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Conceptual design of a Low-Cost Autonomous Mobile Robot for Competitive Citrus Farming in South Africa

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Abstract

Citrus farming in South Africa, has become extremely loop-sided in terms of economic opportunities. The statistics show that the wealthy large-scale farmers simultaneously control 100% of the international export market and 77.1% of the local market hence endangering the prospect of the low and medium-scale farmers. This research presents a novel, low-cost autonomous mobile robot (AMR) designed to support small and medium-scale citrus farmers in South Africa, enhancing their competitiveness in both local and international markets. Developed using GENESYS software for systems integration, the AMR offers real-time crop monitoring to aid phytosanitary regulations compliance, autonomous navigation with object avoidance, error alerts, GPS functionality, and auto-homing when battery levels drop to 30%. Additionally, it captures periodic snapshots of citrus crops for visual inspection and assists with proof of protocols for sustaining citrus and treating infected trees, hence increasing their credibility and accountability for export and local markets. The AMR represents a significant advancement in affordable smart technology for sustainable citrus farming.

Introduction

The South African citrus **$2 billion** farming industry, ranking 10th in production and 2nd in exports worldwide, faces a **chain of challenges**:

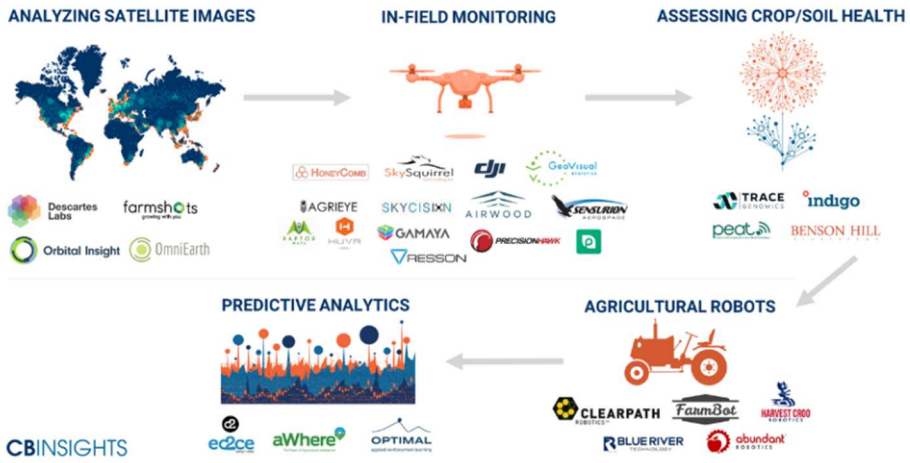
- **Large scale farmers market domination**
- Stringent international requirements and regulations
- Inconsistent weather patterns due to climate change
- Inadequate infrastructure boasted by a struggling economy
- **Pest infestations and ineffectiveness control of disease outbreaks (90% production and $3 billion loss in Florida [1])**

Saving grace: **New age technologies, IoT and AI.** Small to medium scale farmers are faced with numerous adoption constraints.

- High initial investment cost
- Lack of knowledge is and infrastructure
- High maintenance and repair costs
- South African farmers stubbornness paired with lack of proven field success

Developing a **low-cost AMR** that can **mitigate** the **challenges** through **minimising** the **constraint factors** is the **objective**, through utilising the **foundations of systems engineering design principles**.

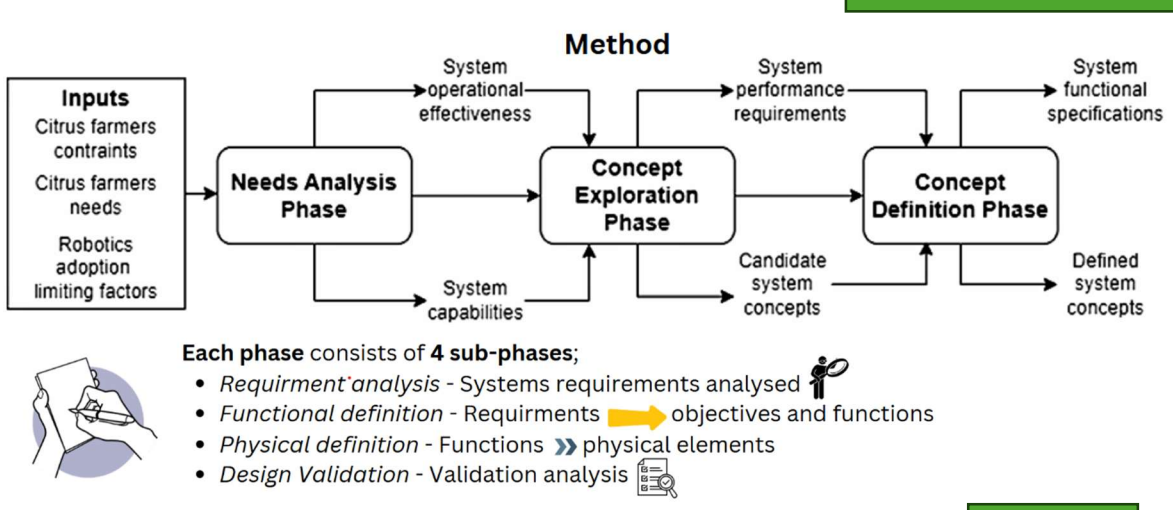
Systems engineering (SE) is a **multidisciplinary engineering** subject that focuses on the design, **integration**, and **management** of **various systems throughout their lifecycle.** It is widely used in agricultural design.



Question? How to apply SE to produce a more optimal and feasible robot design

Conceptual systems development process

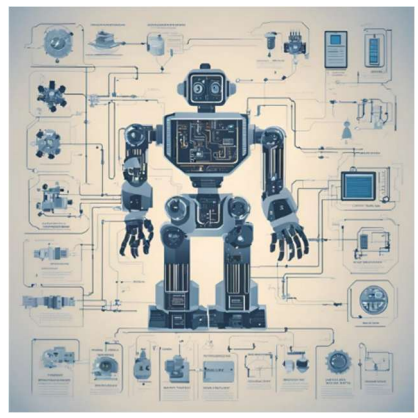
Research Methodology



Each phase consists of **4 sub-phases**;

- *Requirment analysis* - Systems requirements analysed
- *Functional definition* - Requirments → objectives and functions
- *Physical definition* - Functions » physical elements
- *Design Validation* - Validation analysis

Result



Functional block diagram - **describes** the **functions** and **interrelationships** of a **system**

Results

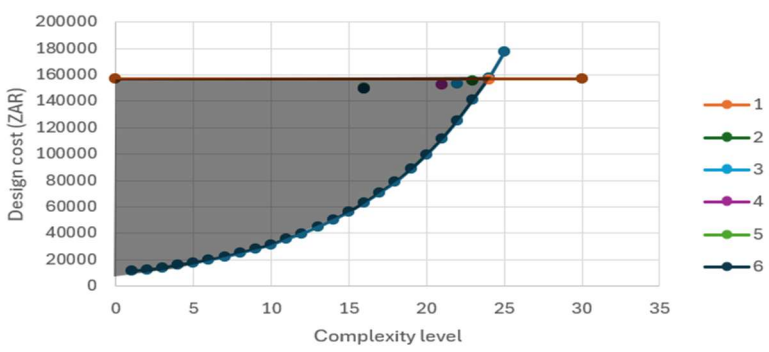
Final robot design candidates:

- Automated mobile robot (AMR) ✓
- Drone ✗

AMR design candidates:

1. Object avoidance capabilities
2. Object detection and avoidance capabilities

Result - Cost-effectiveness analysis for different exoskeleton design options (1-6)



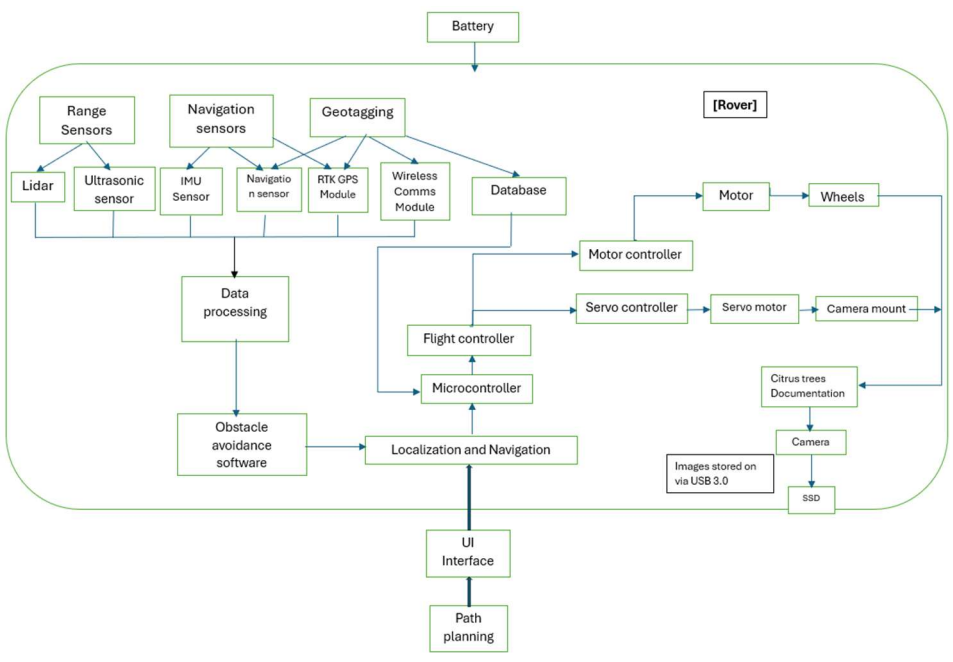
Result – Final AMR design option calculation

Price	Design option 1s Value (Xi + Yi)	Design Option 2s Value (Xi + Yi)
Normal Price	1.259	1.094
Normal Price + 5% markup	1.221	1.046
Normal Price + 10% markup	1.184	0.997
Normal Price + 15% markup	1.147	0.948
Normal Price + 20% markup	1.110	0.899
Total	**5.922**	**4.984**

Design Option 1: R116,499
Design Option 2: R153,499
< WTP: R157,122

AMR Design option 1 - Most optimal and feasible

Final Result – Functional block diagram of AMR



The design could be revolutionary for the South African citrus market

- **Economically viable** for all
- **Niche** market
- **New angle** of citrus **monitoring**
- **DOES NOT** increase **unemployment** rate
- **Adhering** to **requirements** (e.g. Local GAP/Global GAP) **easier**

References

[1] Raphael Morillon, B.H., Patrick Ollitrault, Virginie Ravigné. Plant disease could spell apocalypse for citrus fruits. 2024; Available from: https://theconversation.com/plant-disease-could-spell-apocalypse-for-citrus-fruits-236666.