Art, Robotics, Handicaps and Feelings

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Abstract

This paper describes an attempt at introducing state-of –the art robot control techniques in an animated artwork, with the aim of obtaining an "intelligent" behaviour from a mechanical device. Such attempts are quite common, but in this particular case the application domain is completely different from the common ones, because it lies in the field of artistic representation of feelings. The paper aims at showing how it was possible to cope art and technology, in order to satisfy the needs both of the artist and of the robotics engineer.

1 Introduction

Survivor is an artistic creation, aimed at expressing the horror of landmine-inflicted wounds on innocent people.

A wounded human is here represented by a small, ordinary school chair whose front legs have been cut and replaced by a rough and inappropriate mechanism. A small bag of bomb debris hangs below the chair, as a perpetuum memento.

Survivor is not, by any means, a robot. Its mechanical structure is highly defective, as defective is the structure of a human body that has been deprived of its legs.

The behaviour of a human being who finds him/herself in such situation is affected by several factors: some are due to the objective difficulty of using the new legs, and some are due to emotional factors, that include fear, "shame" of being in such situation, pain, etc.

In order to attain such characteristics in an artificial device we combined the mechanical structure, which was strongly conditioned by artistic requirements, with a control system that exhibits appropriate behaviours.

At the time of writing, a first version of *survivor* has been built and is now operational and constantly on display in art galleries or in mine-action related initiatives. Due to the existence of a previous prototype, this version is called *survivor* 2. In the meantime, a modified and augmented new version (*survivor* 3) is being implemented. This paper doesn't go into deep technical detail, and the interested reader should refer to the appropriate technical website [1] for more information.

2 Robotics and art

Since my first years of robotics research, in the late seventies, I had many chances of studying problems that joined robotics and art together, starting from a robotized theatre that was built around 1980. Milan Polytechnnic Artificial Intelligence Project, where I worked since my un-

Figure 1 - *Survivor* version 2

dergraduate years till 1987, was led by Professor

Marco Somalvico, whose interests were always directed to using technological achievements in support of impaired or otherwise “weak” people. Therefore, I later had many chances of talking and some of co-operating with researchers working on topics related to the aid to impaired people, both from a computer science (AI) and from a robotics point of view.

Since more than five years, Brescia University is also involved in robotics for demining research, a topic where extremely sophisticated technologies must come into close contact with pain and suffering of extremely poor people.

However, in all these years it never happened that an artist asked for cooperation to solve an artistic problem, namely the transposition (not necessarily accurate, but easy to understand and capable of raising strong emotions) of human feelings into a very approximate model of an impaired person. Although the research appeared heavily conditioned by the artistic requirements, it was extremely challenging and unusual. Fore more information about the artistic aspects of the project, the reader should refer to the appropriate website [2].

3 Electro-mechanical structure

The mechanical structure of *survivor*, that is the same for all versions, is very simple (Figure 1). Technically speaking, it is based on the consideration that a four-legged vehicle can maintain its stability while lifting either one of a couple of adjacent legs, provided that its centre of gravity is located in a suitable position. It is impossible to maintain stability if more than two legs must move, unless mechanical systems are used to displace the centre of gravity of the vehicle during its movement. This forced us to have the chair move only the two front legs, while the two rear ones are equipped with wheels and are almost always in contact with the ground.

Loose and quite inaccurate mechanical couplings were chosen for all moving parts, in order to attain a “shaky” and uncertain movement. The “step” derives from the movement of a DC motor with a gear speed reduction system (a car windshield wiper motor was used for each front leg). Such motors provide enough torque for moving the chair, and are equipped with the auxiliary contacts used to stop the motor after each step.

Given these mechanical implements, the control of the chair is quite simple. In section 5 details on the control strategy will be given. If the chair has to move along a straight line, both legs must perform an equal number of steps, i.e steps must be alternately performed by both legs. Having one leg perform more steps that the other one causes the chair to move along a curve.

4 Sensors

The other important issue was the sensory aspect. Clearly, *survivor* needs some sensory input to detect fixed and moving obstacles. Furthermore, an indication of the distance and of the direction of obstacles is needed, as it occurs in humans, to determine the appropriate reactions.

As in humans, no precise measurement is necessary or desirable. It was decided that a number of infrared active sensors would solve the problem.

The chosen devices are based on a triangulation principle, where the IR beam reflected by the obstacle is focused on a photodiode, whose output is (very roughly) inversely proportional to the position where such spot falls on its sensitive surface. As it can be seen in Figure 3, the output is also quite independent from the reflecting material, and the useful range is from 300 to 1200 mm.

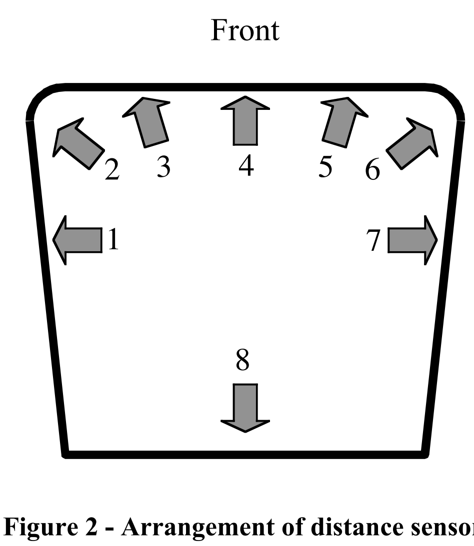

Figure 2 - Arrangement of distance sensors (top view)

Survivor 3 uses eight sensors, whose placement is shown in Figure 2.

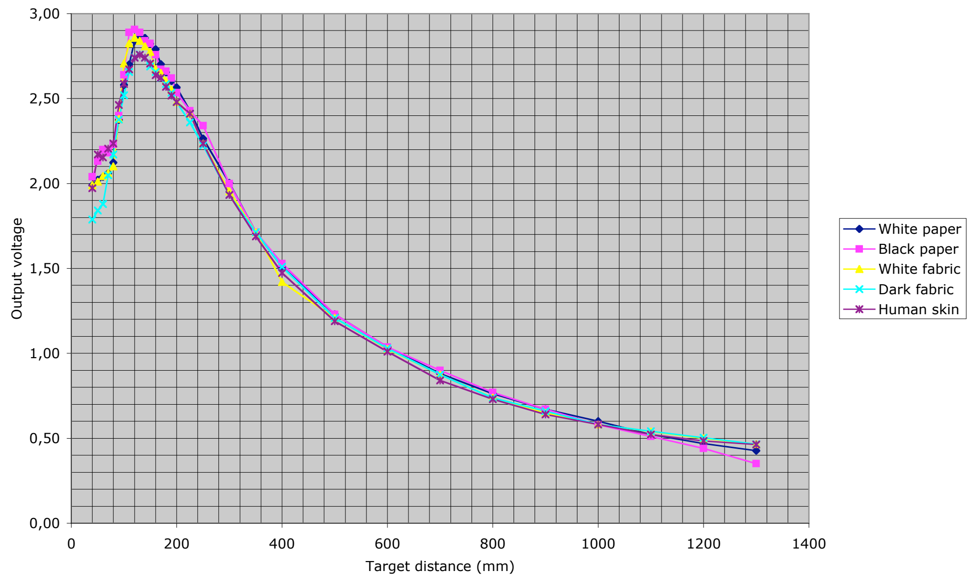

Figure 3 - Distance sensors output Vs/ target distance

5 Control system

In the first implementation, a deterministic approach was used to drive *survivor*. A PIC microprocessor handled all functions, receiving analogue signals from sensors and sending the appropriate movement commands to motors. A simple programme took decisions according to the measured distance. Some parts of the behaviour were based on random quantities, whose seed was derived from the readings of all sensors.

Given the simplicity of the mechanical part, the same structure was maintained also in version 3. A single PIC, namely a component of the Microchip 16F876 series, was enough to handle all the required functions. The only additional hardware is an analogue multiplexer used to provide enough analogue inputs for all the sensors, and an interface circuit for the RS232 serial line used to change behavioural parameters when needed.

Motor control was also kept to a minimum, using only one "intelligent" power CMOS transistor to provide the PWM current for each motor, thus allowing a quite rough speed regulation.

6 The behavioural approach

Since the first experiments it turned out that *survivor* would be best driven by some kind of behavioural architecture, and that a fuzzy logic based control would allow obtaining the desired performance from the system in a much simpler way.

The architecture that best suits the needs of *survivor* is the so-called *subsumption architecture* [1]. Basically, a subsumption architecture is composed of a number of interconnected cells, which form layers in the control system. Each cell has an output, that depends, according to some fixed law, to its input. Inputs can be suppressed and outputs can be inhibited when some conditions are met (Figure 4). A detailed de-

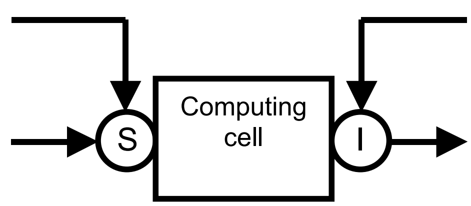

Figure 4 - Basic component of a subsumption architecture

scription of subsumption architectures and of their use can be found in [4].

In our implementation, a modified version of the original Brooks' architecture has been used. Conceptually, cells are analogue computers, that process analogue inputs and produce analogue outputs. They may or may not possess memory, according to the function they must perform.

For those who are not familiar with subsumption architectures, an example of how the whole architecture can be used in *survivor* can be seen in Figure 5: given a normal walking behaviour that would make the chair walk at a constant speed in a given direction, one can imagine a "fatigue" cell whose output increases as time passes. This output inhibits the input to the legs control cells, resulting in a slower motion. But, if for any reason a panic status is triggered, the output of the fatigue cell can be suppressed, and the chair will again run at maximum speed, just as a tired human being would do in a distress situation.

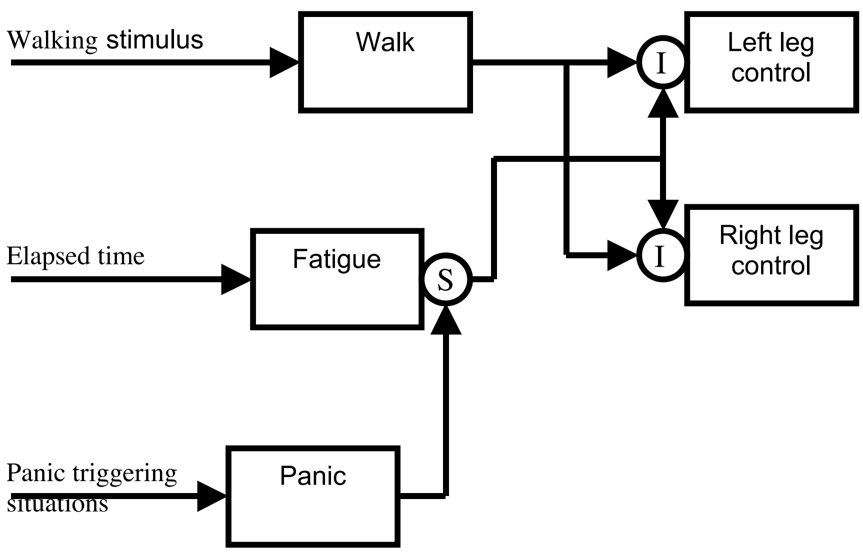

Figure 5 - How panic suppresses fatigue in a subsumption architecture

6.1 External sensor inputs

Range values from sensors are converted at a rate of about 30 readings per seconds, and their values are stored and averaged in order to filter out the noise that affects such signals. Furthermore, the following pieces of information are extracted, and treated separately from each other:

- Contact (the presence of an obstacle closer than a preset threshold (around 150 mm) is considered as a contact with an obstacle in the direction the sensor is pointing to;
- Distance (the actual range from the sensor, averaged over several successive readings, in the direction of the sensor);
- Relative speed: successive readings on each sensor are used to evaluate the relative speed of moving obstacles. Only the radial component of such speed is evaluated, resulting in the approach-departure speed of moving obstacles with respect to the chair.

6.2 Other I/O

A few more sensors and actuators are used to provide the machine with additional data, such as remaining battery charge. Additional details can be found in [1].

7 *Survivor's* behaviour

The need for emulating the behaviour of an injured human being that is undergoing such a dramatic experience has suggested the creation of a behaviour that is subject to the following (fuzzy) rules:

1. If there are no obstacles close to *survivor*, nor people around, the chair will stand still, and occasionally move to another location starting with a random rotation followed by a straight movement.
2. If, during such movements, a fixed obstacle is approached, the chair will avoid it, adding some extra steps to the leg facing the obstacle. If the obstacle is exactly in front of the chair, it will randomly turn 90 degrees to the left or to the right. In general, the turning radius will become smaller as the distance from the obstacle decreases.
3. If a moving obstacle is detected, that can be identified as a human being, the chair will modify its direction in order to move towards the obstacle. This is the only feature that has not been yet implemented in *survivor* 3
4. If a fast approaching obstacle is detected, a "panic" situation will be triggered. The following actions will be turning away from the obstacle, and running in a straight direction for a given amount of time. During this phase, all behaviour modifiers (hunger, fatigue, etc.) will be suppressed, and only obstacle avoidance will remain in effect.
5. During normal movements, a "fatigue" register that affects movement speed. This indicator is simply a timer, that counts upwards when motors are moving, and backwards when they are still. If a panic situation is triggered, this counter will be authoritatively set to the maximum value.
6. Another indicator is "hunger". This timer starts running when the battery voltage falls below a given threshold, and causes a slowdown of all movements as the fatigue register does. When the battery voltage falls below a second threshold, the red "charge battery" lamp goes on, and no further movements are possible, unless a panic status is triggered. In the latter case, the hunger signal is suppressed as the fatigue signal.
7. If the chair gets stuck, i.e. it has close obstacles in front and on both sides, since it cannot go backwards, will enter the "dead end" situation, activating the buzzer and stopping all movements. The only possible exit from this situation is a global reset, or the removal of obstacles in at least one direction, or manually displacing the chair.
8. The same status, but signalled with a different buzzer tone, is entered if any hardware malfunction or motor blockage is encountered.

Using the behavioural approach previously described, an architecture consisting of five layers has been built. The resulting scheme is too complex to be shown here, but the interested reader can find it in [1].

8 Software structure

Although the software that drives *survivor* is simple, its implementation on a small PIC posed some technical problems that had to be solved.

The structure of the programme is a classical interrupt-driven one, where a real time clock dictates the scheduling of all processes. The tasks that have to run concurrently are:

1. left motor control
2. right motor control
3. range measurement for the eight distance sensors
4. obstacle speed measurement based on range readings
5. battery voltage measurement
6. elapsed time measurement
7. behavioural logic computations
8. serial I/O control (debugging and setup only)

A real time clock generates a cyclic interrupt, that triggers execution of the aforementioned tasks. A simplified *crontab* states the periodicity of each task.

9 Conclusions and future developments

At the time this paper was written, *survivor* version 3 was close to completion, and its behaviour was being tested. The development had been carried on using a maquette where sensor data were simulated using potentiometers, and motors were present, but did not move physical legs. All the practical results shown here therefore belong to version 2, which is fully operational and is currently being displayed in art exhibitions and in mine action-related activities.

Aside from the artistic aspect, which cannot be judged in a scientific context, the architecture that has been developed is original and seems to be interesting also from a general robotics point of view. We are planning to replicate and to augment it in a more traditional robot, using the resulting structure as a base for a more sophisticated (and useful) behaviour-based operation.

10 Bibliography

[1] http://www.cassinis.it/survivor/main.html

[2] http://www.survivor-project.it/

[3] Brooks, R.: "A Robust Layered Control System For A Mobile Robot", IEEE Journ. Of Robotics and Automation, Vol. RA2, N. 1, March, 1986.

[4] Connelly, J.H., "A Colony Architecture for an Artificial Creature", MIT AI Memo TR-1151, 1989.

11 Credits and Acknowledgements

Laura Morelli conceived the idea of *survivor*, and designed the overall aspect of the machine.

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Prof. Marco Somalvico (1941-2002) showed me, with his constant, deep interest in arts, philosophy as well as his attention to physically- and mentally-impaired people, that science and technology are null and void if not applied to the welfare of the humanity - both body and mind.