Functional Hierarchy in Autonomous Robot

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Abstract

The process of design and manufacturing of the UX-1 concern with considering a variety of design requirements for the purpose of creating an autonomous explorer robot. However, due to restricted and harsh operating environment, the non-functional requirement such as space and weight highly determine overall design and operation of the system, and therefore the process of developing and building the robot comes with several trials and challenges. Hence the implemented FEM analysis demonstrates the optimize solution by considering the non-functional requirement which in turn directly effect on the design and properties of the robot.

Introduction

The process of design and development of autonomous robot interacts with numerous parameters that need to be fulfilled and evolve during the process of design. Although robots are designed and developed for the different purpose, some common grounds fundamentals need to be taken to account. Despite the fact that design requirements, general hierarchical decomposition has been the topic of system engineering in mechanical design, there have been few research (refer to [1] and [2]) in robotic due to interacting with complex systems. In following the main requirements of the UX-1 (refer to [3]) is categorized and it is described that how Non-Functional Requirement (NFR) parameters can effect on multiple functionalities of the system. Later general hierarchy for an autonomous robot is shown, while there could be an interaction between parameters at different levels or the same level.

Since the design of an autonomous underwater robot interacts with multiple disciplines, evaluating the requirement of the system [refer to 4] become complex. In this work, there are requirements which are not directly related to the technical design of the system. However, they affect to a high degree on the system indirectly. For instance, adaptability and portability in the context of robot operating environment (mines channels and tunnels) effect on the modeling and design of the robot. However, there is no unit or mathematical relation to measuring the effect exactly. But Analytic Hierarchy Process (AHP) is one method in order to evaluate and verify the design method

Requirement Categorization of the system

The following table demonstrates the NFR and FR parameters prior or during the development phase of the project.

Table 1: Requirements Specification

Functional Requirement	**Non-Functional requirement**
Speed 2km/h	End users (stake holders)
5 hours of operation	Pilot sites (internal stakeholder)
Operating depth of 500 m	Degree of freedom
Manoeuvre in vertical shafts and tunnels	Weight and volume (size)

One of the crucial non-functional requirement of the system is the vertical stability of the robot in the water, which can be derived directly from the buoyancy and weight of the robot. As the robot is completely buoyant, then the weight of robot would be maximum 107 kg. Therefore the difference between two parameters determine criteria which further can evaluate the operation of the robot. In our case, it is decided that robot must be completely buoyant and therefore the robot weight is exactly 107 kg.

General hierarchy decomposition of the system

The decompositions in this paper follow the general hierarchical decomposition. It should be noted that the robot includes multiple complex functions however for the purpose of decomposition one objective can include several functions. In brief, the main goal of the robot can be condensed to ‘Autonomous vehicle for extracting mineral information’ which would be on top of the hierarchy. Follwing, several concepts can be extracted from the former statement, which lead to several subsystems. Solely, by considering the mechanical aspect of the project, the main functionality of the system as an autonomous robot forms the main various level of hierarchy as maneuverability, structure, feedback, and power. Each layer can relate to another layer one way or both way.

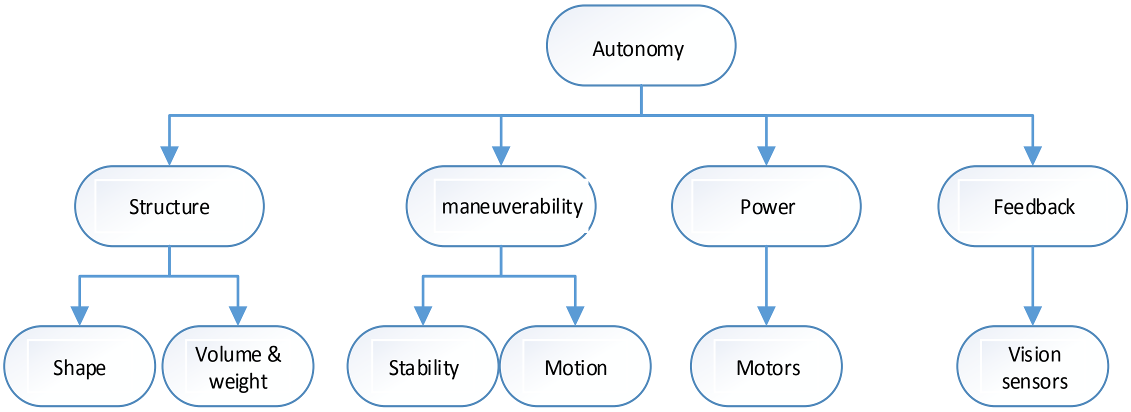

Figure 1: General Hierarchy Decomposition

The degree of freedom as functional requirement of the robot indicates the properties of the system. In this case heave, surge, heading, pitch, roll, and sway are the common degree of freedom for an underwater vehicles. The decomposition of maneuverability demonstrates the necessary degree of freedom which is horizontal and vertical motion (surge, heave), which can be operated independently (decoupled system), and therefore it demonstrates specific function of the system. On the other hand, degrees of freedom such as sway, roll, and pitch motion is not prioritized, and therefore they don't directly effect on accomplishing the goal of the project. Hence, the roll and sway motion is added into the system only after finding an optimized solution for thrusters configuration that supports maneuverability requirement (The functional analysis can determine the relation between sway and surge (or heave) motion that can be deliver as mathematic function. Indeed, further decomposition from feedback system, indicates that the robot must have pitch angle motion, which leads to the design of pendulum system.

Requirement and decomposition

Figure 2 demonstrates how the non-functional requirement of the system effect on the hierarchy. For instance, since the site entrance tunnel is limited, the maximum robot size is required as 60 cm in diameter and consequently it indirectly effect on volume and weight as two major functional parameters of the robot. These parameters determine the robot stability which is sub level hierarchy decomposition of maneuverability. Simultaneously, the volume can determine the shape of the robot which in turn is sub level hierarchy decomposition of the structure. On the other hand, the figure indicates the flow direction in which NFR can determine the sub-functions and not the other way around.

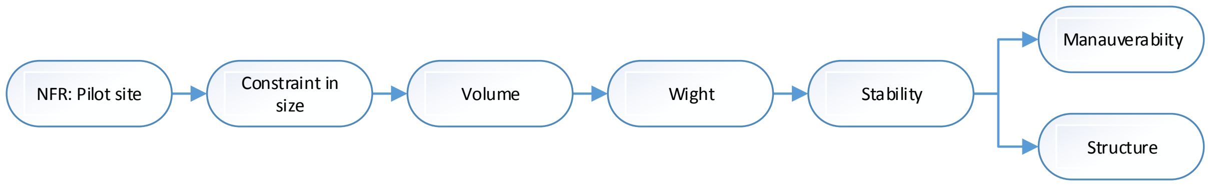

Figure 2: NFR to Hierarchy

Conclusion:

Since during the process of design, numerous parameters need to be taken to account, this paper aim to analyzed the requirements of the project in order to find the relationship between parameters. As future work AHP method can be applied to verify the final solution and design of the robot.

References

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