting* motive becomes inactive right after the child gives a small push to the robot, making it starts to move.

Note that these interactions are different than those involving nurturing and petting gestures. The objective is not to create the illusion that Roball is an entity that needs caring. Instead, we want to create interactions that are more related to the dynamics and the structure of the toy. We also try to make these interactions more personalized by making Roball use the name of the child in some of the messages, like: "Simon, give me a little push please", or "See you later Simon". This helps create more meaningful interactions with the child.

Experiments with Roball

Since the sphere of the first prototype of Roball was not designed to be robust enough to be used in very though interplay situations, tests were done in controlled environments and with a small number of children. Each child can have his or her own way of interacting with a toy: this may depend on age, interest, personality, etc. Without taking all of these aspects into considerations, the goal of these first experiments was only to see how children would interact with Roball in various environments.

Roball was first tested with a 10 months old boy named Simon that had never played with a ball. The experiment was simply to see how the child would interact with Roball. At this age, the boy was not able to understand any verbal commands from the robot, so only the movement of Roball created some type of interactions with the child. In addition, Roball was not equipped with any obstacle detection sensors. The robot just moved around, coming into contact with obstacles and managing to move away from them using its spherical shape. During the first trial, as the robot started to move, Simon immediately started crawling to catch it. When he finally did, Simon tried to grab the robot and immobilize it but could not do so. Roball was always trying to move and every time Simon lost his grip, the robot started to move again in the released direction. Figure 5 illustrates Simon playing with Roball. This catch-and-grab cycle repeated itself a couple of times, as Roball got to move on wooden floor and ce-

[1]http://www.isd.com/.

Figure 5: A 10 months old boy playing with Roball.

Figure 6: Remi, a 3 years old boy playing with Roball on a carpet floor.

ramic, underneath a table and chairs, on the side of a couch, furniture and walls. Simon did not seem to get tired of trying to catch it or of watching Roball move. Just having Roball wander around in the room made Simon want to follow it, also making him practice his crawling and moving skills. After about 30 minutes, the experiment ended when we stopped the robot, which necessarily made Simon very upset. The next day we gave Simon a small basketball, about the size of Roball, to see how Simon would play with a ball. Simon went to grab the ball, played with it for about 30 seconds, and went away to play with other toys. We also gave Simon a small train that can move on the floor, and Simon most often grabbed the toy, threw it on the side and left it there. When the toy train is on the side or in front of an obstacle, it continues to move its wheels, just making a lot of noise until somebody decides to turn it off. Four months later, we let Simon play again with Roball. He then knew how to play with a ball, so he was now trying to lift Roball and throw it on the floor, showing us that robustness of the sphere is very important. But again, since Roball was moving on its own, Simon continuously pursued Roball in the room. With the basketball, Simon still only threw it once or twice, and started to play with other toys.

We also gave Roball to a 3 years old boy named Remi. Remi is a very active boy, always trying out new things. When he saw Roball for the first time, he immediately went to play with it. Remi understood that Roball had to stay on the floor (a carpet in this experiment) to move, so he started to follow the robot around, going where Roball was going (like under tables, in between furniture, etc.). He also played with Roball by throwing the basketball at the back of the robot, again showing the need for robustness. Remi was able to understand Roball, and his first reflex was to talk back to the robot, giving it commands and asking it why it was behaving in particular ways. At one point the robot stopped and since Remi was not getting an answer from Roball, he started to shout his requests to the robot. He knew the robot was able to talk, and expected it to understand what he was saying. Speech interaction seems to be important to create even more interesting interplay situations, and the next prototype of Roball will incorporate this ability.

Another experiment was done with Alexis, a boy about Remi's age. Alexis is calm and shy, so the first contact with Roball was very different than for Remi. The experiment was done on a concrete floor in a small garage, with a small slope toward the drain located in the center of the garage. Roball did not experience any problem in moving around in the garage, not getting stuck at the drain, and even sometimes going outside on the pavement. Initially, Alexis stood outside the garage, looking at Roball and analyzing it from a distance. Alexis was not scared: he was looking at the robot, smiling. He was very intrigued by the fact that Roball was moving on its own. He was used to play with a remote controlled car, and he did not understand how Roball was moving on its own. The fact that Roball talked was also something new to him, and Alexis sometimes repeated to his father what Roball was saying, explaining what the robot was doing. After a couple of minutes and a bit of reassurance from his father (who went to play with Roball), Alexis also went to play with Roball, as shown in Figure 7. He let the robot pass under his legs, and responded to Roball's requests for spinning, shaking or pushing. Contrary to Remi, Alexis was always very gentle with the robot. For instance, Roball barely made one turn the first time Alexis made it spin. For children like Alexis, experiments should be done on longer periods (by letting him

Figure 7: Alexis playing with Roball in a garage.

go home with the robot for a couple of days) to see how he would play with Roball past the familiarization stage. Our second prototype of Roball will allow us to do such tests.

For older children, interactions must be more complex and diversified to create interesting interplay situations. More sophisticated programs and capabilities would need to be incorporated to the robot. Children may also have various use for the robot like using it to play soccer or throwing it high in the air. While physical robustness is then even more essential, these situations may be detected by the robot, and messages can be issued to ask the child to stop using it this way (an eventually cease playing with the child if he does not stop).

Roball and Autistic Children

A robot toy can be used for more than entertainment: it can also serve as a pedagogical tool. One interesting idea is to use robots to help autistic children. Autism is characterized by abnormalities in the development of social relationships and communication skills, as well as the presence of marked obsessive and repetitive behavior. Also associated with learning difficulties, autism is considered to be one of the most severe of the developmental disorders. All people with autism have impairments in social interaction (difficulty with social relationships, for example appearing aloof and indifferent to other people), social communication (difficulty with verbal and non-verbal communication, for example not really understanding the meaning of gestures, facial expressions or tone of voice) and imagination (difficulty in the development of play and imagination, for example having a limited range of imaginative activities, possibly copied and pursued rigidly and repetitively). In addition, repetitive behavior patterns are a notable feature and a resistance to change in routine. Despite several decades of research, relatively little is understood about the causes of autism and there is currently no cure for the condition. However education, care and therapeutic approaches can help people with autism maximize their potential, even though impairments in social and communication skills may persist throughout life.

Different projects have recently started to study the use of robotic toys for autistic children (Dautenhahn 1999; Werry & Dautenhahn 1999; Michaud *et al.* 2000). A robot toy may help autistic children open up to their surroundings, improve their imagination and try to break repetitive patterns. Speech recognition is not necessary, but generating short vocal commands can be quite useful in getting the attention of the child. The robustness of the toy is also of prime importance, since it cannot be assumed that the child will be very careful with the high tech toy. For example, when we brought a common three-wheeled robot, the first thing one child did was to try to take it all apart. Roball is protected against that, and can interact with the child using vocal messages.

Roball was also presented to autistic children, and each child had his or her own distinct way of interacting with the robots. Some remained seated on the floor, looking at the robot and touching it when it came close to them, lifting it and making it spin (but not always when requested by Roball). Others moved around Roball, sometime showing signs of excitation. While it may be difficult to generalize the results of this first experiment, we can say that Roball surely caught the attention of the children, even making them smile. We were somewhat worried about the fixation behavior of autistic children with rotating objects (like a ventilator). This does not mean that autistic children cannot play with balls, but the visual effect created when the ball is moving must not reinforce the rotative movement. While children were intrigued by seeing the internal plateau turn inside Roball it did not seem to affect their behavior, probably because the plateau was not moving continuously and that the robot was talking to them. Making the sphere opaque would also help prevent this possibility.

Summary and Conclusion

This paper first describes some requirements for designing a mobile toy robot. The conditions a mobile robot must face in a household environment are very diversified, and being also a toy for children is even more demanding. We may design a robot expecting children to play with it in appropriate manner, while in practice it may not be the case. A real dog mistreated by a child will indicate its discomfort by barking or by moving away (and hopefully not by biting). But this may not yet be the case for robotic toys. These robots must then be very robust while still being able to create appealing and meaningful interplay situations with the child. This presents important challenges for the research community, with great marketing opportunities. The paper argues and demonstrates how a spherical rolling robot is a simple approach that meet these specifications, at a reasonable cost.

Another interesting aspect is that we are able to integrate the physical structure of the robot, its dynamics and its control to create interactions particular to Roball. The spinning interactions with the robot is a good example of this property, which help establish the believability in that the robot is actually playing and not simply executing a program. We are working on a new pre-commercial prototype of Roball. This will allow us to conduct more experiments with children of different ages and for long-time usage of the robot, and acquire more quantitative results to evaluate how Roball makes an interesting autonomous toy robot. While the number of sales can give an indication of the success of the toy, this measure is also influenced by marketing, and potential investors usually need such assessments before commercializing the product. Measures like the mean time before failure, the average time a child plays with the toy (during the day and over the years), also compared to the selling price, would be useful. Qualitative evaluations of the ability of the toy in making the child learn news things and minimize disturbances in the household (like continue talking when nobody is playing with the toy) are also important. These factors are more useful since they evaluate child's interest and parents' concerns. Different categories of Roball are also in preparation, starting with a small version that can simply move, to more complex designs of various shapes and sizes and that can make Roball perceive various things in the world, creating more elaborate interactions with children of all ages.

All children eventually get bored with their toys, but high tech toys have the advantage that changes can be made to their programming to create new interplay situations. These changes can be done by designing new programs to control the robot, or by giving the toy the ability to learn and evolve over time. The architectural methodology followed for the design of the software mechanism for Roball will facilitate the addition of these abilities in future developments. Artificial intelligence and autonomous robots research can benefit greatly from the field of entertainment, using it as an experimental setup for developing innovative ways of making physical machines interact intelligently in real life situations.

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