

Kheperoo, A Robotic Exhibition For QUT Innovation Train

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Abstract. The QUT Innovation Train has taken its message of innovation and technology to Queensland. The QUT Innovation Train completed its five-week 10,000 km trip around regional Queensland and thousands of people have climbed aboard to learn more about innovation and how it fits into everyday life. The Smart Devices Laboratory contributed a robotic exhibition consisting of an autonomous Khepera 2 robot dribbling a tennis ball back and forth around a playing field. We give an overview of the system and describe how its technical challenges have been addressed.

1 Introduction

The QUT Innovation Train helps demystify science and technology. Many people from rural areas who come to the train are unable to visit a major museum or science centre on a regular basis, the QUT Innovation Train is trying to take that experience to them. The initiative has been accepted as an official event of the Year of the Outback.

Over 12 months, the same team who designed the university's first two trains; The Science Train in 1997 and the Science and Technology Train in 1999 (which attracted almost 50,000 people) has been working on four carriages to make the 2002 train the brightest and most dynamic train produced by the university so far by involving all areas of the university for the first time.

The IT faculty has contributed two exhibits to the 2002 train. One exhibit was devoted to encryption and consisted of a network of three computers running a demonstration program showing how encryption allows us to send information such as credit card numbers safely when for example using the Internet to place orders. The other exhibit was a robotic exhibit by the Smart Devices Laboratory.

We programmed a Khepera 2 robot to dribble a tennis ball alternatively from one goal to the other in a soccer playing field. The goal was simply a barcode landmark made of black and white vertical stripes about 2cm wide. Given its journey in the outback, we nicknamed the robot "Kheperoo" (a crossover between Khepera and Kangaroo).

Figure 1 shows the playing field and its protective plexiglass box. The cables supply electricity to the robot and four halogen lamps.



Figure 1 The playing field installation



Figure 2 Kheperoo

2 Educational Objectives

The main objective of the robotic exhibit was to illustrate behaviour robotics [2], by showing that a combination of elementary behaviours is all you need to get a robot perform autonomously simple tasks. The non trivial behaviour achieved by Kheperoo demonstrates that domestic chores like mowing the lawn or vacuuming the house do not require symbol manipulation or a level of intelligence higher than that of a cockroach.

The exhibit was also expected to act as a trigger for school discussions. In a flyer, the public was invited to reflect on the applications of autonomous robots, and realize that the frivolous exercise of getting a robot to dribble a ball was a milestone for engineers who are designing robots whose duties include more serious tasks like cleaning, mining and de-mining, garbage sorting, people rescuing, surveillance, planetary exploration, and personal assistance to the disabled or the aged.

In order for the layperson to appreciate the difficulty of the task assigned to the robot the following explanations and analogies were given to describe the sensors.

How does Kheperoo sense its environment?

Kheperoo is equipped with a number of sensors;

- *A ring of eight infra red proximity sensors that can detect obstacles (but only at very short range; within 2 or 3cm). Imagine being able to feel the proximity of objects only by the heat they radiate.*
- *A linear camera whose image is an array of 64 x 1 grey level pixels. Imagine looking through a horizontal slit filled with a string of 64 semi-transparent beads. The linear camera detects only brightness levels (from black to white), but does not differentiate colours (white and yellow look the same through this camera). Kheperoo's field of vision is relatively narrow (a cone of 36 degrees). In other words, if Kheperoo was human, it would probably be considered legally blind!*
- *Wheel encoders that monitor the rotation of the motors of the two wheels.*

3 Design Issues

Although a person of the IT faculty was supposed to be around the exhibit most of the time, it was considered to risky to let the public (including mischievous kids) interact unsupervised with a Khepera robot. We decided to protect the robot with a plexiglass box (see Figure 1). This constraint added the requirement that the robot be completely autonomous. In particular the robot should neither get stuck on the field nor enter a fixed pattern of motion. These goals were achieved by using a combination of elementary reactive behaviours and a grain of randomness. The transition between the different behaviours is governed by an automaton. More precisely, Kheperoo switches successively between a number of behaviours according to its recent history and its current perception of the environment. We had also to anticipate some variation in the lighting and temperature conditions that could affect the sensors. Kheperoo was bound to get lost in its environment as it is short-sighted with respect to the size of the playing field; when the robot is positioned next to a goal and looking towards the opposite goal, the remote goal is not visible through the linear camera. When confused, Kheperoo wanders over the field for a few seconds in the hope that it will end up in a better position.

The persons who were looking after the robot on the train were volunteers with no technical background. This turns out not to be a problem as the Khepera 2 is very easy to use once the program has been written in its flash memory. To start the demonstration, just plug in a cable in the power supply. To stop the demonstration, just unplug the cable.

4 High Level Description of the Behaviours

To achieve its mission, Kheperoo tries first to position itself near the centre of the playing field. Kheperoo does this by comparing the apparent widths of the goals and their relative angles with respect to itself. As Kheperoo is short-sighted, it is not always able to detect both goals when doing a 360 degree spin (to get a panoramic view). In these confusing circumstances, Kheperoo switches to a wandering behaviour for a few seconds.

To better appreciate how challenging the situation can be, image yourself having to go to the centre of a soccer playing field covered with a fog thick enough to prevent you from seeing a goal from the other goal (at the other end of the playing field).

Once approximately at the centre of the playing field, Kheperoo looks for the ball, goes to the ball, then dribbles the ball towards the farthest goal. When Kheperoo realises that it is pushing the ball against the target goal, the whole cycle (go to the centre, look for the ball, dribble the ball to the farthest goal) starts again.

5 Low Level Description of the Behaviours

The **go_to_centre** behaviour is based on the fact that when near the centre of the field, the goals are diametrically opposite and look about the same width. A fuzzy controller determines in which direction the robot should make a step to get closer to the centre by combining the outputs of two elementary behaviours. The first elementary behaviour returns

a direction based on the apparent widths of the goals (in fact it simply returns the direction of the smaller goal). The second elementary behaviour considers the relative angles of the goals and returns the median direction (see Figure 3). The directions of the two behaviours are then combined.

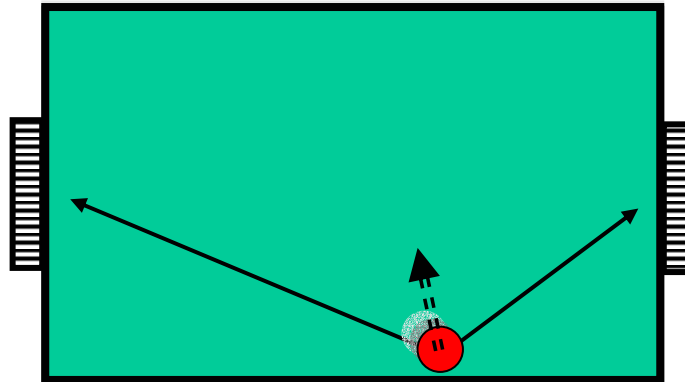


Figure 3 Median direction

The **look_for_the_ball** behaviour uses a **get_panoramic_view** behaviour. Recall that Kheperoo sees only a horizontal cone of 36 degrees (must make 10 rotations of 36 degrees to get a panoramic view). Because a tennis ball looks like a white stripe, a contextual analysis of the images is required to discriminate between the goals and the ball.

Fortunately, determining whether an image of the linear camera corresponds to the wall alone is easily done by comparing the maximum value of the pixels and a threshold. If an image contains some pixels with a high intensity, then the ball or a goal must be in the field of vision. The image analysis starts with a filtering (mask that removes some noise), followed by the extraction of the monotonic sequences of pixel intensity. We call a *zig* a non-decreasing sequence of pixels, and a *zag* a non-increasing sequence of pixels. With the knowledge of the zigs and zags, all the plateaux of highest intensity are determined. They correspond to the white stripes and the ball. Because the ball's plateau should be markedly larger than the other plateaux (of the goals), it is possible to detect whether the ball is in front of a goal by considering the relative sizes of the highest plateaux.

Once the ball is in sight, getting to the ball is not difficult.

The **dribble_the_ball** behaviour relies mainly on the proximity sensors. The robot circles the ball to position itself before pushing the ball. Thanks to the wheel encoders, the robot can estimate its orientation with respect to the axis going through the centres of the two goals (the wheel encoders are reset each time the robot estimates that it is near the centre of the field). If when pushing the ball the robot goes astray of more than 30 degrees with respect to the direction of the goals, it circles the ball to start pushing again with a symmetric angle of 15 degrees. The dribbling behaviour has been explored by many teams in robot soccer [3]. In Khepera robot soccer competition, we observed that the robots do not always manage to unstuck a ball from a corner. Because we were running short on time, we decided to prevent this deadlock by fitting an ellipsoidal skirt around the playing field.

To detect that it is pushing the ball against the wall, Kheperoo compares the actual speed of its wheels to the desired speed. If the actual speed is less than the desired speed, it means that something is opposing the forward motion of the robot (must be the wall!). We use a separate process to monitor the difference between the actual speed and the desired speed of the

wheels. This watchdog process manages a flag that indicate a deadlock situation. Most of the behaviours regularly check this flag and abort if needed.

6 Little Technical Problems

We had to put a small wedge at the back of the linear camera turret. Its role is to keep the linear camera slightly tilted so that when the electric cable pulls the robot backwards the ball does not disappear under the camera horizon. A side effect of this tilt was that the white skirting band around the field provokes some ghost balls to appear. A reduction in the height of the white skirting band fixed the problem.

When the train was in Mt Isa, the temperature of the carriages was in the high thirties. Kheperoo did not do well in these conditions (could not see or feel the ball). The people looking after the robot in the train were reduced to only run the exhibit early in the morning when the carriage was relatively cool.

7 Effectiveness of the Behaviours Used

In temperate conditions, Kheperoo requires an average 3 or 4 steps to get close to the central circle of the playing field. Once the robot is about the centre, it rarely (less than one time out of ten) fails to see the ball. Similarly, once the robot has the ball in sight, it reliably goes to the ball. The dribble behaviour is also very robust; even when the ball rolls erratically (because of the groove of the tennis ball or dust particles) and the robot loses track of the ball (if the ball strays to far away from the proximity sensors), Kheperoo recovers from the mishap by temporarily switching to the `look_for_the_ball` behaviour.

Two videos showing Kheperoo in action are available on-line

<http://sky.fit.qut.edu.au/~maire/KheperooVideo1.AVI>

<http://sky.fit.qut.edu.au/~maire/KheperooVideo2.AVI>

The files are about 5 Mbytes.

8 Feedback From The Public

What was really interesting to see was the number of older people getting on to the train and really enjoying the new technology. Children cheered loudly Kheperoo when it was looking for the ball. Adults were impressed by the dribbling skills of the robot and its ability to keep track of its orientation. Most people were surprised that such a small robot could show some form of intelligence. The performance of the robot gave rise to some unrealistic expectations; a little boy seriously asked whether the robot would be able to do his homework!

9 Conclusion

The use of all available sensors of the Khepera robot has enabled us to create an entertaining and educative autonomous robot exhibit. The educational value of such exhibit should not be underestimated. Watching people thoughtfully looking at the exhibit and speculating on how the robot was working was a rewarding experience for us.

References

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- [3] Adam R. Bockrath, Adapting Linear Neurons to Robot Football, FIRA Robot Congress Proceedings, 4 pages, 2002. (<http://www.dcs.qmul.ac.uk/~adamb/FIRA171.pdf>)