For use by the Project lecturer	Approved		Revision required	

Feedback

Approved

Good project and thorough document, but scoped too large for Project.
You don't have any requirements for the robot itself.
You may scale requirements 4 to 7 down to minimal requirements and ensure that the project focus is with requirements 1 to 3.
Approval is conditional on this: that you understand that the core focus is on Requirements 1 to 3, and the design and building of the platform.
A revision is not required, but if preferred you may submit one in which these requirements are scaled appropriately.

Symbol awarded: A

To be completed by the student

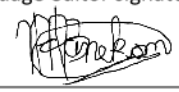
PROJECT PROPOSAL 2021

Project no	IKC7	Revision no	0

Title	Surname	Initials	Student no	Study leader (title, initials, surname)
Mr	**Hanekom**	**MB**	18007432	Prof IK Craig

Project title

Robotic vacuum cleaner

Language editor name	Language editor signature
MB Hanekom	
Student declaration I understand what plagiarism is and that I have to complete my project on my own.	**Study leader declaration** This is a clear and unambiguous description of what is required in this project
Student signature 	Study leader signature and date 21 May 2021 

1. Project description

What is your project about? What does your system have to do? What is the problem to be solved?

Domestic chores such as cleaning the floors takes considerable time and energy. People have to sacrifice work, leisure and family time to keep their houses clean. This project will aim to lessen the domestic burden by designing a autonomous vacuum cleaner, that can clean the whole or specified areas of the house with as little human intervention as possible.

The robot will map out a specified floor area, estimate the time required to clean the area and commence cleaning, which involves vacuuming dirt everywhere in the room. The thoroughness of the cleaning operation will depend on the amount of dirt present. The autonomous robot will also be able to manage its own power and return to the source when it needs to recharge. The robot also needs to be smart enough to avoid falling off stairs or leaving the specified room via an open doorway.

2. Technical challenges in this project

Describe the technical challenges that are *beyond* those encountered up to the end of third year and in other final year modules.

2.1 Primary *design* challenges

- An efficient mapping algorithm needs to be designed that is capable of mapping a room of any shape to a certain size accurately.
- A thorough navigation algorithm and driving control system needs to be implemented which will guide the robot everywhere safely.
- A dirt sensing evaluation algorithm needs to be developed to enable dirt dependent cleaning.
- An obstacle avoidance algorithm needs to be designed that successfully avoids colliding with static objects.

2.2 Primary *implementation* challenges

- The docking station and way to dock with the power source needs to be built that allows the robot to easily and consistently connect to its own power.
- A powerful vacuum pump and brush technique needs to be constructed to suck large and small dirt particles.
- A dirt sensor, which will be mixture of off the shelf and custom sensing components needs to be correctly built and positioned for optimal efficiency.
- The optimal positioning and amount of sensors needs to be chosen to see the environment clearly and accurately.

3. Functional analysis

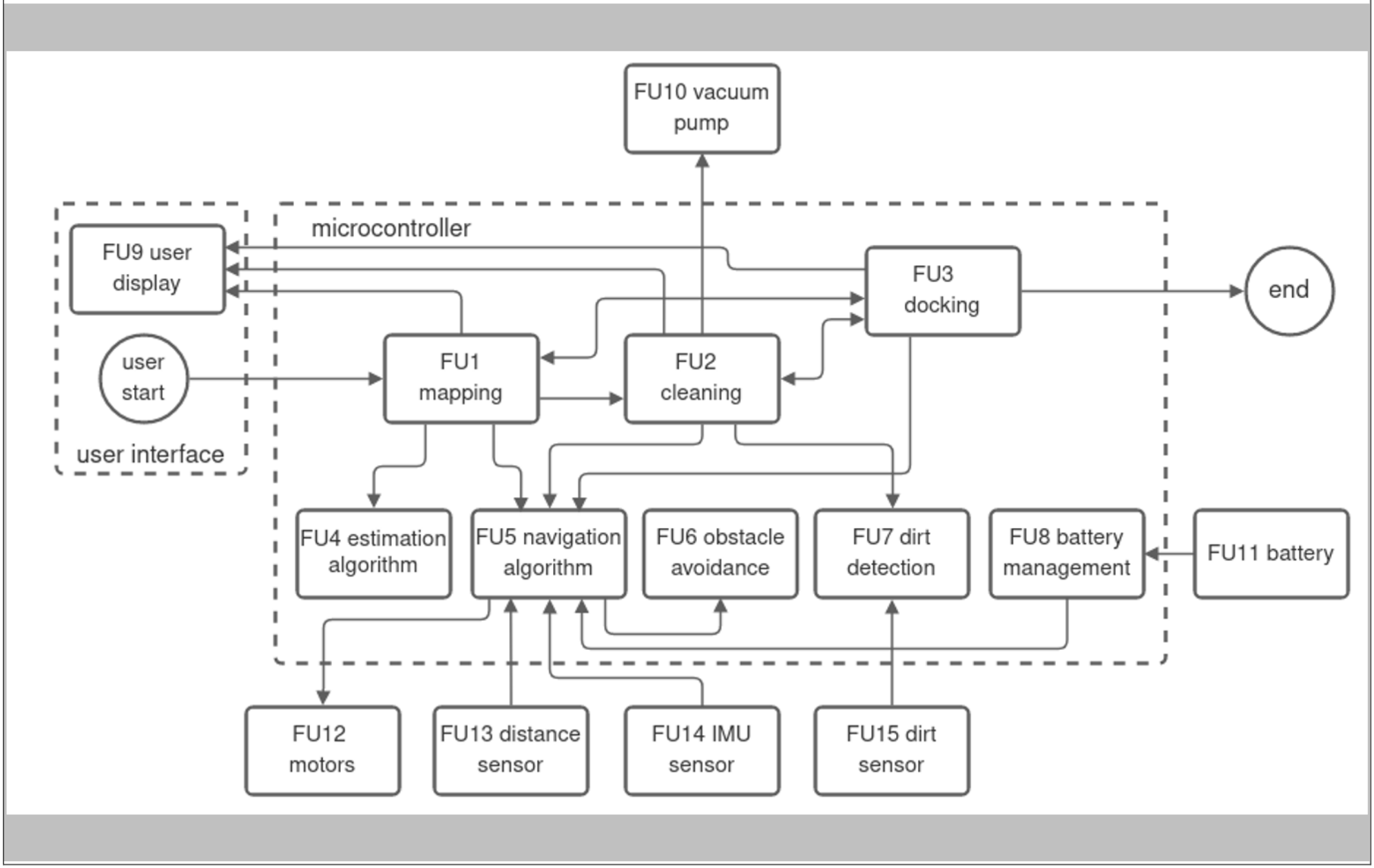
3.1 Functional description

Describe the design in terms of system functions as shown on the functional block diagram in section 3.2. This description should be in narrative format.

The robot starts by first mapping the available floor space (FU1). This state uses the navigation algorithm (FU5) to move around and when it finishes uses the measured floor space to estimate the time required to clean the area (FU4) and displays both the measured space and the estimated time on the display (FU9). The robot then proceeds to cleaning (FU2), which involves driving the vacuum pump (FU10), navigating the area (FU5) and detecting the dirt (FU7), as well as displaying its progress on the display (FU9). After cleaning is complete, or during mapping or cleaning if the battery level is too low, the robot will initiate the docking sequence (FU3) after navigating to the power source (FU5). If the robot is finished, it will remain docked at power, otherwise it will continue the current task when its battery is recharged. The battery level and percentage cleaned is also displayed on the user display (FU9).

The navigation algorithm (FU5) takes as input the current distance to the nearest object from the distance sensors (FU13), the acceleration from the IMU sensor (FU14) and the battery level from the battery management unit (FU8), which it measures from the battery power level (FU11). The algorithm then guides the robot through the room by driving the motors (FU12) and calling the obstacle avoidance algorithm (FU6) to avoid colliding with objects. The dirt detection algorithm (FU7) takes as input the dirt level from the dirt sensor (FU15) to determine how thorough the robot should clean a given area.

3.2 Functional block diagram



4. System requirements and specifications

These are the core requirements of the system or product (the mission-critical requirements) in table format IN ORDER OF IMPORTANCE. Requirement 1 is the most fundamental requirement.

	Requirement 1: the fundamental functional and performance requirement	**Requirement 2**	**Requirement 3**
1. Core mission requirements of the system or product. Focus on requirements that are core to solving the engineering problem. These will reflect the solution to the problem.	Autonomous navigation in an area: the robot should be able to navigate a known area thoroughly and completely.	Autonomous 2D mapping of an area: the robot should be able to map an unknown area accurately.	Obstacle avoidance: the robot should not bump into objects, but rather navigate around them intelligently.
2. What is the target specification (in *measurable* terms) to be met in order to achieve this requirement?	The robot should cover at least 95% of the mapped floor space while cleaning.	The robot should map the specified area with a 10cm^2 tolerance in two dimensions. It should map an area smaller than 20m^2 completely to within 10cm^2 tolerance.	The robot should not collide with static objects, stopping at least 1cm before the object and going around it.
3. Motivation: *how* or *why* will meeting the specification given in point 2 above *solve the problem*? (Motivate the *specific* target specification selected)	The robot can only clean where it walks, thus in order to clean properly everywhere, it needs to go everywhere. why 95%?	Mapping an area before cleaning will allow the robot to know the bounds of the specified room, calculate the best cleaning route and give an estimate of its workload, which will enable it to clean the floor more efficiently. where do the numbers come from?	The robot can injure itself or others if charging into objects. It can also get stuck in loose clothes, which would render it unable to clean the floor. Where does 1 cm come from?
4. How will you demonstrate at the examination that this requirement (point 1 above) and specification (point 2 above) has been met?	100 rice grains will be scattered evenly over a known floor area and allow the robot to clean. It should clean at least 95 of the grains, thus there should be 5 or less remaining grains when it is finished.	Place the robot in an unknown space no greater than 20m^2. The robot should map the area and give its size, which should be accurate to 10cm^2.	Place one or more static objects in the room, the robot should navigate around it without bumping into any of them.
5. Your own design contribution: what are the aspects that *you will design and implement yourself* to meet the requirement in point 2? If none, *remove this requirement.*	navigation algorithm, sensor data processing, spatial sensing and motor control system.	mapping algorithm, sensor data processing, user interface, spatial sensing and motor control system.	sensor data processing, object collision algorithm, spatial sensing and motor control system
6. What are the aspects to be taken off the shelf to meet this requirement? If none, indicate "none"	microcontroller, distance sensor, DC motors, wheels.	microcontroller, output display, distance sensor, DC motors, wheels.	microcontroller, distance sensor, DC motors, wheels.

these are good for a commercial product, but may be scaled down for Project

The core focus will be requirements 1 to 3

System requirements and specifications page 2

	Requirement 4	Requirement 5	Requirement 6
1. Core mission requirements of the system or product. Focus on requirements that are core to solving the engineering problem. These will reflect the solution to the problem.	Dirt detection and removal: the robot should clean more or less thoroughly depending on the amount of dirt present at the current location.	Autonomous power management: the robot should return to docking station when necessary and never run out of power.	User feedback: the robot should estimate its cleaning time accurately.
2. What is the target specification (in *measurable* terms) to be met in order to achieve this requirement?	The robot should be able to clean three different levels of dirty, which is measured in the amount of rice grains spread over 10cm^2. The robot should clean at least 90% of the rice without wasting time (continue cleaning when it is already clean).	The robot be should aware of its power levels and return to the station when battery falls below 20%. It should dock itself to the charge port before battery falls below 5%.	After mapping the room the robot should estimate the cleaning time accurately to within 5 minutes, taking in consideration the size of the room, dirt level at samples and obstacles present. It should also display what it is busy doing (cleaning, mapping, returning to dock) visibly for the user.
3. Motivation: *how* or *why* will meeting the specification given in point 2 above *solve the problem*? (Motivate the *specific* target specification selected)	The robot needs to clean the floor thorougly and efficiently. It should not waste energy by overcleaning a relatively spotless floor and it should also not miss dirt in a particularly dirty environment. An adaptive system would meet the goal the best.	If the robot fails to charge itself before its power runs out it will need human assistance, which prohibits the robot from being a fully autonous device.	Accurate feedback and estimation on its tasks allows the user to do other things while the robot is cleaning and add cleaning to the weekly planner.
4. How will you demonstrate at the examination that this requirement (point 1 above) and specification (point 2 above) has been met?	Demarcate three 10cm^2 areas. Add 1 teaspoon of rice to Area 1, 1 tablespoon to Area 2 and 3 tablespoons to Area 3. The robot should spend more time in each successive area. Afterwards collect remaining grains, which should be less than 1 full teaspoon.	The robot should start cleaning with 30% battery capacity. At 20% power it should return to the power source and dock before it has 5% power remaining.	The robot will map an unknown space no greater than 20m^2, and then give an estimation of the cleaning time. A timer will run during the subsequent cleaning operation. Afterwards the difference should be no more than 5 minutes.
5. Your own design contribution: what are the aspects that *you will design and implement yourself* to meet the requirement in point 2? If none, *remove this requirement.*	dirt detection algorithm, navigation algorithm, sensor data processing, motor control system.	power management algorithm, navigation algorithm, battery input data processing, power source docking station .	mapping algorithm, navigation algorithm, estimation algorithm, user interface, spatial sensing.
6. What are the aspects to be taken off the shelf to meet this requirement? If none, indicate "none"	microcontroller, dirt detection sensor hardware, DC motors, wheels.	microcontroller, battery, output display, DC motors, wheels, power source (wall plug).	microcontroller, output display, timer, LEDs.

System requirements and specifications page 3

same comments as for Req 4 to 6

	Requirement 7	Requirement 8	Requirement 9
1. Core mission requirements of the system or product. Focus on requirements that are core to solving the engineering problem. These will reflect the solution to the problem.	Mission focus: the robot should not leave the current room during cleaning nor fall down stairs.		
2. What is the target specification (in *measurable* terms) to be met in order to achieve this requirement?	The robot should stop at least 1cm before stairs or similar altitude drops, during a cleaning operation it should not exit the room via a doorway.		
3. Motivation: *how* or *why* will meeting the specification given in point 2 above *solve the problem*? (Motivate the *specific* target specification selected)	If the robot falls from a height it might get damaged or break apart, and not be able to continue cleaning. If it leaves the assigned room it might continue cleaning, but not where the user wants it to, thus not fulfilling the mission.		
4. How will you demonstrate at the examination that this requirement (point 1 above) and specification (point 2 above) has been met?	Put the robot on a table and watch that it does not come closer than 1cm to the edge with its wheels when cleaning. Clean in a room with a door that the robot should not go into.		
5. Your own design contribution: what are the aspects that *you will design and implement yourself* to meet the requirement in point 2? If none, *remove this requirement.*	mapping algorithm, navigation algorithm, sensor data processing, spatial sensing and motor control system.		
6. What are the aspects to be taken off the shelf to meet this requirement? If none, indicate "none"	microcontroller, distance sensor, DC motors, wheels.		

System requirements and specifications page 4

	Requirement 10	Requirement 11	Requirement 12
1. Core mission requirements of the system or product. Focus on requirements that are core to solving the engineering problem. These will reflect the solution to the problem.			
2. What is the target specification (in *measurable* terms) to be met in order to achieve this requirement?			
3. Motivation: *how* or *why* will meeting the specification given in point 2 above *solve the problem*? (Motivate the *specific* target specification selected)			
4. How will you demonstrate at the examination that this requirement (point 1 above) and specification (point 2 above) has been met?			
5. Your own design contribution: what are the aspects that *you will design and implement yourself* to meet the requirement in point 2? If none, *remove this requirement.*			
6. What are the aspects to be taken off the shelf to meet this requirement? If none, indicate "none"			

5. Field conditions

These are the REAL WORLD CONDITIONS under which your project has to work and has to be demonstrated.

	Field condition 1	Field condition 2	Field condition 3
Field condition requirement. In which field conditions does the system have to operate? Indicate the one, two or three most important field conditions.	The robot should operate indoors on a relatively flat surface.	The robot should be able to operate in rooms with static obstacles.	
Field condition specification. What is the specification (in measurable terms) for this field condition?	The floor should not have sharp steps or troughs having a sudden incline of more than 8 mm - this also includes the incline to get onto a carpet.	There may be a mixture of static (motionless) objects, such as chairs, boxes and tables, but no more than 10 per room.	

6. Student tasks

6.1 Design and implementation tasks

List your primary design and implementation tasks in bullet list format (5-10 bullets). These are *not* product requirements, but *your* tasks.

- Design the hardware layout of the robot.
- Calculate the optimal amount and position of the distance and dirt sensors.
- Acquire hardware and build prototype.
- Build a docking station for the robot to draw power from.
- Design a navigation algorithm and iteratively improve it by testing on the prototype.
- Design a mapping algorithm and iteratively improve it by testing on the prototype.
- Design a docking algorithm and iteratively improve it by testing on the prototype.
- Add obstacle avoidance functionality to the robot.
- Add dirt dependent cleaning functionality to the robot.

You may not write in the imperative form

6.2 New knowledge to be acquired

Describe what the theoretical foundation to the project is, and which new knowledge you will acquire (beyond that covered in any other undergraduate modules).

- The student will need to learn about Lidar distance sensors and implementation.
- The student will need to learn how 2D space mapping and modelling works.
- The student will need to learn about image filtering used in the dirt detection techniques.
- The student will need to understand the control systems involved in navigating a robot with wheels.
- The student will need to learn about battery management and charging.