The Robotic Soccer Turing Test

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Abstract

One of the long-range objectives of the RoboCup initiative is to develop robotic technology to the point that, within the next fifty years, robots can play soccer at a competitive level against humans. In this paper we first make some comments on the Turing Test, proposed by Alan Turing in 1950, and then advance a proposal for a new kind of experiment to allow machines to compete against humans. We suggest to give human operators the same view of the playing field as that of autonomous robots, to let persons operate a team by driving them, and thus let humans play against a fully automatic robot team. In this way soccer matches of humans against robots could be held in the immediate future and the perceptual capabilities and ability of the autonomous robots could be more adequately assessed. We propose to held a "Robotic Turing Test Challenge" at RoboCup tournaments which would allow us to gauge the state of the art in this field.

1 The Turing Test

Alan Turing, the renowned pioneer of computer science, considered in 1950 the question of how to decide if a machine is intelligent or not. Clearly, this is a very subjective question and it is difficult to conceive a definitive test that could allow us to qualify a machine as intelligent as a human or not. His answer to this dilemma, which he called the Imitation Game, came to be known later as the Turing Test.

Turing proposed to let a human interrogator ask questions to a computer and to another human, using a keyboard and a computer screen [Turing 1950]. The interrogator cannot see the other person nor the computer, and can only read their answers. The interrogator can ask any kind of questions to both interlocutors and has to decide which is the computer and who is the person. If in a series of tests the interrogator cannot distinguish with more than 50% accuracy between the human and the computer, then the machine is said to be intelligent.

Notice that Turing did not propose to let the interrogator *speak* with the hidden person and the computer. He was aware that speech recognition and the synthesis of natural-sounding speech would still take many years and, therefore, simplified the task by letting all parties involved communicate using the lowest common denominator available at the time, that is, a screen and a keyboard. Of course, a better test would be to include speech recognition and synthesis in the task, but Turing was interested in the cognitive part of the task, rather than in the sensory aspects, and made therefore these simplifications. What Turing wanted to explore was if the computer could understand the context of questions, argue with a human, make logical inferences, and even deceive. The test, in which all aspects of human communication are involved, has been called the "Robot Turing Test" by Stevan Harnad [1989]. The robot he refers to, is one capable of simulating a human, but its cognitive abilities are still the main aspect to be tested.

One of the stated goals of the RoboCup Initiative, started in 1997 with the yearly RoboCup contest, is to bring robotic technology to the point that robots can play soccer against humans at a competitive level. The timeframe for this objective has been set at around fifty years. It would be the equivalent of the development that took place in the field of computer chess, which got started in 1945 and culminated in the defeat of Gary Kasparov by Deep Blue in 1998, i.e., 53 years later.

However, like in the case of the original Turing Test, some of the difficulties involved in this undertaking have to do more with rather mundane aspects than with strategy, context, ability, team play, and deception. One of the most difficult problems is to provide the required energy to the robot at the rate which is needed to activate all of its actuators. Human muscle is unique in which it not only exerts a force and can produce movement, but it also has a "modular" design. Every single cell produces its own energy, i.e., has its own micro-power plant in the form of reduction of ATP molecules, the energy currency of the biological world. It will take decades before modern technology can achieve such a feat and it is questionable if robots will be able to move as elegantly as humans, before this problem is not completely solved.

Therefore, we are faced with a paradox: even if we develop computer vision algorithms that can compete with the human eye, even if we know how to balance humanoid robots now, and even if we know how to make them play as a team, the envisioned match against humans will have to wait many years because the energy problem will constantly hold back this endeavor.

In order to avoid this difficulty we propose to adopt the same approach as Alan Turing: let us simplify and temporarily remove some of the sensorial and motor aspects of the game. Let us embrace, as Turing did, the lowest level denominator at which humans can play against robots, and let them play now, and not in fifty years. We propose a new Turing Test for the field of robotics and specially for the RoboCup challenge.

2 The Robotic Soccer Turing Test

A robotic soccer Turing test could be conducted as follows: let two teams of robots play against each other, but let one of them consist of autonomous robots which are controlled by embedded processors or by computers off the field. Let the other team be controlled by human operators immersed by telepresence in the game. For this, the robots will all have a video camera in the front -- the image can then be transmitted by a radio link to computer screens. Humans provided with head-mounted computer displays, or with plain computer screens, observe the field from the perspective of the robot they have been assigned. The human can drive the robot using a steering wheel and pedals, just like if it was a car. They can drive forward, backward, accelerate and rotate to the left or right. They can also activate any kicking devices or actuators on the robot just by pushing buttons.

A Dutch group has developed a virtual reality tool using a cave, in which a human can play against simulated software players for the RoboCup Simulation League [Spoelder et al. 1999]. The human sees himself placed in a soccer stadion, and the other players can be humans, connected remotely, or virtual players. The navigation capabilities in the cave are still rather limited, but this kind of approach comes close to what we propose in this paper. The main difference is that we suggest to use real robots and there is no VR field of play -- it is instead a real one in which robots compete against each other. What we propose is more related to the field of robotic telepresence, which has been studied recently for telemedicine applications [Simsarian 1999].

In our approach, the humans involved in the game will have at their disposal the same data as the computers, i.e., just the camera picture. The purpose of the game is to see if the robots can defeat humans playing soccer. In this case, there is no interrogator; if the robots win, they have passed the test.

Notice that this test could evolve from year to year. Radio communication between the robots could be prohibited, to avoid giving them an unfair advantage against the humans. Also, only embedded processing could be allowed, in order to eliminate external processors and make the robots be really autonomous and self-contained. Eventually robots on wheels could be replaced by robots on legs, etc.

The objective of this exercise is to assess the strategic and computer vision abilities of the robotic teams, to see if in the immediate future they can become better than humans in restricted domains. Eventually this would lead to the stated grand objective of letting robots and humans play on a real field, but this approach provides an evolutionary path towards this objective.

3 Architecture of our system

We have already built a system and we have already organized some games "human vs machine" at our lab at the Free University of Berlin. Mark Simon, one of our undergraduate students, is the best human operator we have and he has been able to defeat one robot, but has also lost some matches. Our system will be expanded to handle three human players in the next weeks. We can mix human and robotic players in the two teams.

We have developed two robots with two different kinds of video cameras. One of the robots has an omnicam mounted on top, that provides a 360-degree view of the field. The camera is pointed upwards and the image comes from a parabolic mirror that reflects the field towards the camera. This image can be used by the robots to find the ball, other robots, and its position on the field. It is difficult for a human player to interpret this image but it can be done without additional processing. We are planning to process the image to eliminate the distortion and provide the human player with a more natural view of the field. Figure 1 shows a diagram of the robot with the omnicam. Figure 2 shows an image of the field as seen by a robot located exactly in the middle of the field.

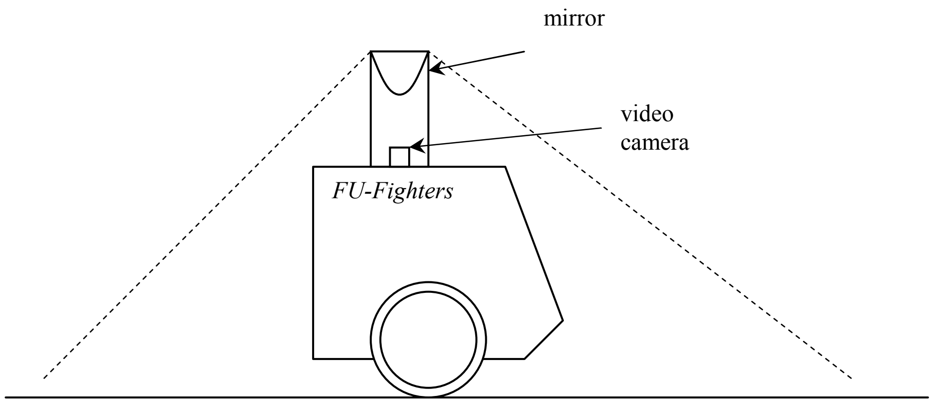

Figure 1: One of our robots with an omnicam

Figure 2: Complete view of the field from the omnicam

The second robot has a camera mounted in front and provides the human player with a very good view of the field and the ball, when the latter is in front of the robot. Figure 3 shows a diagram of the system. The frontal camera produces a more natural image, but the human player has to rotate the robot in order to find the ball. The robot has a radio-link module that sends the image to the external computer at a rate of 25 frames per second with 320 by 480 pixels resolution.

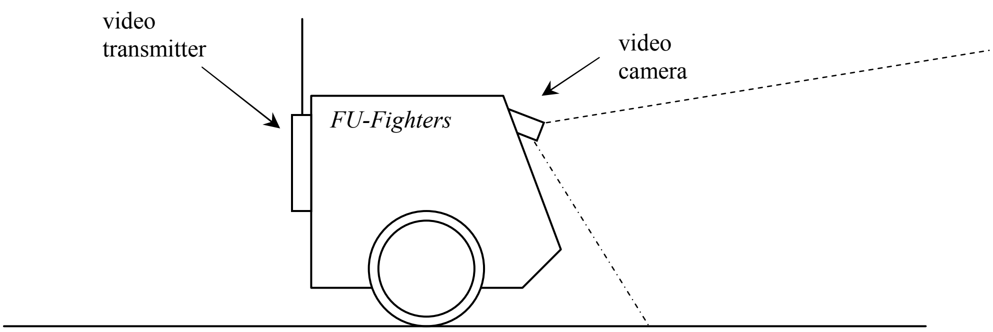

Figure 3: One of our robots with a camera in the front

4 First experiences

After RoboCup 1999 we started working on a new generation of robots that will allow us to play in the F-180 League with purely local vision. We immediately saw that this provides us with an opportunity to let humans play against our robots. We have held some matches at our lab and the results have been very interesting.

Right now, the main difference with our real objective is that the automatically controlled robots are driven to the ball with the help of a global camera mounted on top of the field. The robots can find the ball faster than the human, but the human drives better, so that we have had very close matches. Figure 4 shows a frame of an image recorded during an actual RoboCup game.

Figure 4: A view of the field from the perspective of a robot

Our experience is that human players adapt immediately to the system settings. Driving the robot is not very different to driving a car in computer games. As the human operator gains some experience controlling the robot, the its paths become smoother and more elegant. The main disadvantage for the human player is that, when the robots know exactly the position of the ball they can usually drive faster and be more aggressive. But if soccer robots with enough fault tolerance can be built, robotic soccer of humans against machines could even become a business opportunity in the infotainment sector.

5 Conclusions

In this paper we discussed first the Turing Test in the form originally proposed by Alan Turing. He decided to simplify the test for intelligence by eliminating speech recognition and speech synthesis from the task, selecting the lowest common denominator that could allow communication between humans and machines. We argued further, that adopting the same philosophy, the soccer contest between humans and robots envisioned by the RoboCup Initiative can be done now, rather than in several decades. For this purpose we adopt also the lowest common denominator, that is, we provide the human with a view of the field of play as seen by the robots, and allow him to drive a robot as one drives a car. Matches between humans and machines can then be organized as we have done already at our lab at the Free University of Berlin.

We propose to held in the future a "Robotic Turing Test Challenge" at RoboCup World Championships in which humans will play against robots in the way described in this paper. This would not be another RoboCup league, but just an opportunity to show to the community and to the rest of the world the advances made every year in the field of autonomous robots. We think that such a challenge would arise much interest in the media and would further contribute to educate the public and publicize our efforts. The Robotic Turing Challenge would be made more difficult from year to year, until eventually, robots and humans can clash at a soccer stadium, certainly not in our lifetime. Let us advance the clock by implementing this proposal.

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