survivor: emulating human behaviours in an animated artwork

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Abstract

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

The behaviour of a human 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. Behavioural control, a technique developed for the control of mobile robots, was used in *survivor*, and it was implemented over a modified version of the traditional Brooks’ subsumption architecture. This technique makes it possible to emulate normal behaviours such as the need of avoiding obstacles and typical animal feelings such as curiosity, hunger, fatigue and fear.

The paper describes how such results were attained, discusses in detail the implemented behaviours, and presents some ideas for the application of the same architecture to other artistic creations.

1. Introduction

Women and children are the main victims hit by mines.

How does art relate to a humanitarian problem?

Can ethics be a meeting and exchange point among art, technology and other aspects of human knowledge?

Is it possible to develop, trough cooperation among art and technology, objects and art processes that can become understandable symbols or metaphors?

From such questions the *survivor*-walking chair, and subsequently the *survivor*-project were born.

More specifically, the goal was to realize a mobile, relational object that would implement the concept of “remembering pain”, meant as the psychological threshold that marks the transition from the dramatic situation of a victim to the more optimistic one of a survivor.

Survivor-walking chair is a common primary school chair that walks moving its front legs in a way that recalls the uncertain and shaky movements of a person that has just learned how to use crutches and artificial limbs.

The project aims at building an object that can be a recognizable metaphor through its shape, its behaviour, and its capability of establishing relations. This object should be easily recognizable by the majority of individuals, thus being able to awaken the public opinion through emotions and personal feelings. In the final implementation, five of these devices should be placed in various symbolic places around the world, connected via a video-conferencing system, in order to superimpose virtual and actual perceived images, thus reducing the psychological perception of distance.

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, substituted by some rough mechanical devices such as prosthetic limbs.

Some sensors gather information from the surrounding environment, to understand if people and obstacles are present and if they can threaten *survivor*, and some monitor the internal status of the chair: for instance, the remaining battery charge is acquired as a measure of the “hunger” of the device, and the elapsed time from the beginning of the last movement sequence is used as a measure of the fatigue of the machine.

The resulting actions of the chair are a compromise among the various emulated feelings, and its overall performance, that ranges from quietly walking when no one is around to quickly trying to escape from fast-moving objects, usually triggers surprise and desire to interact in the audience. The system is also capable of recognizing unmanageable situations, such as being trapped in a dead end, and emits a sound that signals the need of human intervention.

At the time of writing, a first version of *survivor* has been built and is now operational. Due to the existence of a previous prototype, this version will be referred to as version 2. In the meantime, a modified and augmented new version is being implemented. This paper shortly describes version 2, and extensively discusses the improvements and additions that are being applied to version 3.

2. Structure

Artistic building elements

Chair: From a primary school

Easily recognizable: an everyday object in all western countries and an object known worldwide – Has several purposes and serves different needs – Refers to children and to childhood

Old: perceived in western countries as a no-value object because it is not "brand new"

Hanging bag: Under the chair, it contains bomb debris from Afghanistan:

When the chair walks and for some time after it has stopped, the bag keeps swinging – memory, recall – collect and order the debris

Fully visible mechanics: show a defenceless body

Perception of disorder, incompleteness, restlessness

Walking chair: A movement that will represent the interior image.

Alternate movements of the front legs – avoids contact with people and objects – if an object comes too close the artwork emits a sharp sound, as alarm and distress call

The artwork is autonomous, and there are no cables or other connections to the outside world

Error, fortuitousness, uncertainty, inaccuracy as fundamental element pertaining to the work of art

Electro-mechanical

The mechanical structure, that is the same for both versions, is very simple (Figure 1). 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 complicated 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.

Figure 1 - *survivor* version 2

In order to attain a suitable position of the centre of gravity, the batteries were placed in the rear part of the chair, and some lead counterweights were added to the rear legs.

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 power 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 4 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.

In version 2, it was decided that no step could be initiated before the previous one had come to an end. The only available feedback is the contact that signals the end of each step, but, since it has been seen that the speed of the motor is quite constant regardless of the load conditions, a slightly more sophisticated control can be implemented if needed, that also allows moving both legs at the same time if a sort of "fall down" is required.

3. 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 roughly proportional to the position where such spot falls on its sensitive surface.

These sensors, currently manufactured by Sharp under the catalogue number IGP2Y0A02YK, exhibit very good characteristics at a relatively moderate price. Their output is an analogue signal, whose characteristic can be considered roughly linear for distances ranging from 30 to 120 cm.

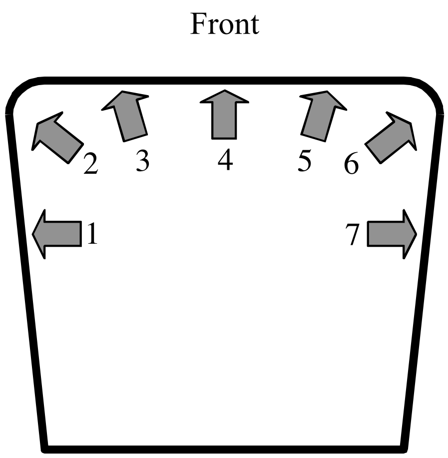

Figure 2 - Arrangement of distance sensors (top view)

As far as the placement of sensors is concerned, the five sensors originally used soon had to be augmented to seven, because since their viewing angle is quite limited, some small obstacles (and even human legs) were undetected. *Survivor* version 2 uses seven sensors, whose placement is shown in Figure 2. Since the original software was designed to handle only three sensors, namely left, front and right, the seven sensors were grouped as follows: sensors 1 and 2 constitute the "left" group, sensors 3, 4 and 5 the "front" group, and sensors 6 and 7 the "right" group. For each group, the smallest reading is taken as the correct reading for the whole group. In *survivor* version 3 this grouping will be removed and all the sensors (including one additional sensor in the rear part of the chair) will be used in a more effective way.

4. 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 program continuously converted data from the range sensors, and 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, electronic circuits are also very simple. It has been decided that a single PIC, namely a component of the Microchip 16F876 series, would be 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.

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

5. The behavioural approach

It turned out very quickly, however, 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.

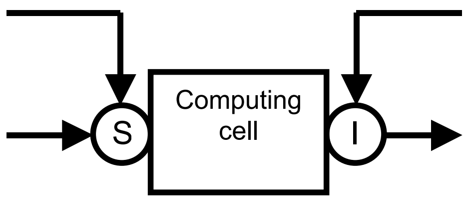

Figure 3 - Basic component of a subsumption architecture

The architecture that best suits the needs of *survivor* is the so-called *subsumption architecture* 0. Basically, a subsumption architecture is composed of a number of interconnected cells (Figure 3), 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. A detailed description of subsumption architectures and of their use can be found in 0.

In our implementation, a slightly 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* is the following: 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 walk at maximum speed, just as a

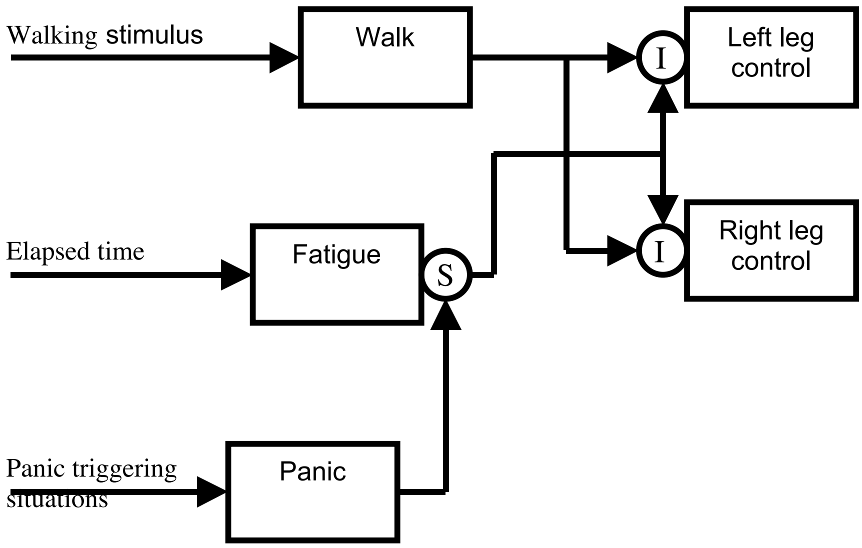

Figure 4 - How panic suppresses fatigue in a subsumption architecture

tired human being would do in a distress situation (Figure 4).

6. Interfacing with the environment

This section deals with the interaction means of the chair with the surrounding environment

External sensor inputs

Survivor receives information about the surrounding environment through a very simple sensory system. Only range sensors are used in version 3, although the information they provide is treated in a slightly more sophisticated way than in the first prototype.

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 200 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.

Internal sensory inputs

Internal sensors are also quite limited: the battery voltage is acquired as a measure of the "hunger" of the device, and the elapsed time from the reset and from the start of the last movement sequence are used as a measure of the fatigue of the machine.

Each leg is equipped with a mechanical switch that indicates the end of each step. In order to keep things simple, no other feedback is provided from the movement mechanism. The mechanical switches are also used to provide an indication of a possible blockage of a motor. Since this can occur simply because the characteristics of the floor change as the chair moves, a sophisticated self-calibration routine has been implemented.

For safety reasons, a watchdog system has been implemented, that resets the whole control system if the microprocessor appears to be stuck in a loop.

Outputs

Outputs include a PWM output for each leg. This allows a rough control of the speed of the motors.

Other outputs were provided for a red LED signalling the need for the battery to be recharged, and a buzzer intended to signal a distress situation, such as *survivor* trapped in an unmanageable cul-de-sac.

Auxiliary I/O

In order to simplify the debugging of the developed software and the fine-tuning of parameters, a serial channel has been implemented that allows connecting a terminal, or a PC running a terminal emulator program, to *survivor*. All constants that can require adjustments during the setup of the device are stored in EEPROM, and can be changed without the need of reprogramming the device.

Also, some statistical values are stored in EEPROM and can be accessed using the aforementioned terminal.

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*, or 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 with the leg facing the obstacle. If the obstacle is exactly in from 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.

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.

8. The same status, but signalled with a different buzzer tone, is entered if any hardware malfunction or motor blockage is encountered.

8. Software structure

The architecture that implements these functions is being developed.

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 program 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. 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 an interrupt every 10 ms that triggers execution of the aforementioned tasks. A simplified *crontab* states the periodicity of each task.

9. Experimental results

During 2003 the project has undergone a number of tests, where *survivor*-walking chair was brought in everyday places, such as marketplaces, shopping centres, streets, art galleries. Each performance lasted about one hour, and each time people passing by stopped and formed a circle that kept a distance of approximately three meters from the chair, making comments about the display.

Later, more structured actions were performed, with the aim of modifying the perception of the common space.

The last performed action is *the perfect survivor* installation that was shown at Bangkok World Trade Centre mall from September 16th to 21st, 2003, during the 5th Meeting of the State Parties of the International Campaign to ban Landmines.

In this case the chair was shown together with some large pictures taken by Giovanni Diffidenti, a photographer that reports since ten years landmine victims throughout the world. The installation was in a transit area and was structured in such a way that no privileged viewing points existed. People were invited to enter the installation and to become a part of it, interacting with *survivor*.

This activity resulted in a substantial number of visitors, and in a great interest of national and international communication media.

10. Conclusions and future developments

At the time this paper was written, *survivor* version 3 was close to completion, while version 2 is fully operational and almost constantly on display in art exhibitions and in mine action-related activities.

As it has been said, the full programme includes the realization of five *survivor*-walking chairs, operating in particularly symbolic places scattered around the world (weapon industries, hospitals, political and economical organizations headquarters, museums and art galleries, etc.). The five chairs should be operated concurrently, and all the exhibitions should be connected with each other via videoconference system.

Aside from the artistic aspect, however, the behaviour of *survivor* is interesting also from a general robotics point of view, and we are planning to replicate and to augment its control structure in a more traditional robot, using the resulting behaviour as a base for a more sophisticated (and useful) behaviour-based operation.

The techniques employed in *survivor* will also be investigated as the basis of other machines designed to emotionally interact with men and women.

Credits and Acknowledgements

Giovanni Diffidenti stimulated the artistic creation through his human experience and the photographic materials gathered during his journeys in mine-affected countries.

Virgilio Fidanza, photographer, provided the picture of *survivor*.

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The Italian CBL, ICBL and Power sponsored the installation "the perfect *survivor"*

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