THE UNIVERSITY OF QUEENSLAND

AUSTRALIA

Thesis Proposal

Neural network model of rat whisker sensory system for texture recognition applications

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Abstract

The Thesis proposal outlines the aspects of the project based on modelling of biological systems in the rats for texture discrimination. This project is an extension of the current iRat developed by the Co-Innovation Research group at UQ. The purpose of the project is to develop a neural network on Matlab that would make the iRat to discriminate textures useful for navigation and recognizing objects. Also, it addresses how biomimetic robotics are a relevant topic not only for engineering but to continue studying the neuroscience behind biological models. Considering that, there are many rat bio-inspired robots that can estimate distance, navigate and recognize objects, but there are not many that can classify textures. Also, the significance of this project relies on how it would introduce a new technology with the type of sensors used in the biomimetic whiskers. Finally, a project plan is presented for the organization and accomplishment of the objectives with a risk assessment for correct operation.

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1. Introduction

The development of robots based on biological sensorimotor systems of animals has been a technological approach for testing hypothesis on biological systems and revealing the technical parts are on biomimetic robots [1]. There are many neuroscience researches on animal behaviour, especially on sensory systems and how the brain processes those complex functions, this has been exploited or implemented in Biorobotics and Neuro-robotics. These robots can detect sensory signals as an animal with biological algorithms or neural networks training.

Therefore, embodied physical models of animal parts such as artificial rat whiskers can be modelled for tactile sensors in autonomous robots [2]. Whiskers can know the position, size, shape and texture of an object when they are in contact [3], then neuroscience studies have been conducted to understand the biology behind the processes which is implemented in rat robots such as iRat (Intelligent Rat Animat Technology), Psikharpax, AMouse, Shrewbot, etc.

All previous technology has a wide range of implementations and the biomimetic whisker is used to evaluate the spacing around based on tSLAM (tactile Simultaneous Localisation And Mapping) [4]. This computational problem is ideal for knowing the position of objects while the robot keeps navigating and updating the map of where it is [5]. All this is achieved with sensory-motor equipment and neural control architecture or neural networks.

However, most of the research done on whiskers is about object distance, position, shape, etc. and even though neuroscientist have come with hypothesis and investigations on how whiskers discriminate texture, there is little applications of this on Biorobotics. The current biomimetic whiskers on the iRat have been modelled for sensing motion but has the capability to extend it for texture discrimination.

Thus, the proposal for the thesis is to design, develop and implement a texture recognition on iRat whiskers based on texture coding of the sensorimotor system on rats. The approach is to understand the basics of how biological whiskers work and how they interact with the brain, so it can be implemented into neural networks. There are going to be simulations and then incorporation of the model into the biomimetic whiskers.

1.1. Project Definition

The whiskers of the rat have sensitivity functions such as localizing objects and recognizing surface structures similar to the functions of the humans' fingertip. For that reason, this mechano-sensitive organ has become an influence for new models of computation. The final purpose of this biological system implemented into an autonomous robot like the iRat (Intelligent Rat Animat Technology) is to discriminate textures that can help to classify objects.

There are many Biorobots that are currently using the whiskers of a rat, such as the Psikharpax and Shrewbot with the purpose of finding the localisation of objects, but little applications on texture recognition has been developed. For that reason, the development of this biological functional based computation on neuro-robotics can introduce a new system for object recognition, not only based on position, shape or size but a new whole classification related to surfaces. This can also be applied to the current navigation systems that the actual biorobots perform.

1.2. Project Objectives

The project is going to focus on implementing a biological algorithm on biomimetic whiskers for texture discrimination using neural networks on Matlab. For the achievement of the whole project there are specific aims:

- Understand the functionality of whisker sensory pathways and processing on the brain,
- Design a model that corresponds to the barrel cortex and whisker connection using neural networks,
- Develop the model on Matlab while testing the neural network outcomes,
- Integrate the finished model into the biomimetic whiskers for final operation.

1.3. Scope

This project proposal will outline the basic concepts for understanding the neuroscience of the whiskers, the sensory pathways that begin in the whiskers follicle to the barrel cortex in the brain. Then, the barrel cortex is explored in more detail for the neural network modelling. After this, the model can be designed by choosing a neural network and implementing it on Matlab while testing and updating the network. Finally, it will be implemented with the physical whiskers for final testing. For the testing of the neural networks, a set of whiskers would be needed, which have been developed before by the Co-Innovation research group.

There is also a Gann Chart indicating the activities with a weekly plan of goals and milestones that need to be completed in the process. An Occupational and Health Safety (OHS) risk assessment is presented as an important evaluation for the identification of risks related to the project tasks and how to control those risks.

2. Literature Review

2.1 Whisker sensory system

The whiskers of the rat also known as vibrissae are tactile hairs that have mechanoreceptors, which is the reason they are called mechano-sensitive organs [6]. The follicle itself is similar to a small sac where the whisker (inner material) rests but it becomes sensitive because the follicle has around 200 cells of trigeminal ganglion innervated [3]. Figure 1 shows how the first stimuli is originated from trigeminal ganglion cells and conducted to the central branch. Normally, rats use their whiskers localized on each side of the snout while moving them at a specific frequency back and forwards as a process called whisking [7] when they are navigating. After encountering an object, the mechanoreceptor cell will fire because of the whisker deflection and the nerve endings of the trigeminal ganglion cell convert that mechanical energy into action potentials [8].

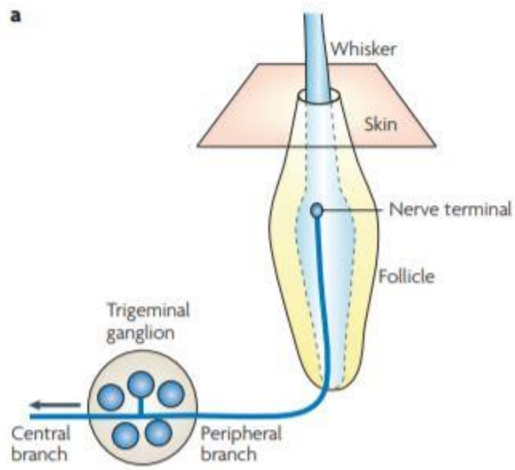

Figure 1: Whisker Follicle with mechanoreceptors that indicate movement and encode this information by sensory pathways. [Source: Diamond et. al., 2008 [3]].

After the excitation of primary afferent cells, the signal travels across the sensory nerve, arrives to the central branch where the cell body of the trigeminal ganglion is and forms synapses in the brainstem [9]. Then it conveys the signal data to thalamus via parallel pathway [3] to finally arrive at the barrel field of the somatosensory cortex.

2.1.1 Parallel Pathways

Before the afferent signal arrives to the barrel field of the somatosensory cortex, this is processed in three different or parallel pathways that originate from the trigeminal nuclei (TN) [3]. These are the Lemniscal, Extralemniscal and Paralemniscal pathways, all of them end in the cortex.

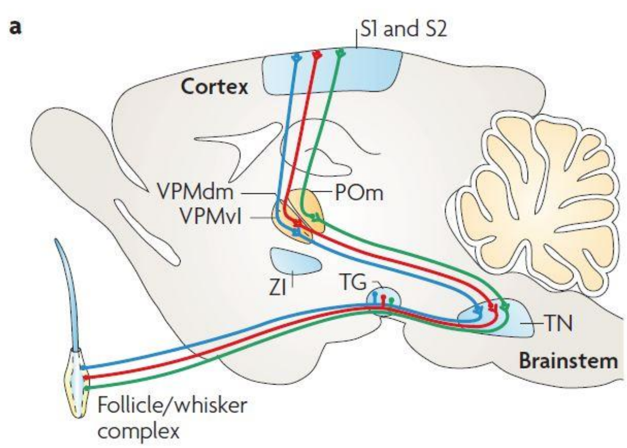

Figure 2: Parallel pathways in the brain, Lemniscal (red), Extralemniscal (blue) and Paralemniscal (green). [Source: Diamond et. al., 2008 [3]].

Each pathway has its own neurons location and sections to project as shown in figure 2 and table 1.

Table 1: Parallel Pathways system [3]

Action	Pathway		
	Lemniscal	**Extralemniscal**	**Paralemniscal**
Neurons location in	Principal TN, clustered into barrelets	Caudal part of the interpolar TN, clustered into barrelets	Rostral part of the interpolar TN, not spatially clustered (integrates multiple whisker information)
Project to	Ventral Posterior Medial nucleus (VPMdm) of thalamus	Ventrolateral domain of VPM (VPMvl)	Medial sector of posterior nucleus (POm)
Those axons neurons project to	Primary somatosensory cortex (S1) in layer V	Septa between barrel of S1and S2 (secondary somatosensory cortex)	Layer 5a of S1, S2 and primary motor cortex (MCx)
Function	Convey whisking and touch information	Convey contact timing	Convey information about whisking kinematics

2.1.2 Barrel Cortex

The thalamic pathways, sensorimotor paralemniscal and sensory lemniscal are the major input of the barrel cortex where they are transformed [10]. The brainstem trigeminal nuclear complex (BSTC) has a spatial arrangement for a single whisker of neuronal module into barrelets, where each row-arc map to the facial whiskers [11]. While in the VPM the pattern is named barreloids which has an inverted orientation. Figure 3 shows how an individual whisker has its own mapping in the barrel cortex.

The barrel cortex is in the somatosensory cortex and is mainly in the S1 area where there are not only barrels but also another structure called septa. These are sections between the barrels where information is processed just as the barrels do, but it has a low cell density in comparison with the barrels [12]. Besides that, the barrel cortex has 6 layers named from L1 to L6, where each layer has a row-arc of barrels, this is showed in figure 4A.

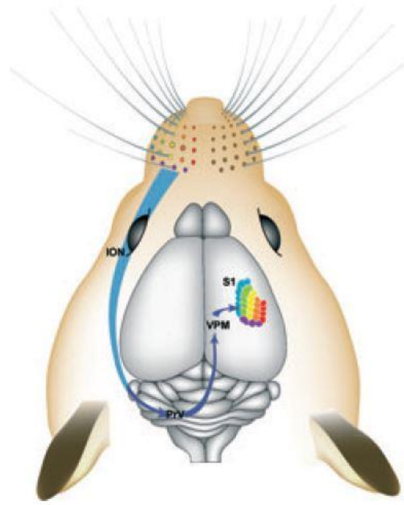

Figure 3: Whiskers transmit sensory information to the brainstem and then the barrel cortex. [Source: Wu, Ballesterd & Lu, 2011 [11]].

The layer organization in the neocortex is used to describe the cortical circuitry, how the sensory signals are processed and the function of each layer [13]. Considering that, each layer would have different neuronal cell types corresponding to different functions and structures. There are also inhibitory and excitatory cells in each layer, where the cell density varies as well.

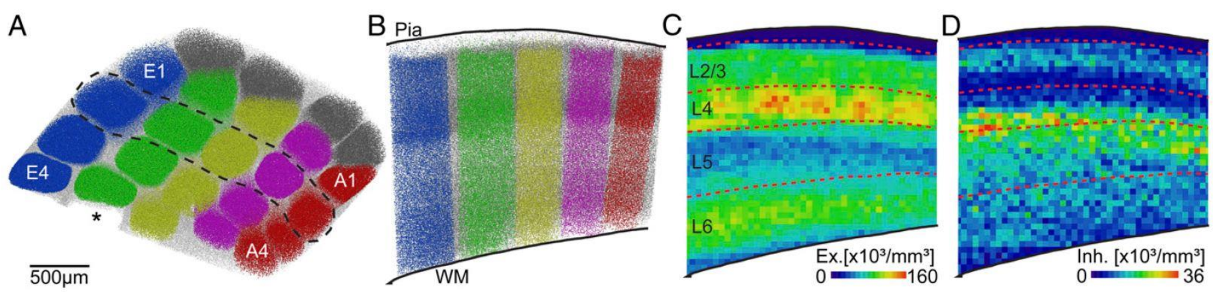

Figure 4: Barrel cortex and layer organization in A and B. C) 2D projection of the 3D excitatory neuron density. D) Projection of inhibitory neuron density in each layer. [Source: Meyer et. al., 2013 [14]].

Most of the research done on excitatory activity in the barrel cortex as in [10], [13], [14], [15] state that the sensory inputs innervate strongly in L4 barrel neurons, making the excitatory and inhibitory neurons distinguishable in that area. The theory behind this is called "canonical circuit", after L4 processed the cortical information it propagates to L2/3 and then L5/6, the output of all cortical layers [14].

Figure 4C and 4D show how layer 4 and layer 5 have the most spiking activity for excitatory and inhibitory neurons. According to [14] there are 10 dendritic cell types classified as shown in table 2.

Table 2: Cell types corresponding to each cortical layer [14]

Layer	Cell type
L2	• Pyramidal neurons
L3	• Pyramidal neurons
L4	• Spiny stellates • Star pyramids • Pyramidal neurons
L5	• Slender pyramids • Thick-tufted pyramids
L6	• Corticocortical pyramids • Corticothalamic pyramids

Even though the specific cell types are found in each layer, there can be an extension of these neurons to other layers because of their axons, this is how the neural circuitry is formed and allows interaction between layers.

2.2 Rodent Texture Discrimination

2.2.1 Texture Coding

Rats can identify some physical properties of objects like texture, useful for deciding which materials to use for nest building [3]. Most of the studies to understand the neuronal representation of texture come from experiments with anaesthetized rats. It was found that when measuring whisker vibrations happening during whisking across surfaces there would be a "kinetic signature" which is unique to each texture [16]. This kinetic signature is a movement profile indicating the magnitude and temporal pattern of low and high velocity at which the whiskers move [17].

Then, a kinetic signature is a velocity profile, this theory states that rough textures give irregular bursts of low and high velocity [16]. From Figure 5 it can be noticed that while the texture is rougher there is a higher magnitude velocity specially in the retraction state of the whisker. Also, it shows more irregularities in both protraction and retraction. Those irregularities are also known as slip-stick referring to the whiskers motion on surfaces [18].

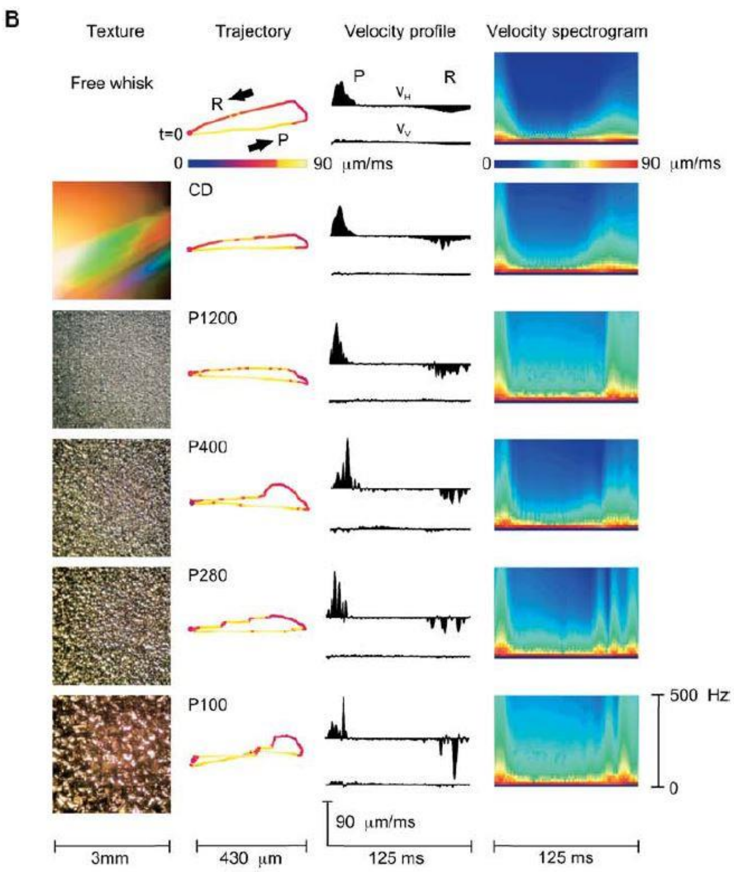

Figure 5: Velocity profile for different textures, also indicating the trajectory of whiskers and the velocity spectrogram.
[Source: Arabzadeh, Zorzin & Diamond, 2005 [16]].

However, this is not the only theory on how to discriminate textures, since it can also be done by the firing rates and slip-stick events as a major parameter [18]. The firing rate coding refers to the count of spikes per whisk which are measured in the barrel cortex and trigeminal ganglion [16], which is shown in figure 6.

Another term related to the velocity profile, besides the low/high velocity, can be the low/high acceleration. Then, because when rats are whisking in rough surfaces, they need to apply more forward force during whisking (protraction and retraction), the reason is that rougher surfaces have more friction and therefore they need more force to overcome that static friction [19]. Thus, more force applied induces to high acceleration slips in rougher surfaces versus smooth textures. The results from experiments in [17] clearly shown in figure 6 demonstrate that while the surface is rougher the firing rate increases in both ganglion and cortex.

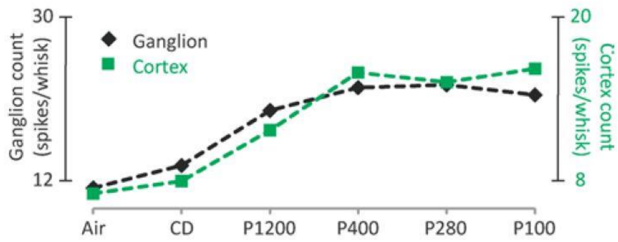

Figure 6: Firing rate in trigeminal ganglion and cortex at different surfaces. [Source: Diamond, Heimendahl & Arabzadeh, 2008 [17]].

Besides the mentioned theories, there is also the resonance hypothesis, this one states that since whisker length decreases from the back to the front the resonance frequency decreases as well [17]. Thus, when whisking across a surface, the resonance frequency driven would match the texture spatial frequency, that means there is a certain frequency for each texture that would fire a specific part in the barrel cortex.

2.3 Bio-Inspired Computation Systems

2.3.1 The iRat

The rat-sized bio-inspired robot developed by the Co-Innovation Research group at UQ has a navigation and mapping system known as RatSLAM [20]. The robot implements a cognitive control architecture which is another term to refer to neural networks with feedback control. Figure 7 shows the robot rat which has a size of 80mm wide, 150mm and 70mm high with a mass of 0.5Kg which is like the real rat. This robot can operate for 2 continuous hours and it is able to use C/C++, MATLAB and Python APIs [21]. A better description of the iRat is shown in table 3.

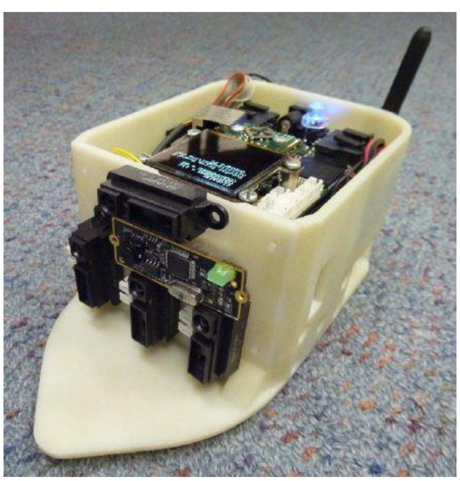

Figure 7: iRAT showing all the sensors, camera, LCD and navigation components. [Source: Ball, et. al., 2010 [20]].

Besides this robot, there are also previous technology inspired on rodents such as the AMouse, Psikharpax and Cyber Rodent. All these robots differ on sizes and functionalities, the AMouse has an omnidirectional camera with whisker arrays used for navigation and texture discriminations in any lighting conditions [20]. The Psikharpax is a more complete animat also implementing sensors and actuators, but it can move its head with eyes and can also grab objects with the foreleg, it also has a whisker system with visual sensors and auditory system [21]. These rats are being to use to model real rats and implement their functionality in useful activities, they are also applied to continue neuroscience studies such as the one done with the Mouse-No. 2 and a real rat. Researches at Waseda University found that the real rat identified the movements of the robot influencing its behaviour [21].

Table 3: iRat version 1.0 design specification [21]

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.

In addition, the iRat aspires to include more functions by incorporating stereo camera vision, head mobility and whisker array which is currently in research process.

2.3.2 Biomimetic Whisker

As part of the sensory system on a rat bio-inspired robot, there are the whiskers which work as tactile sensors. There are many biomimetic whisker designs in current biorobotics as the Psikharpax and AMouse. The AMouse uses natural rat whiskers connected to capacitor microphones, while the Psikharpax uses carbon fibre stem whiskers connected to conductive elastomer, plugging conductive vibrissae in between conductive probes, then when the whisker moves the variation in resistance is measured [22]. Furthermore, each vibrissae is surrounded by

4 probes that help to measure deflection in 2-axis, this sensor mechanism is like a voltage divider, where the voltage in each direction is being measured with a FPGA (Field Programmable Gate Array) [22].

There are more implementations of sensors for whiskers such as a combination of Hall-effect and piezo sensors positioned in orthogonal pairs, this helps to measure the whisker deflection in two dimensions, this technology was developed by Kim and Möller [22]. Another implementation done by Seth was by using flex sensors that measure the curvature on one dimension only. Finally, Fox created a mobile robot with strain gage-based sensors.

All these arrangements of sensors and whiskers aim to measure deflection in two dimensions, and the whiskers being developed by the Co-Innovation research group also aim to measure deflection of whisker by using pression sensors arranged around the whisker in a triangular shape. That arrangement allows to measure the deflection and direction at which the whisker moves. The material used for the whisker is ABS (Acrylonitrile Butadiene Styrene).

2.3.3 Whisker-inspired texture discrimination

Neural Networks are algorithms based on the brain used to identify patterns with the help of sensory information and raw inputs [23]. They can recognize those patterns as numbers in vectors, therefore all data needs to be transformed. Being able to identify something means that these algorithms objectives are to classify, therefore they are useful for texture discrimination.

Input transformation from the sensors to the neural network needs to be processed before it can be used in the network. The input vector calculation depends on the type of sensors being used but for the previous developed technology they have been using statistical rules like Bayes' rule, Principal component analysis (PCA), power spectral density (PSD), Fast Fourier Transform Algorithm with filters and windows like Low Pass filter and Blackman window [24].

After that, the classification is done with a network [24], [25], used the feed-forward neural network which recognizes patterns with multi layer perceptron (MLP). The number of neurons input, layers and outputs differ in each research but [25] uses 120 inputs, 20 neurons in hidden layer and 4 output neurons corresponding to each texture. Then, the weights were learnt with backpropagation and gradient descent using the cost function of root mean square error. Another network used for training is the Levenberg-Marquardt algorithm, which is an interpolation between the gradient descent and Gauss-Newton algorithm [26].

A more complex kind of network is the deep neural network (DNNs), where they include spatial and temporal information. Figure 8 shows the different types of these architecture families. The Simultaneous Spatiotemporal Integration consists of convolution layer before a fully connected layer, this convolution happens simultaneously in spatial and temporal dimensions [27]. That means, the whiskers' temporal and spatially responses are in a simultaneous combination.

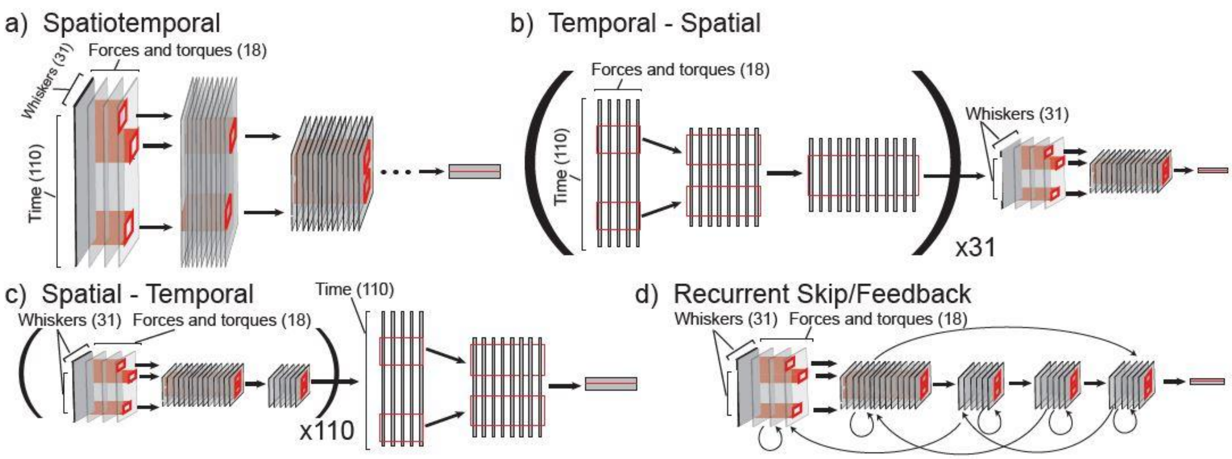

Figure 8: Different types of Deep Neural Networks referring to spatial and temporal information. [Source: Zhuang, et.al., 2017 [27]].

Now, there is the Separate Spatial and Temporal Integration that integrated the spatial and temporal information separately, it can be temporal first, then spatial or viceversa [27]. In the first case, each whisker temporal information is integrated and later that is combined on higher layers. After temporal processing the spatial convolution is applied. With the second case, the whiskers are integrated for later using the temporal combination. The last architecture is the Recurrent Skip/Feedback network, this one makes the temporal processing with updates of temporal system.

3. Methodology

The literature review done for the project analyses and explains in a deep extension about biological concepts and previous technology on robotic rats including biomimetic whiskers. Among all those biological concepts such as the sensory pathways, barrel cortex and how a tactile information is conveyed from the follicle to the different neurons in the barrels, just the excitatory and inhibitory neurons are going to be modelled in the neural network. There are many cells that have different functions (excitation or inhabitation) on each layer, but for the design of neural networks only one excitatory and one inhibitory cell are going to be used.

Also, with many neural network models going from simple design to more complex ones the actual networks to be used are the feed forward networks. Many of the past researches indicate the type of whisker sensors used and how they process that information into useful data for further processing on texture discrimination. However, the whisker and type of sensors used for this project are completely different giving other type of data, also they are arranged in different ways, so the result of the whisker deflection depends on the three sensors used. For that reason, the research on this project is meaningful as it would introduce new technologies on texture discrimination.

4. Project Plan

The project needs to be developed according a plan including tasks/milestones, duration, resources that follow an adequate order of stages for the project completion. The stages are presented and explained in figure 9.

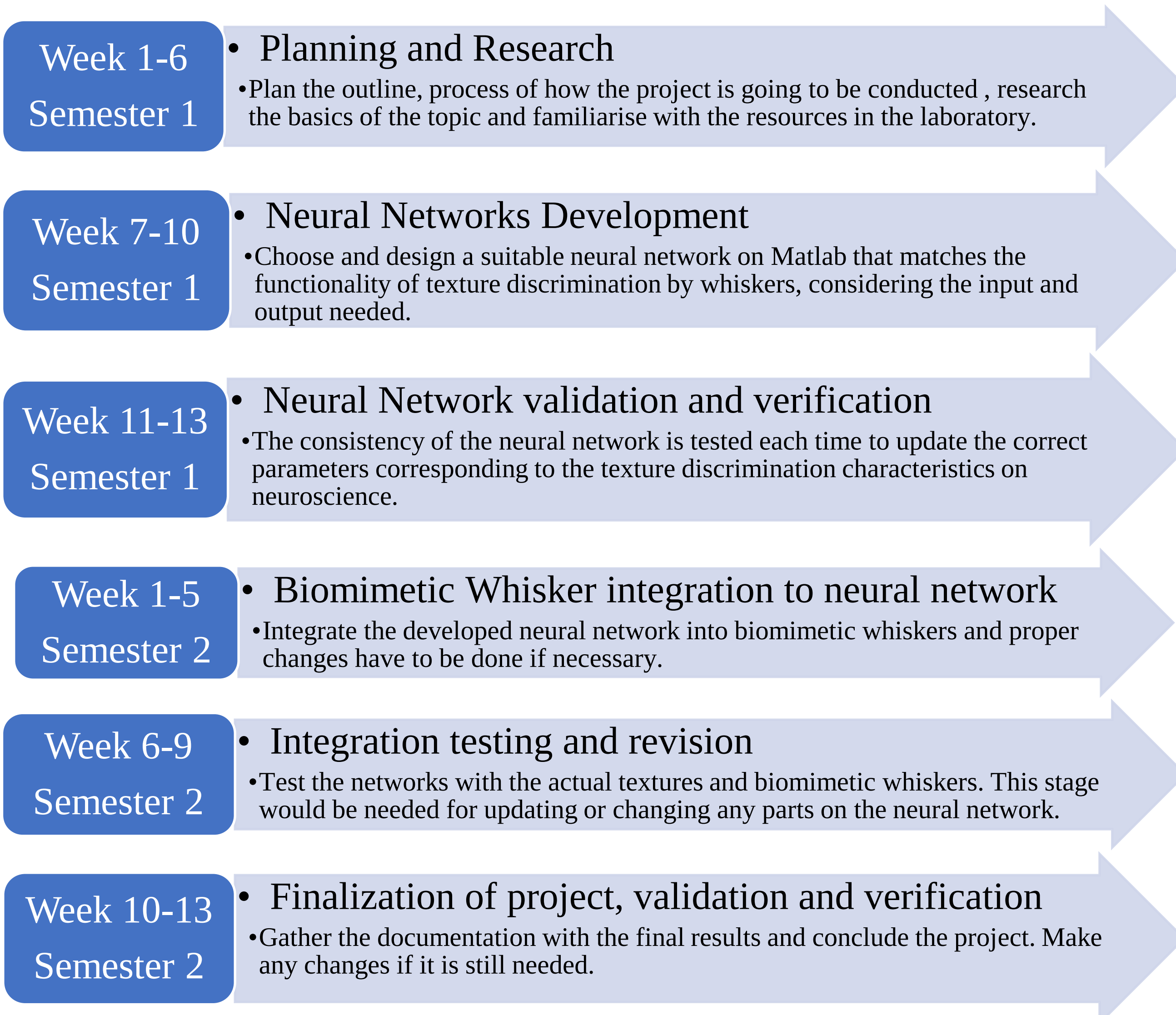

Figure 9. Stages for development of the project during semester 1 and semester 2.

4.1 Milestones

- UQ Academic Integrity Tutorial – Pass/Fail
- Project Proposal submission - Assessment
- OHS Risk Assessment submission
- Finalization of first prototype
- Progress Seminar - Assessment
- Testing prototype
- Finalization of final product
- Poster and Demonstration - Assessment
- Thesis Report submission - Assessment

4.2 Project Progress

Since the beginning of the semester until now, there are some tasks that have been completed:

- UQ Academy and Integrity Tutorial: This tutorial is a pass/fail requirement about plagiarism and how to make a good writing report based on good practices.
- An OHS risk assessment was done according the project requirements.
- Stage 1 research has been done since week 1.

4.3 Task and Resources

According to the stages of the project there are specific tasks and resources needed for each one as shown in table 4.

Table 4. Stages showing the tasks to be completed with the resources needed

Stage	Task	Resources
Planning and Research	Literature Research	Google scholar, UQ Library
	Project Proposal	Internet, PC
	Software training	Computer, Matlab, Internet
	Hardware training	Biomimetic Whisker, Power supply
Neural Network Development	Software set up	Matlab, computer
	Models of neural circuits design	Research papers, books, Matlab, computer
Neural Network validation and verification	Testing of neural network	Matlab, computer
	Progress Seminar	PPt slides, Literature, Progress work

Biomimetic Whisker integration to neural networks	Set up of whisker	Biomimetic whisker, power supply
	Upload network on whisker	Matlab, computer, whisker, power supply
Integration testing and revision	Set up scenario testing	Different textures, whiskers
	Test integration	Whisker, surfaces
Finalization of project, validation and verification	Poster Demonstration	Poster, prototype
	Thesis Report	Networks, computer

Task	Days	Start	Finish	Semester 1												
				Week												
				1	2	3	4	5	6	7	8	9	10	11	12	13
				23/07/ 18	30/07/ 18	06/08/ 18	13/08/ 18	20/08/ 18	27/08/ 18	03/09/ 18	10/09/ 18	17/09/ 18	01/10/ 18	08/10/ 18	15/10/ 18	22/10/ 18
Literature Research	40	23/07/ 18	31/08/ 18													
Project Proposal	10	13/08/ 18	23/08/ 18													
Software training	8	23/08/ 18	31/08/ 18													
Hardware training	8	23/08/ 18	31/08/ 18													
Software set up	3	03/09/ 18	06/09/ 18													
Models of neural circuits design	28	07/09/ 18	05/10/ 18													
Progress Seminar	7	01/10/ 18	08/10/ 18													
Testing of neural network	19	08/10/ 18	26/10/ 18													

				Semester 2												
				Week												
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
				25/02/19	**04/03/19**	**11/03/19**	**18/03/19**	**25/03/19**	**01/04/19**	**08/04/19**	**15/04/19**	**29/04/19**	**06/05/19**	**13/05/19**	**20/05/19**	**27/05/19**
Set up of whisker	**3**	**25/02/19**	**28/02/19**													
Upload network on whisker	**29**	**28/02/19**	**29/03/19**													
Set up scenario testing	**7**	**01/04/19**	**08/04/19**													
Test integration	**26**	**08/04/19**	**03/05/19**													
Poster Demonstration	**10**	**06/05/19**	**16/05/19**													
Thesis Report	**10**	**17/05/19**	**31/05/19**													

Figure 10. Gantt Chart for project plan.

5. Risk Assessment

As part of the assessment and successful competition of the project, potential risks and harms need to be recognized to minimize them. Table 5 shows the risk assessment in more detail.

Table 5. OHS Risk Assessment. [School of Mechanical and Mining Engineering].

Section One: Communication and Consultation			
Risk Assessment Title	**Thesis Project**	**Date of analysis**	**21/08/2018**
Facilitator	**Professor Janet Wiles**	**Assessment by**	**Ivonne Vera**

Section Two: Risk Assessment Context	
Internal Context	**Must comply with UQ OHS policy**
External Context	**State OHS legislation.**
Risk Management Context	**Students must ensure they conform to UQ OHS policy.** **Motivation: Student undertaking thesis project**
	Assumptions: **- Student is aware of their safety obligations and perform all tasks in accordance with approved processes**

Risk Reduction Measures RRM	
HIERARCHY OF CONTROL	
1. ELIMINATE: The complete elimination of the hazard	**4: ISOLATE:** Isolating the hazard by guarding or enclosing it
2. SUBSTITUTE: Replacing the material or process with a less hazardous one	**5: ADMINISTRATIVE:** Providing control such as training, procedures etc.
3. REDESIGN: Redesign the equipment or work process	**6: PPE:** Use appropriate and properly fitted PPE where other controls are not practical

Section Three: Risk Criteria

All risks will be assessed for positive and negative outcomes to:

PEOPLE – internal and external to our organisation.

ASSETS – internal and external to our organisation.

ENVIRONMENT – internal and external to our organisation.

REPUTATION – primarily to our organisation but also how it will affect the Universities and our research reputation.

Each of the above criteria's will be quantified as an expression of consequence verses likelihood in accordance with the Risk Matrix. The highest score must be documented.

Loss Type			Hazard Effect / Consequence (Severity)				
			1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
(P)	Harm to People		First aid treatment. minor cuts, bruises or bumps	Disabling injury requires medical treatment	Serious injury (permanent disability, amputation)	Fatality	Multiple fatalities
(E)	Environmental Impact		Negligible environmental damage	Minor environmental damage	Serious environmental damage	Major environmental damage	Extensive environmental damage
(A)	Asset Damage and other Consequential Losses		Negligible financial loss (< $5000) No disruption to operation	Notable financial loss ($5000 to $50,000) Brief disruption to operation	Substantial financial loss ($50,000 to $500,000) Partial shutdown of operation	Significant financial loss ($500,000 to $1m) Partial loss of operation	Significant financial loss (>$1m) Substantial or total loss of operation
(R)	Impact on Reputation		Slight impact – public awareness may exist	Limited impact –some local public concern	Considerable impact – regional public concern	National impact – national public concern	International impact international public attention
Likelihood		Likelihood Examples	Risk Rating				
A	Rare	- that the unwanted event has never been known to have happened within a University, or is highly unlikely that could ever occur	1A	2A	3A	4A	5A
B	Unlikely	- that the unwanted event has happened within a University at sometime, or could happen once in 100 years	1B	2B	3B	4B	5B
C	Possible	- that the unwanted event has happened within the University at sometime, or could happen once in 10 years	1C	2C	3C	4C	5C
D	Likely	- that the unwanted event has happened within the faculty (EPSA) at sometime, or could happen more than once a year	1D	2D	3D	4D	5D
E	Almost Certain	- that the unwanted event has happened within the School of Engineering at sometime, or could happen more than once a year	1E	2E	3E	4E	5E

Low Risk	**Continue activities using RRM (Risk Reduction Measures) to manage for continuous improvements**
Medium Risk	**Continue activities using RRM (Risk Reduction Measures) to reduce the risk to ALARP (As Low as Reasonably Possible) over time**
High Risk	**RRM to be completed and implemented to reduce the risk to ALARP before activities commence**
Extreme Risk	**Activity must not be conducted until RRM has been applied to reduce risk to High or below**

Section Four: Operational Risk Assessment

Step One: Identify Risks			Step Two: Analyse Risks				Step Three: Evaluate Risks		Step Four: Treat Risks			
										Treatment Plans		
Operational Activity	Associated Hazards	Associated Risks	Current Controls (refer to Hierarchy of Controls at end of document)	Severity	Likelihood	Level of	Set Priority	Assign Accountability	Further Control options	Action	Account ability	Residual Level of Risk
Literature Research	Exhaustion	Back, neck, shoulders pain, eye strain	Use of ergonomic materials such as mouse pad, keyboard, chairs. Level of chair at the same level as computer.	1	D	1D	HIGH	Student, Supervisor	Muscles stretching, take breaks, acquire good posture, work on environments with good illumination			1C
Project Proposal	Exhaustion	Back, neck, shoulders pain, eye strain	Use of ergonomic materials such as mouse pad, keyboard, chairs. Level of chair at the same level as computer.	1	D	1D	HIGH	Student, Supervisor	Muscles stretching, take breaks, acquire good posture, work on environments with good illumination			1C
Software training	Exhaustion	Back, neck, shoulders pain, eye strain	Use of ergonomic materials such as mouse pad, keyboard, chairs. Level of chair at the same level as computer.	1	C	1C	HIGH	Student, Supervisor, Lab research worker	Muscles stretching, take breaks, acquire good posture, work on environments with good illumination			1B
Hardware training	Electrical	Electric shock, Fire, short circuit	Label all electrical machinery with the current power ratings.	2	D	2D	HIGH	Student, Supervisor, Lab research worker	Cover all wires with insulation material if they are damaged.			2C
Software set up	Exhaustion	Back, neck, shoulders pain, eye strain	Use of ergonomic materials such as mouse pad, keyboard, chairs. Level of chair at the same level as computer.	1	C	1C	HIGH	Student, Lab research worker	Muscles stretching, take breaks, acquire good posture, work on environments with good illumination			1B
Models of neural circuits design	Exhaustion	Back, neck, shoulders pain, eye strain	Use of ergonomic materials such as mouse pad, keyboard, chairs. Level of chair at the same level as computer.	1	C	1C	HIGH	Student	Muscles stretching, take breaks, acquire good posture, work on environments with good illumination			1B

Testing of neural network	Exhaustion	Back, neck, shoulders pain, eye strain	Use of ergonomic materials such as mouse pad, keyboard, chairs. Level of chair at the same level as computer.	1	C	1C	HIGH	Student, Supervisor, Lab research worker	Muscles stretching, take breaks, acquire good posture, work on environments with good illumination				1B
Progress Seminar	Exhaustion	Back, neck, shoulders pain, eye strain	Use of ergonomic materials such as mouse pad, keyboard, chairs. Level of chair at the same level as computer.	1	D	1D	HIGH	Student, Supervisor	Muscles stretching, take breaks, acquire good posture, work on environments with good illumination				1C
Set up of whisker	Electrical	Electrical shock, Fire, short circuit	Label all electrical machinery with the current power ratings.	2	D	2D	HIGH	Student, Lab research worker	Cover all wires with insulation material if they are damaged. Ask for help when connecting whisker				2C
Upload network on whisker	Electrical	Short circuit	Revision of connections before and after the implementation.	2	C	2C	HIGH	Student, Lab research worker	Cover all wires with insulation material if they are damaged.				2B
Set up scenario testing	Sharp edges or textures, use of hand tools	Finger cuts, skin cuts.	Read manuals of hand tools, use gloves.	2	D	2D	HIGH	Student, Lab research worker	Ask for help when using tools or lifting weights.				2C
Test integration	Malfunctioning of hardware	Short circuits	Cover wires with insulation material, label the correct power ratings.	2	C	2C	HIGH	Student, Supervisor, Lab research worker	Avoid any wet environment or liquids				2B
Poster Demonstration	Exhaustion	Back, neck, shoulders pain, eye strain	Use of ergonomic materials such as mouse pad, keyboard, chairs. Level of chair at the same level as computer.	1	D	1D	HIGH	Student, Supervisor	Muscles stretching, take breaks, acquire good posture, work on environments with good ilumination				1C
Thesis report	Exhaustion	Back, neck, shoulders pain, eye strain	Use of ergonomic materials such as mouse pad, keyboard, chairs. Level of chair at the same level as computer.	1	D	1D	HIGH	Student, Supervisor	Muscles stretching, take breaks, acquire good posture, work on environments with good ilumination				1C

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