Modularity In Design

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Abstract

Modularity is the practice of introducing parts or modules that can be exchanged or rearranged for increased functionality of a product. Implementing modularity in a senior design project can simplify the mechanical, electrical, and software components and help achieve the goals of the project.

Introduction

Modularity is the amount to which a system's elements may be separated and joined. These elements and their components are interchangeable based on a number of criteria; including applications, time, and resources. Modularity in a senior design project is a powerful tool to combat problems that arise from a low budget, common in an undergraduate course.

In team Mahogany's senior design project, a black box system was designed to be attached to a vehicle in order to assist first responders after a dirty bomb or natural disaster. This system has a camera, thermal camera, a Geiger counter, and a GPS chip. A big concern during the design of this system was the payload weight of the unmanned aerial vehicle (UAV) utilized as the proof of concept. Since the UAV cannot support the weight of the total system, modular parts are used in the form of *clip-in* sensors or interchangeable cameras and modules. This increased the usability of the system by decreasing the weight but allowing for the same sensors to be attached. That way, the UAV is able to fly along the same path multiple times.

Software modularity was designed in to simplify system which are run by using Arduino software. With functions and modular programming, the UAV will be able to utilize the black box system in multiple ways, depending on the sensors attached. This project is just one example of the far-reaching benefits of incorporating mechanical, electrical, and software modularity in design.

Figure 1: Team Mahogany's 3DR Solo Drone collecting GPS and radiation data

Mechanical Modularity

Mechanical Modularity often involves the use of bettering mass production. Using the idea of strategic flexibility (the ability to predict changes and adapt to changes by rethinking current strategies) (Adamides 1), the addition of modularity in physical products in mass production will create an easier testing environment, as well as replace construct parts more easily (Kusiak 3). As products become more complicated and have more parts that work

together, modularity is important, since it can parse large objects and goals into smaller functions. Overall, the addition of modular components, which may cost more, since they have to accomplish a task themselves, outweighs the cost of time spent building, since building each component is much easier. For example, a SONY Walkman→, was created after mixing and matching over 160 different combinations of modular components that did set functions. In addition, SONY's video cameras were also created through a succession of trial and error with modular components.

An important concept in mechanical modularity is the balance of different elements that are implemented based on function. For example, in our senior design project, when different cameras needed implementation in a circuit, the balance of the system on it's mounting had to be taken into consideration. If the weight wasn't kept similar on both sides, the risk of making unsteady system was greater, where stability is crucial on a UAV. Another property to be taken into account is structural modularity of the system. If different cameras or sensors were used in the same circuit, connections had to be created between each of these modules that is the same, and can easily snap together for different functionality. This would go together well with modular software, that has different settings for whatever sensor is attached. Finally, cabling is another major concern when building mechanically modular parts. In order to allow for easily switching parts and modules, these connections had to be taken into account, and be able to manage the power delivered to each sensor.

Electrical Modularity
Speaking of power consumption, electrical modularity often requires the management of power between components, especially if different sensors are being applied to the same point in the circuit. For example, modular inverters, which are inverters that have adjustable resistances, can control AC motors and *clip-on* - physically snap onto and off of - a circuit (Modern Materials). In some drive systems that use multiple AC induction motors (conveyors or molding machines), different inverters are necessary to control the speed of the motors and the voltage each

motor produces. For example, up to 24 inverters can be placed next to one another in order to control the motor in different ways. These inverters can change an AC motor's voltage from 3 to 60 kV. Adding more inverters minimizes the space needed for the motor by up to 50%. In senior design, the challenge of a weight constraint is most important. When this constraint prevented the group from attaching all sensors and modules at once, electrical modularity techniques were utilized in order to control the power to each module when replaced in the circuitry. It enabled the ability to pilot the drone multiple times along the same circuit, but with different sensors. Since some sensors need 3.3 volts, and other sensors require 5 volts, power must be managed between the attachments. This led to success of the project, since managing power was crucial to attaching multiple sensors.
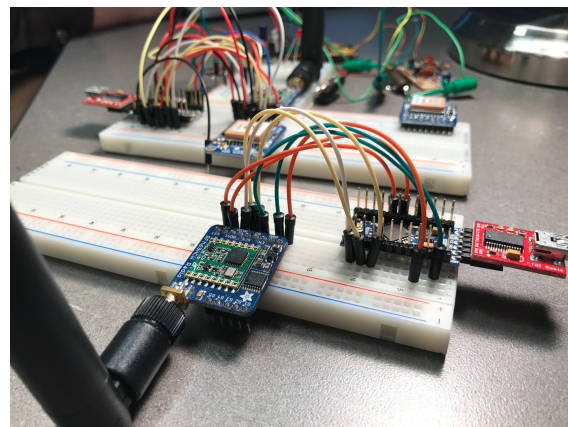
Figure 2: Picture of our transmitting and receiving circuitry, which utilizes both mechanical and electrical modularity through power management and structural similarity between sensors.

Software Modularity
Software Modularity implements functions throughout programs to minimize space and increase abstraction. Zanetti and Schweitzer have developed a method of software modularity and networks over a number of years (Zanetti 4). When implementing software modularity, they suggest changing your abstraction technique base on the language. Some languages allow for easier implementation of modular functions than others. In an object oriented language, such as Java, its quite easy to see how each component can accomplish it's function and be referenced in different places throughout the program.

However, it's often practice when implementing abstraction techniques to put the modular pieces in an order where they work closely together, rather than spreading the corresponding components throughout the code. That will minimize the storage used.

In a senior design project, functional modularity is incorporated by writing effective functions and software programs. A lot of modular software design depends on the style and preference of the programmer. There are specific criterion to follow when performing software modulation and abstraction. This criterion is called an Augmented Constraint Network (ACN). Depending on the variables (V), domains (D), and constraints (C), you can select a number of modules that will support both the number of variable, and the constraints set by each function the program is expected to perform (Cai 4). By allocating the minimum number of modular pieces to accomplish all functions necessary for success, functionality of each module increases, and testing each component is more comprehensive. By implementing these criterion, the necessary variables in order to accomplish the goals of our black box circuitry system are minimized.

Figure 3: Image of our user interface, which utilized multiple types of software modularity

Conclusion

Modularity is a powerful and useful tool in design. By implementing modular designs, one can change the functionality of their project as well as test their project easily and efficiently. In any senior design project, incorporating modularity can solve a multitude of existing constraints, especially with budget concerns. Whether adding a "clip-in" component in a physical design, or abstracting software design, modularity is the answer to limited payload or time frame.

References

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