Project Proposal	April 2017	Note:

Student to complete this section						
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Design of a holonomic five legged robot			**Study leader: Dr D le Roux**			
Class group: Afrikaans	**Project number:**		DLR5	Revision number:	0	
Type of project: Design	Degree programme enrolled for: Electronic Engineering					
Student declaration: I understand what plagiarism is and that I have to complete my project on my own.	Student signature		Date			

Declaration by language editor (proofreader)	
I have been allowed adequate time to read this document carefully and to make corrections where necessary (date received indicated below). To the best of my knowledge, correct formatting, spelling and grammar are used throughout the document.	
M. Steyn (language editor)	Date

Declaration and recommendation by study leader		
1. Have you (the study leader) been allowed adequate time to read and comment on the Project Proposal?	Yes	No
2. Is the Project Proposal a <u>correct</u> and <u>complete</u> description of what is required?	Yes	No
3. Is the Project Proposal <u>clear</u> and <u>unambiguous</u>?	Yes	No
4. Recommendation: Do you recommend that the Project Proposal be approved?	Yes	No
Dr D le Roux (Study leader)	Date	

This section to be used by the Project lecturer					
Content /20		Attended lectures:	Yes	No	
Subtract for editing errors / 10		Language editing adequate:	Yes	No	
Final mark /20		Approved? (If "No", a revision must be submitted):	Yes	No	Prof. J.J. Hanekom

1. Problem statement

Motivation. The steering systems used on conventional passenger vehicles all suffer from a phenomenon called the parallel parking problem [3]. This restricts the vehicle to forward and backward movements only, while slightly turning the front wheels. The vehicle is therefore capable of moving in arcs but never sideways. The alternative to this type of movement is holonomic movement, this allows the vehicle to move in any direction from a stationary position - even sideways. The motivation for this project is using a five-legged approach to solve the parallel parking problem while still being able to move over the bumps and small obstacles that a normal vehicle would be able to cross.

Context. One approach to achieve holonomic movement in vehicles is to swop the cylindrical wheels found on most vehicles for spherical wheels [4]. While this solution solves the parallel parking problem, it introduces a new restriction of only functioning properly on relatively flat surfaces, unless very complicated suspension mechanisms are implemented. This solution is therefore not suitable for any off-road application. This project will extend on this to solve the problem of terrain without sacrificing holonomic movement.

Technical challenge. The engineering challenge in this project is the development of a control system algorithm that is accurate and complex enough to calculate all necessary outputs with the minimum number of assumptions while still being efficient enough to not cause a sluggish response. The product delivered should be a working prototype that functions in real life, not just a proof of concept.

Limitations. One of the technical limitations that makes this project challenging is that the algorithm should be as efficient as possible to make maximum usage of the limited capabilities of the microcontroller. This is mainly because of the many floating point operations involved in the trigonometry of the inverse kinematic calculations. A second limitation to be taken into consideration is the limited torque that the servo motors can produce. This places a definite limitation on the maximum weight of the robot for which the legs are still able to lift the body.

2. Project requirements

ELO 3: Design part of the project

2.1 Mission requirements of the product

The requirements of the product that would determine whether the project is successful can be summarized in the list below.

- The robot should be able to move in any direction from a stationary position.
- The robot should be able to rotate about its own axis while remaining in the same position.
- The robot should be controlled remotely by using a smartphone application.
- The robot should use five legs to execute any of the required movements.
- The robot should be able to move on both smooth and coarse surfaces to improve on the spherical wheel concept.

2.2 Student tasks: design

The tasks that are vital to ensuring that the product meets the mission critical requirements are listed below.

- The mathematical analysis and design for the movement of the legs should be done on paper.
- The design should then be implemented in a graphical mathematics package such as Python for further refinement.
- Once the algorithm design is sound, electronic design can commence in a simulation environment such as LTSpice.
- The design can then be implemented in electronics using a microcontroller and support electronics together with some driving circuitry.
- A smartphone application should be developed to remotely control the robot.
- Each subsystem should be tested for isolated functionality as well as interaction with other subsystems to make sure all requirements are met.

<u>ELO 4: Investigative part of the project</u>

2.3 Research questions

The investigative question addressed in this project is whether design of a holonomic robot with a legged approach solves the problems apparent in the spherical wheel approach. Can a holonomic five legged robot move on a variety of surfaces?

2.4 Student tasks: experimental work

The experiments that will be conducted to address the research questions above are listed below.

An experimental setup to test the ability of the robot to move on a variety of surfaces is required.

- The robot will be placed on both smooth and coarse flat surfaces to perform the same manoeuvres.
- The robot should be able to perform these manoeuvres with a similar degree of difficulty and in similar time.

Another experimental setup is required to test the robot's ability to handle small obstacles and bumps.

- The robot will be placed on a surface with bumps and small obstacles such as rocks.
- It should be able to execute the same set of manoeuvres mentioned in the experimental setup above in similar time.

3. Functional analysis

The functional analysis of the system can be shown best in a flow diagram. This can be seen in Figure 1 below.

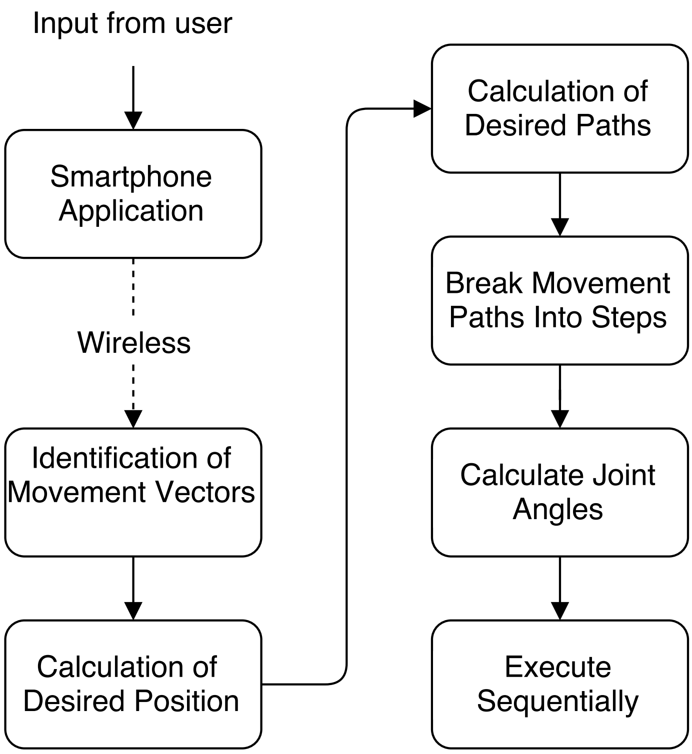

Figure 1. Functional block diagram of the product.

In Figure 1 above, the process is shown to begin with the input from the user into a smartphone application. This consists of a user interface on the screen of the smartphone that the user can interact with. The user interface will allow the user to make the robot translate as well as rotate. This information is sent to the microcontroller on the robot via some wireless technology. The robot analyses this combination of translation and rotation commands and breaks it into a separate vector for each of the legs. The final position of each leg as well as the route to each individual leg destination is computed next. This makes use of a process called inverse kinematics. The manoeuvres requested by the user can be realized through a series of movements with servo motors installed on the joints of the robot legs. In order to make a limb move, the exact required angle of each joint is calculated and communicated to the servo. This process is repeated continuously to make the robot react to the varying inputs of the user.

4. Specifications

4.1 Mission-critical system specifications

SPECIFICATION (IN MEASURABLE TERMS)	ORIGIN OR MOTIVATION OF THIS SPECIFICATION	HOW WILL YOU CONFIRM THAT YOUR SYSTEM COMPLIES WITH THIS SPECIFICATION?
The robot should be able to move in a given direction in 90 degree increments from a stationary position.	Proving that the robot can move straight forward, left, backwards and right (directions spaced 90 degrees apart), will prove that the robot is holonomic.	The robot will be placed on a grid on the floor and instructed to move in one of the chosen directions at a time.
The robot should be able to rotate 90 degrees without translating the centre of the body by more than 5% of the body diameter.	Rotating 90 degrees proves that the robot does not suffer from the parallel parking problem. 5% of the robot diameter can still be considered negligible and prove that no translation is required to rotate.	The robot will be placed on the grid on the floor and instructed to rotate. The translation of the centre of the body will be noted.
The time it requires to complete a manoeuvre should not vary more than 25% between smooth and rough surfaces.	A variation of less than 25% in time can still be considered to be a similar time. This proves that the robot can move over different surfaces with similar difficulty.	The robot will be instructed to complete a specific set of movements on a flat smooth surface and the time to completion will be recorded. Various obstacles will be placed in the way of the robot (small blocks, sand, etc.), and the robot will be instructed to repeat the specific set of instructions and the time difference will be noted.

Table 1. Mission-critical system specification

4.2 Field conditions

REQUIREMENT	SPECIFICATION (IN MEASURABLE TERMS)
The robot should be in range of the wireless smartphone controller.	For wireless communication to work reliably, the user with the smartphone should be less than 10m from the robot.
To prevent falling over, the robot should walk on surfaces close to horizontal.	The robot should not be operated on surfaces with an incline of more than 10%
The robot should stay dry to protect electronics.	The robot should never be operated near water or wet surfaces.
The robot should work in normal temperature conditions for South Africa.	The robot should be operated in the temperature range 10^oC to 40^oC.

Table 2. Field conditions

4.3 Functional unit specifications

SPECIFICATION	ORIGIN OR MOTIVATION
FU1. The smartphone application should communicate commands from the user interface to the robot at a frequency of at least 10 Hz.	The robot should be in constant communication with the smartphone application to update the trajectory vectors. An update frequency of 10 Hz will update the robot fast enough to make the robot feel responsive.
FU2. The inverse kinematics calculator of the robot should be able to calculate the joint positions correctly to move each leg to the desired location.	The joints should all be calculated correctly in order for the robot to make the correct set of movements to walk.
FU3. The servo motor angles should all be within 5 degrees from the calculated values.	The servo angles have to be accurate in order to make the robot walk predictably. A tolerance of 5 degrees can still be considered accurate for hobbyist servo motors.

Table 3. Functional unit specifications

5. Deliverables

5.1 Technical deliverables

DELIVERABLE	DESIGNED AND IMPLEMENTED BY STUDENT	OFF-THE-SHELF
Microcontroller for control of the robot.		X
Control code for inverse kinematics and servo control.	X	
Android application with a user interface for control of the robot.	X	
Wireless module for communication between the smartphone interface and the robot		X
Circuits implemented on PCB for interfacing all hardware with the microcontroller.	X	
Servo motors for movement of the joints.		X
Robot body and legs.	X	
Simulations on all implemented software and analogue design	X	

Table 4. Deliverables

5.2 Demonstration at the examination

1. The robot will be placed on a grid on the floor and the examiners will be shown that the robot is capable of holonomic movement.

2. The centre of the robot will be noted on the grid and the examiners will see that the robot is capable of rotating around its centre without translating.

3. The robot will execute a specific set of movements while the time to completion is being recorded.

4. Small obstacles will be placed in the way of the robot to make movement more challenging. This includes small blocks to step over as well as a change in surface such as sand.

5. The robot will repeat the set of movements over the obstacles while the time to completion is measured again.
6. The examiners will see that the robot is capable of moving with similar effort over various surfaces.

6. References

[1] J. Hanekom. (2017) 2017 study guide part 1. Accessed 2017-02-20. [Online]. Available: http://www2.ee.up.ac.za/ epr400/StudyGuide.pdf

[2] Hanekom. (2017) Requirements for written reports. Accessed 2017-02-20. [Online]. Available: http://www2.ee.up.ac.za/ epr400/APPENDIX2_2017.pdf

[3] J. Reeds and L. Shepp, "Optimal paths for a car that goes both forwards and backwards," *Pacific Journal of Mathematics*, vol. 145, October 1990.

[4] K. Tadakuma, R. Tadakuma, and J. Berengeres, "Development of holonomic omnidirectional vehicle with omni-ball: spherical wheels," *Intellegent Robots and Systems*, vol. 2007, November 2007.