iRat: Intelligent Rat Animat Technology

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Abstract

This paper presents the iRat (intelligent Rat animat technology), a robot designed for robotic and neuroscience teams as a tool for studies in navigation, embodied cognition, and neuroscience research. The rat animat has capabilities comparable to the popular standard Pioneer DX robots but is an order of magnitude smaller in size and weight. The robot's volume is approximately 0.08m^2 with a mass of 0.5kg and has visual, proximity, and odometry sensors, a differential drive, a 1 GHz x86 computer, and LCD navigation pad interface. To facilitate the value of the platform to a broader range of researchers, the robot uses the Player-Stage framework, and C/C++, Python, and MATLAB APIs have been tested in real time. Two studies of neural simulation for robot navigation have confirmed the rat animat's capabilities.

1 Introduction

In the neuroscience and cognitive science communities, there is a growing interest in the use of robots to address a variety of research issues, including embodiment and emergence - exploring how physical interactions with the world constrain the structure and function of a cognitive architecture. Robots are beginning to be used to test models of neural systems, particularly for direct comparisons between the behaviour of a robot equipped with a model of neural systems and the behaviour of the biological organism that forms the basis of the model.

The correlates between behaviour and neural systems have been extensively studied across various species of rodent. There has been extensive work investigating how rodents learn and navigate, in particular experiments on rats to understand how the hippocampus and associated regions localize, map and navigate an environment. There is a need for a robot rat for neuroscientists and modellers to use to test their theories of neural function. This research addresses the need for rodent-sized robots with navigation capabilities that are suitable for generic neuro-robotic research.

To develop a rat animat platform that will be widely used in neuroscience and cognitive science it is important to determine essential and desirable features in its design. One defining requirement for the use of a rat animat in laboratory neuroscience is that the rat animat be able to complete similar tasks to those performed by real rats, preferably using the same equipment and in some cases in collaboration with the rodents. For example, simple mobility and navigation experiments involve running through circular and figure of eight tracks. More complex tasks include learning and orienting towards spatial and temporal stimuli.

From a functional perspective, many of the capabilities required to perform rodent-robot comparisons are provided by the MobileRobots Pioneer DX robot which supports a wide range of capabilities including professional camera, and proximity sensors, differential actuation and onboard PC. However, the Pioneers are not suitable for many neuroscience tests as they are simply too large to operate in rodent-sized environments. Proportionally scaling the test arenas would be feasible in some simple cases, but precludes studies that compare rodents and rat animats on the same equipment and any task involving interaction or mimicry between rodents and robots. Since the first Pioneer there has been miniaturisation of electronics and sensors which should permit a smaller robot with capabilities suitable for research. Recently, low power miniature x86 computers (which run a standard Windows or Linux OS) have become available. This means that small robots can be built without compromising on computational capacity.

This paper describes a new intelligent Rat animat technology platform, named the iRat, which takes advantage of the recent miniaturization of PC equivalent computational parts, and reviews two previously reported studies that demonstrate the capabilities of the iRat. The first study investigated the ability of the iRat to perform Simultaneous Localization and Mapping (SLAM) using

RatSLAM [Milford and Wyeth, 2009]. RatSLAM is based on the rodent hippocampus, it seemed an appropriate navigation system to test on the iRat as a step towards implementation of a biologically plausible mapping system. The second study investigated the control of the iRat by a spiking neural network [Wiles, et al., 2010] which could direct the iRat to rapidly respond to temporally varying stimuli, by using the inherent abilities of the spiking neural circuit to encode the precise timing between stimuli in the relative timing between spike events. These two studies illustrate the value of the iRat platform for rodent to robot comparisons in a neuro-scientific setting.

The following section provides a brief overview of other robot rat designs. Section 3 has the iRat specification, then the design to meet the specification and results showing the resultant robot platform. Section 4 includes the two previously published studies which demonstrate the capabilities of the robot using bio-inspired algorithms of different fidelity. Sections 4 and 5 describe future research work for the platform and conclude the paper, respectively.

2 Previous Robot Rats

Neuroscientists and roboticists have collaborated on a variety of robot rat studies, but none have developed a complete robot with the computational power of an x86 in a size small enough to navigate in a typical neuroscience laboratory. Components of neural architectures that have been or are currently being developed include navigational skills comprising models for place cells, head direction, and grid cells, and complete rat-inspired SLAM [Milford and Wyeth, 2009].

Tactile sensors are important for rodents for estimating the distance of objects and object discrimination. A range of robot rat studies have developed whisker systems using a variety of materials, whisker actuation methods and processing algorithms [Pearson, et al., 2007, Fox, et al., 2009, Fend, et al., 2006]. The AMouse [Fend, 2004], developed at the University of Zurich is a mouse-like robot developed as a collaboration between physiologists, neuroscientists and roboticists. Starting with the Khepera robot platform, the AMouse added two whisker arrays, each whisker implemented using natural rat whiskers attached to capacitor microphones. Using a subsumption architecture the AMouse was able to avoid obstacles and discriminate textures in changing light conditions.

The body of a rat animat is a significant practical engineering challenge. Psikharpax was designed to be a complete rat animat, with sensors, actuators and control architectures mimicking those of an actual rat [Meyera, et al., 2005]. The prototype was launched in 2009. Mechanically, the rat is 500mm long and has two wheels that allow a maximum speed of 0.3m/s. Psikharpax can move its head and eyes and is designed to be able to rear and grasp objects with its foreleg. The sensors include two visual sensors and a more recently added omnidirectional visual system [Lacheze, et al., 2008], an auditory system and a 32 whisker haptic system.

In contrast to the focus on bio-mimickry, the Cyber Rodent project was designed to study biological reward systems, and hence the cognitive architecture was inspired by neuromodulation (in particular dopamine, serotonin, acetylcholine and noradrenaline), targeting self-preservation and self-reproduction in a reinforcement learning framework [Doya and Uchibe, 2005]. The robot is not as large as Psikharpax ,but is still larger than a typical rodent, 220mm long and weighs 1.75kg. It has two wheels that allow a maximum speed of 1.3m/s. Sensors include a camera, range and proximity sensors, gyros and accelerometers, and microphones. For communication the robot has a speaker and tri-color LED. Computationally, it has custom embedded hardware for on-robot learning.

In contrast to the rat animats designed to mimic rat abilities, robot rats have also been developed in order to study interactions with real rodents. In collaboration with animal psychologists, Kimura and colleagues at Waseda University have developed a sequence of rodent robots, known as Waseda Mice. An early version, Mouse-No.2 (WM-2) [1998] had a similar size and mass to rat, with a fur coat to achieve a similar appearance albeit using wheels for mobility. An embedded microcontroller handled sensors, motors and communication with the host computer over an IR link. Komura and his colleagues demonstrated that a real rat recognized the movement of WM-2, and that the robot influenced the rat's behavior, helping it to learn response to stimulations [Ishii, et al., 2006]. Arms were added in a later version, WM-6, which enabled it to push with levers. Bluetooth was used to communicate wirelessly with the host computer. In a recent version, legs have been added to the robots with overhead vision, enabling autonomous control of the robot and more complex interactions including the robot teaching the rat to push a lever to obtain food [Patanè, et al., 2007].

3 iRat Design

This section describes the design of the prototype iRat version 1.0. A systematic design process was followed to construct the iRat which began with a specification of the design. The focus of the prototype1.0 design was to build a rat animat that is the size of large rodent using as many off the shelf and easy to use and manufacture components as possible.

3.1 Design specification

The first design decisions were regarding the mechanical design. While it was tempting to biologically mimic the rodent and develop a quadruped robot, to save significant development time and increase the space for computers and sensors, wheeled locomotion was used for this iRat version. Heglund et al [1974] report a rodent trot between 0.11 – 0.67m/s and gallop between 0.67m/s and 1.78m/s. A speed of 1.5m/s is a typical human walking pace so the desired top speed was set at 1.5m/s. It is desirable to be able to brake rapidly for obstacles so an acceleration of $4m/s^2$ was selected. Other actuation for the head or tail was considered but ruled out for this version to simplify the design.

Pass and Freeth [1993] report the Norway adult rat mass between 0.3 and 0.8 kg. Their length can be over 200mm including the tail. These parameters will define the size and mass of the iRat.

A real rodent uses its eyes to sense the environment. The typical combined FOV of the eyes is 270^{o} horizontally. While the rodent sees predominately greyscale it can see some colour. Therefore for this robot a single camera with a wide FOV (180^{o} maximum for a single camera) was desired for the iRat.

The real rodent uses its whiskers to sense within its peri personal space. This robot will need a similar sense to deal with local obstacles. The other rodent sensors such as smell, touch, and hearing were not considered for this version of the iRat.

There were also several technical specifications for this iRat version. The iRat's batteries should be able to last for at least an active two hour experiment. Running a common OS on the robot would allow standard development tools and programs to be used. Lastly the robot should support an open source standard cross platform robot control interface that abstracts away the specifics of the robot.

Table 1 - iRat version 1.0 specifications.

Parameter	**Specification**
Locomotion	Wheeled 1.5m/s top velocity and 4m/s^2 top acceleration.
Mass	0.3 – 0.8kg
Size	150mm (length) x 60mm (width) x 60 mm (height) body. Tail can add extra length.
Vision	Wide angle colour camera with up to 180^{o} FOV.
Proximity	Ability to sense close objects in front of the robot
Run time	120 minutes active (180 minutes idle)
Technical	Run a standard OS with standard interfaces.
Software framework	Should support a generic framework that abstracts the details of the robot.

3.2 Design

This section uses the rodent capabilities that were translated into a desired engineering specification in the previous section to detail a design for the iRat.

Actuation

This section shows the process for selecting the motors and drive train, based on the actuation requirements described in Section 3.1. Approximate motor power can be computed using the robot's specified mass, speed and acceleration:

$$F = ma = 0.5\,\text{kg} \times 4\,\text{ms}^{-2} = 2\,\text{N}$$

$$P = Fv = 2\,\text{N} \times 1.5\,\text{ms}^{-1} = 3\,\text{W}$$

Given that there are two actuators in a differential drive robot each motor will need to be approximately 1.5W although typically a motor with a greater rated Watts is selected to account for inefficiencies, friction, etc. The Faulhaber 1724 SR DC brushed motor is a 2.5W motor with a recommend maximum speed of 8000 RPM and continuous torque of 42 mNm. In order to allow precise velocity control the IE-512 counts encoders are added which adds only 1.4mm to the total motor length.

In order to keep the centre of mass low, and the mechanical design simple the motors should be located as close to the ground as possible. From a simple robot construction point of view it would be ideal to include a standard gearbox on the front of the motor, rather than design a gear system. However, for an acceptable gear ratio the standard gearbox would make the robot too wide. Therefore, the motors are arranged in parallel to each other with a simple gearbox connecting them to the motor. The highest gear ratio possible or a simple gearbox is given by the radius of the motor, thickness of the robot base and desired ground clearance which is equivalent to the wheel radius. These calculations allow for a 15mm wheel radius and a 5:1 gear ratio can be used. The suitability of the motor and gearbox for the desired acceleration and velocity can be readily verified for a robot with 15 mm wheel radius, r_w, maximum rotational angular velocity, w, and 5:1 gear ratio, N. The top translational speed of the robot, v_{max}, can be calculated:

$$v_{max} = \frac{2\pi r_w w}{60N} = 2.5m/s$$

Similarly, for the motor's specified continuous accleration of the motor τ, and mass of the robot, m, the robots translational acceleration, a, can be computed:

$$a = \frac{2\,\eta\,\tau N}{m r_w} = 6.2m/s^2$$

where η is the assumed 90% efficiency of the gears. These numbers mean that there is leeway to achieve the specified velocity and acceleration.

For the third contact point skids were selected over a castor wheel due to tight space constraints. SlickSurf skids were selected as they have better durability than Teflon. The skids are located at the front and back of the robot, with the robot resting on the back skids during normal operation.

Brain selection

A number of different embedded computers were considered for the 'brain' of the iRat. Recently a number of small high powered computers are available as OEM in mass production. These computers were considered against the desired robot capabilities and using selection criteria appropriate for a small mobile robot and research platform. The selection criteria were:

- Processor speed - The computer's processing speed will affect the algorithm complexity and loop frequency.
- Memory – The computer's memory will affect the possible algorithm complexity.
- Power use – As the robot is small the battery will be small which means power use must be small.
- Size and mass – The physical size and mass of robot is constrained
- OS support –Desirable to be flexible and support a variety of operating systems.
- WLAN – As a mobile robot which we want to access

other computational resources WLAN is critical. Standard wireless communication support would be preferred, such as 802.11g as a minimum.
- Interface support – USB, Serial, CAN, Card interface.
- Other hardware required – preferably the computer should require a minimum of external hardware to provide power and permanent storage.

Table 2 lists the performance of three readily available boards against the selection criteria. The Via ITX board is too large and consumes a large amount of power, especially considering that it needs an external HDD. The other two embedded computers will fit. The RoBoard is the largest of the remaining two computers but also has the greater feature set included, in particular able to run a variety of operating systems and support for an onboard HD. Standard connectors also make it a platform for rapid development. Because it will fit, has low power usage and the largest amount of features built in the RoBoard was selected for the iRat.

Table 2 - Properties of the three miniature embedded computers considered for the iRat's brain.

Criteria	Via Pico ITX	Gumstix	RoBoard
CPU Speed	1GHz X86	Cortex 600MHz	1GHz x86
Memory	Module	256MB	256MB
Power Use	13W	Low	2W
Size / mass	100mm x 72mm heavy	17mm x 58mm x 4.2mm 42.6g	96x56x20mm 40 + 20grams
OSes	x86 OS. DOS, CE, XP, Linux	Linux Windows CE	x86 OS. DOS, CE, XP, Linux tested
WLAN	Seperate module	802.11g Bluetooth	miniPCI 802.11g
Interfaces	Standard PC interfaces including	I2C, PWM A/D UART, SPI, USB, Microphone, Headset	3 x USB, UART, I2C, SPI, PWM, Microphone, Headset
Other	Requires an external HDD	Add on board required standard interfaces	Requires microSDHC card for HDD

Camera selection

The two ends of the range of options for a camera for the iRat were a high quality expensive professional camera and lens such as from Point Grey, or, at the other end, a cheap webcam. One of the primary reasons that a professional camera was preferred is because typically they have CCD sensors which have a global shutter and gives clearer pictures while the robot is in motion. However, the cheap webcam option was investigated first in order to keep the cost of the robot down and because only low image resolution could likely be processed on-robot anyway.

Webcams typically have a narrow field of view as they are designed to focus on a single human face. However, as described above the robot will benefit from a wide field of view. Three cameras were investigated: the Logitech Pro 9000, the Microsoft Lifecam VX-500 and the Microsoft Lifecam Cinema. The Logitech Pro 9000 immediately crashed the RoBoard on loading the driver under Windows XP. The VX-500 was a cheap camera however its driver didn't support changing any settings such as shutter speed and brightness which will help with reducing image blur while the robot is moving. The Lifecam Cinema was investigated and ultimately used because it has: a widescreen sensor which gives more pixels in the important horizontal field of view; its driver supports adjustment of common parameters; it has a small physical size shaped appropriately for the robot; it has an inbuilt microphone; the image quality is high; and the existing lens can be removed and replaced with a lens that gives 110^{o} FOV. The Microsoft Lifecam Cinema works under Windows and Linux.

Proximity sensor selection

From a biological stand point, proximity sensing for the iRat would ideally be accomplished with vision for long to medium range and bio inspired whiskers for short range avoidance. Visual obstacle avoidance and bio inspired whiskers are in development but are not considered ready for this iRat version. Therefore this iRat uses more typical robot proximity sensors.

The generally available sensors for mobile robot obstacle avoidance are sonar, IR and laser range finders. While laser range finders would give the best coverage performance they are too large for a small mobile robot platform. The size, range performance and power consumption were similar across sonar and IR sensors. Ultimately the iRat design includes the Sharp GP2Y0A41SK0F IR sensor as they consume only 15mA and detect obstacles within a range of 40 to 300 mm. This sensor is more tolerant of lighting conditions and surface properties because it uses triangulation to measure the range rather than the amount of light. Three IR sensors are arranged across the front of the robot to give obstacle detection.

Actuator and Sensor interface

The iRat's electronics need to be able to control the motors, interface to the sensors, interface to the LCD and navigation pad, and control battery charge and discharge. The first possibility considered was to design slave electronics that would be controlled by the RoBoard directly using its PWM, A/D, and serial interfaces. Slave electronics would reduce software and electrical complexity as there would be no need for a microcontroller with its own codebase. However there are several reasons to use a separate microcontroller:

- Running a control loop on the microcontroller will allow more precise timing control of the motors which will mean better robot motion.
- The use of the microcontroller will reduce the load on the main CPU.

- Stable microcontroller firmware will remove dependence on the RoBoard's OS for robot performance and stability. This is important given that users can run their own code on the RoBoard.

The iRat uses the Freescale MC56F8365 60MHz microcontroller which is setup to control 2+ motors with PWM, quadrature decoders and fault lines. The microcontroller has extra PWM, 16 x 10bit A/D, SPI, CAN, 2 x UART, IRQ and GPIO interfaces. The free development environment includes software beans as standard interfaces to the peripherals.

Motor control is accomplished through a STMicroelectronics VNH2SP30-E fully integrated 16V H-Bridge motor driver with 19mOhm on resistance, in built protection for under and over voltage, thermal shutdowns, 5V control, and analog current sense.

Power is managed through the Texas Instruments bq24103 switchmode charge management IC with integrated power FETs that can autonomously charge up to a three cell Li-Ion battery at 2A. The IC has a charge timeout for safety. With some external components in normal operation the battery supplies the robot's power, however when plugged into a DC source the battery is charged and the robot powered from the DC source.

The microcontroller board has a user interface provided by the 4D Systems intelligent OLED-128-G1 1.5" colour display module with 128 x 128 @ 256/65K colour resolution. The module is called 'intelligent' because it has a standard set of interface commands for drawing text, shapes, and images. This is combined with a navigation pad to allow user control.

The actuator and sensor interface board components were populated on a PCB the same length and width as the RoBoard, 96 x 56mm.

Battery Selection

The first step for selecting the battery was to calculate an energy budget for the robot given the previous decisions made. The following lists the major components and an estimate of the amount of power they will consume:

- Computer – 1W (idle), 2W (active)
- WLAN – 2W
- USB Camera – 1W
- 4 x IR Sensors – 1W
- Actuator and Sensor Interface – 1W
- 2 x Motors – 2W (active)

This gives the robot's total power consumption of 6W while idle and 9W while active. As the Roboard requires 6-24V for operation and 6V DC motors are standard the battery should have a nominal voltage higher than 6V.

Lithium-Ion batteries were selected due to their higher energy density over Nickel-Cadium and Nickel-Metal-Hydride and safer charge and discharge characteristics over Lithium-Polymer. Lithium-Ion batteries with a nominal voltage of 7.4V are standard. For a desired two hour run time, an approximate battery capacity is calculated as follows. For a given active power consumption of 9W, P, for a two hour run time, t, and a 7.4V nominal battery voltage, V_{nom}, the required battery capacity, C, can be calculated as follows:

$$C = \frac{P \times t}{V_{nom}}$$

A standard Lithium-Ion cell is the 18650 available with a 2.6Ah capacity. This comes in a 7.4V (nominal) pack with part number LC-18650S2WR-2600 from Battery Space.

Robot Interface Selection

A number of the standard robot interfaces for abstracting the robot's hardware from the programmer were considered. So that the software for the iRat can be freely released, extended, and widely used only open source, cross platform interfaces were considered. One of the most popular is the robot server-client interface, *Player-Stage* [Gerkey, et al., 2003, Vaughan, 2008] and is suitable for use as an interface framework for the iRat. The interface supports studies in real and virtual reality environments, has pluggable modules for tasks, and has existing visualisation tools. The strongest feature for the iRat is the server-client network interface that allows for distribution of computation across different computers. *Player-Stage* supports APIs in a variety of languages with the core in C/C++. The interface also supports interpreted programming languages, such as MATLAB and Python, which enable rapid prototyping and are more commonly used by neuroscientists.

3.3 Result

Figure 1 shows the final prototype iRat. The cream body is machined using a CNC machine from ABS plastic. The front mount shows one possible configuration of the IR and camera sensors.

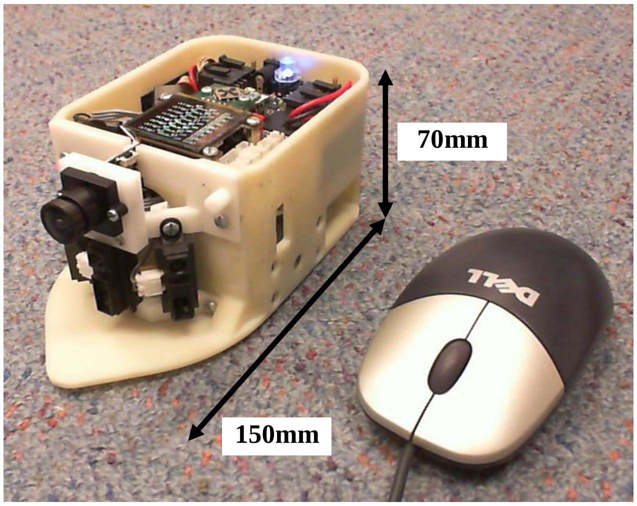

Figure 1 - The prototype iRat on the left shown next to a standard computer mouse to show relative size.

Table 3 shows a comparison between the iRat's desired specifications with the final prototype results. Most of the specifications have been met although the size of the robot is slightly larger than desired. The larger size is primarily because of the space required for the RoBoard. Having a slightly larger robot was considered an acceptable compromise for the quicker development time.

With regard to the locomotion result, while the iRat is capable of the desired velocity and acceleration, the movement performance is poor. The robot movement is not straight had has a bias towards the left. Future work on the movement controller will investigate better control strategies. Regardless at greater than 0.5 m/s the iRat is moving faster than its ability to sense and avoid obstacles given the delay in sending sensor readings and movement commands between the robot and the host PC. On some deep carpets the robot sinks into the carpet far enough that the bottom of the robot body makes contact. In this case the robot has trouble generating enough traction force to overcome this contact and the robot does not move. Changing to larger tyres or adding tread may alleviate this problem.

Table 3 – Comparison of the desired capabilities and achieved result. The battery life is determined when the iRat stops responding to WLAN ping requests.

Parameter	Specification	Result
Locomotion	Wheeled 1.5m/s top velocity and 4m/s^2 top acceleration.	Capable on smooth surfaces.
Mass	0.3-0.8kg	0.56 kg
Size	150mm (length) x 60mm (width) x 60 mm (height) body. Tail can add extra length.	150mm x 80mm width x 70 mm height
Vision	Wide angle colour camera with up to 180° FOV.	Wide angle colour camera capable of 110°.
Proximity	Ability to sense close objects in front of the robot	Has 3-4 Sharp IR sensors arrayed at the front.
Run time	120 minutes active	118 minutes (189 minutes idle)
Technical	Run a standard OS with standard interfaces.	Minimal Windows XP
Software framework	Should support a generic framework that abstracts the details of the robot.	Player-Stage

Figure 2 - A 424 x 240 pixel image from the iRat's camera compressed as a JPG and transmitted over the WLAN. The field of view is 110° horizontally.

Most of the RoBoard CPU time is spent grabbing images from the web camera, compressing them to JPGs and sending them across the WLAN. Currently this is performed at 5Hz for 424 x 240 24bit images compressed into JPGs with 30% compression resulting in 5-8KB images. As Figure 2 shows, the image received by the remote PC is still of acceptable quality. Frame speed could be significantly increased if the JPG compression could be performed on the web camera.

4 Preliminary Studies

Two published studies have demonstrated the capabilities of the iRat. The first study showed the iRat's ability to SLAM. The second study shows iRat using a spiking neural network to attend to temporal events.

4.1 RatSLAM

Due to its name, inspiration from rodent biology and common use in our group, using the RatSLAM as the first system to test the iRat's capabilities seemed appropriate. The core of the RatSLAM system has three modules; an appearance-based visual template recognition system, an attractor network that approximately represents the pose of the robot, and a semi-metric topological graph based experience map. A complete technical system description can be found in (Milford & Wyeth, 2008, 2009).

A MATLAB version of RatSLAM was used to process video recorded from the iRat as it autonomously navigates around a figure of eight environment described in [Ball, et al., 2010]. Figure 3 shows the overhead tracking of the iRat and the final topological experience map. The experience maps paths show approximate coherence with the actual environment even though the three loops do not completely overlap. The most important reason for the paths not overlapping is that the robot uses a forward facing camera and so from its perspective those two paths are completely different experiences. These loop closures demonstrate that the iRat is capable of SLAM navigation.

This study demonstrated the ability to rapidly apply the RatSLAM algorithm to another robot system with only minor adjustments to parameters. Since this paper the result has been repeated with RatSLAM controlling the robot in real time. A MATLAB version of RatSLAM can be downloaded from ratslam.itee.uq.edu.au to process pre-recorded videos. The online version will soon be updated to the version used in this paper, which uses the compiled DLLs (written in C) to speed up processing and has the ability to interface to Player-Stage for real time robot control.

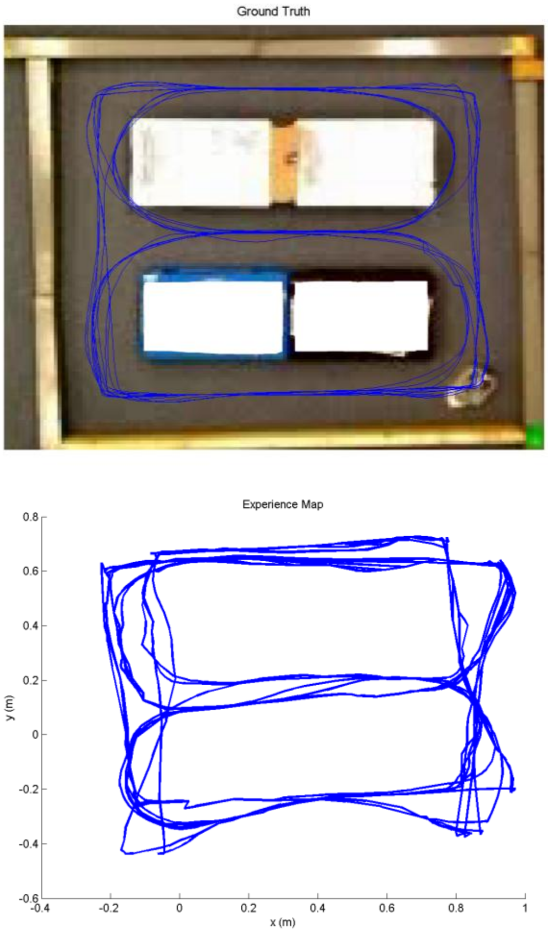

Figure 3 – Comparison between the tracked position of the iRat (top) and the generated map (bottom). Reproduced from [Ball, et al., 2010].

4.2 Spike Time Robotics

The aim of this study was to explore the iRat's ability to perform phototaxis in real time to a flashing light source using a virtual spiking neural circuit as described in detail in [Wiles, et al., 2010]. The virtual neural circuit was simulated using the Parallel Circuit Simulator (PCSIM) [Pecevski, et al., 2009], an open source comprehensive software package for the simulation of large neural networks. The technical architecture for this study is shown in Figure 4.

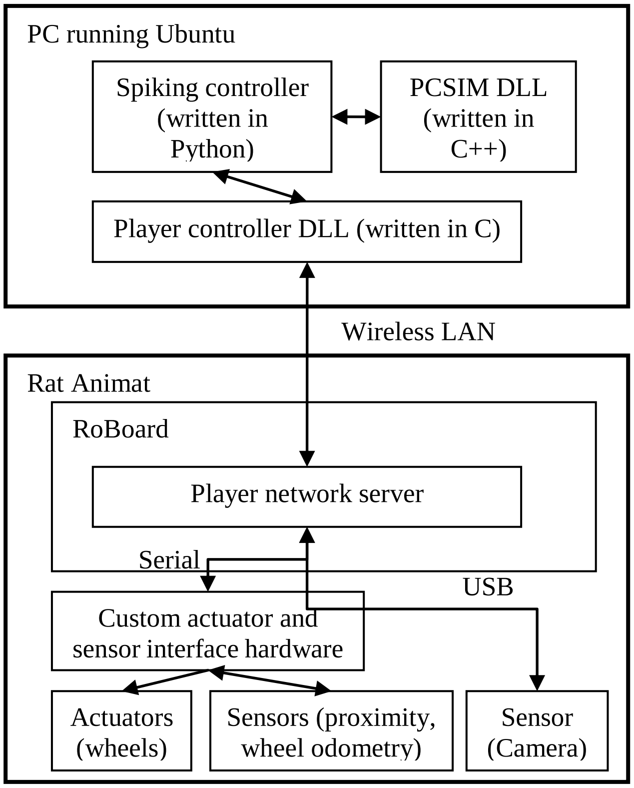

Figure 4 - Technical architecture for connecting the virtual Spiking Neural Network simulated in PCSIM to the iRat in real time. Across the Wireless LAN images from the camera are transmitted from the robot's camera and wheel velocity commands are sent from the SNN.

The robot architecture, experimental setup and results are shown in Figure 5. The overall architecture for the study was a Braitenburg vehicle with crossed connections between left and right sensors and actuators. However rather than the typical rate coded input, a flashing light source and an edge detector served as a temporal input. The neural circuit between the sensor and actuator is in effect a resonator that responds to a temporal input of a certain frequency. The resonator circuit consisted of connected excitatory and inhibitory neurons. When the resonator circuit fired a spike was generated and converted into a velocity which was sent to the corresponding actuator. In this way the iRat approached a flashing light which with the same frequency as the tuned resonator circuit.

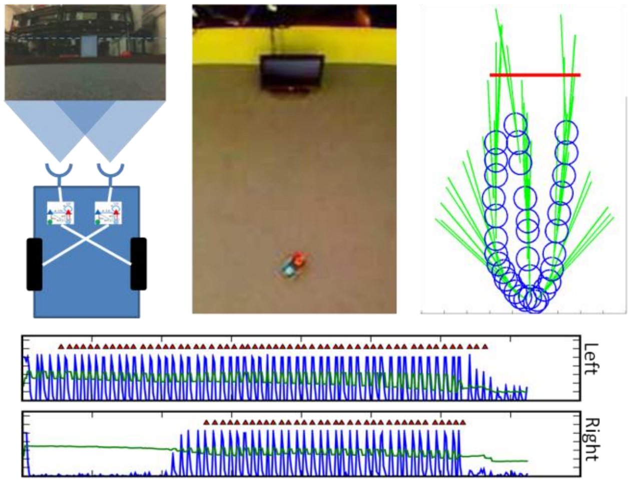

Figure 5 - This figure shows the tracked iRat location and SNN output while seeking a 1Hz flashing stimulus. (top left) A Braitenburg architecture showing two sensors, their respective resonant circuits and crossed connections to the actuators. (top middle) Overhead tracking view of the iRat and the flashing light stimulus. (top right) Tracking data showing three trials, first with the robot directly facing the flashing stimulus, then rotated approximately 45° to the left and right. (bottom) Left and right sensor-actuator responses. Reproduced from [Wiles, et al., 2010].

5 Future Work

There are exciting possibilities to further develop the rat animat into the future.

The primary work left for this prototype version is the development of a dock to allow the robot to autonomously recharge replacing the need for a human to manually plug in the power cable. This will allow researchers to conduct longer fully autonomous experiments, and also allow interactions with the robot by users from around the world via an existing web based system.

A current research plan is to increase the biological fidelity of the next phase iRat, which could incorporate a mobile head, whiskers, and stereo cameras. These changes will allow the IR sensors to be removed from the design.

A further avenue for future work is to conduct interaction experiments with the iRat and a real rodent. The robot could be used to teach the rodent navigation tasks.

5.1 Commercialisation

Work has begun with an industrial design company, Infinity Design to produce a version of the iRat that can be commercialised. The target market for the iRat will be the growing mechatronic and neuroscience programs at universities and research programs involving robots nationally and internationally. Towards this end, time will be spent adding support for a variety of popular robot frameworks (such as Robot Operating System) and simulators. The framework, tools and modules will be open sourced and made freely available.

6 Conclusion

This paper has presented a detailed design of the iRat robot. The robot demonstrates intelligent rat animat technology including a similar level of capabilities as the popular Pioneer robot in an order of magnitude less size and weight. The robot is slightly larger than a real rodent but this design compromise was favoured over a longer development time. This platform has already demonstrated from the RatSLAM study that it enables collaboration with roboticists and from the SNN study that it enables collaboration with neural modellers.

There is a broad scope for future work ranging from navigation studies to applying more complex neural models of the brain to increasing the biological fidelity of the physical robot. As the miniaturisation of technology continues, the possible capabilities in the future for a rodent sized animat are exciting.

Acknowledgements

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