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# TELEOPERATED MODULAR SNAKE ROBOT

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***Abstract:*** *Snake-like robots, technically termed as hyper-redundant robots, are, as their name suggests, elongated robotic devices that are designed to mimic their biological counterparts not only in shape but also in functionality. These types of robots are highly maneuverable, have a high mechanical redundancy, and are flexible. This allows such robots to easily maneuver through complex environments cluttered with many obstacles when compared to conventional robots. Generally, hyper-redundant robots are constructed by connecting several rigid links using joints.*

***Key words:****Modular, robot, maneuverability, hyper-redundant, NC manufacturing, product concept.*

## 1. INTRODUCTION

Robots are being used today to do the tasks that are deemed either too dirty, dangerous, difficult, repetitive or dull for humans. These refer mostly to industrial robots used in manufacturing lines. Other applications include toxic waste handling and cleanup, space exploration, mining, mine finding and also aids search and rescue teams. Manufacturing remains the primary market where robots are utilized. In particular, articulated robots, similar in motion capability to the human arm, are the most widely used for applications like welding, painting and machine loading.

## 2. DESIGN OF SNAKE ROBOTS

Designing a highly maneuverable and strong, yet compact, robotic joint is the main mechanical design challenge for constructing hyper-redundant robots.

Designing a three-dimensional hyper-redundant robot impacts several design choices for the robotic joint. At the very least, the robotic joint should be strong enough to produce high torque to counteract not only the static loads due the robot's own weight but also the dynamic loads produced by the robot's spatial motions. Moreover, since snake robots have a serial kinematic structure, any external load will be resisted by all joints throughout the snake robot as opposed to parallel kinematic structures where the external loads are divided among several limbs. This high strength requirement should not add to the joint's size and weight. Moreover, the joint should have high maneuverability to demonstrate complex motions. Finally, each of the joints should have a reasonable speed of motion.

In this paper you will find some of the steps taken in designing and developing a snake-like, teleoperated modular robot that can be used as follows:

1. assist search and rescue teams in locating people that are trapped under the debris of a collapsed structure or a highly cluttered area, like rubble ;
2. pipe inspection and repair - as it’s small cross section to length ratio allows it to move into, and maneuver through environments that tend to be long and thin ;
3. wildlife spotting - being able to integrate into the environment in the disguise of a snake ;
4. military reconnaissance - reducing the risk of human casualties to a minimum; ability to blend in a large variety of environments; has high speed and maneuverability;
5. as a play/entertainment robot.

Snake robots are of various shapes and sizes, from the three meters long, firefighting “snakebotto” a medical snakebot developed at Carnegie Mellon University that is thin enough to move around organs inside a human chest cavity without doing damage.

In 1995, Hirose developed a snake-like robot named Genbu that is characterized by having multi bodies connected by passive joints and multi active wheels of large diameter. One of the typical application of Genbu is Fire Fighting Robot as a water discharger pulling fire hoses (Fig.2). The robot is moved by hydraulic motor in the wheels using the pumps of fire engines.

**Fig.1.**_Application for Fire Fighting Robot driven by hydraulic power of the fire engine_

## 3. COMPETITIVE DESIGN ANDDE-VELOPMENT OF THE PRODUCT

**The first stage** in developing the new product is done by resolving the ViP (Vision in product design) (Fig.2.1.). The essence of this is to create the reason of existence of a future product by creating a context before designing it.

The process of ViP starts by selecting a set of factors (ideas, observations, principles, states, developments, beliefs, trends, obsessions) that form a context from which an appropriate product can be designed.

**The second stage** in developing the product is the market segmentation. A market segment is a sub-set of a market made up of people or organizations sharing with one or more characteristics that cause them to demand similar product and/or services based on qualities of those products such as price or function. By completing this stage, the final product obtained will be much more customer oriented and personalized. Also the VOCT (Voice Of The Customer) approach will be used here to gather information from a variety of potential clients and identify their expectations and needs of the product.

For the **next stage**, the TRIZ method is utilized, the data acquired so far will be sorted and organized. Also, the conflicts that might appear between the needs must be sorted out.

**Stage four** is ranking the needs. This can be done with the AHP method by comparing the inputs to one-another.

In **stage five,** three levels of the QFD (Quality Function Deployment) will be used to define the performance characteristics of the product and their qualities. The functions will be defined next and their connection to each other. And in QFD III, the modules and interfaces will be developed.

**Stage six** refers to the design of the product and the building of the prototype. When we have a physical robot to test on, improvements can be made if the need arises.

If these stages will be followed, the resulting product is easily and correctly developed.

## 4. DESIGNING THE SNAKE ROBOT

### 4.1. Designing the body of the robot

The prototype was built based on the information analyzed above, from light-weight materials, like polycarbonate Plexiglas that is used to create the housing of each module of the robot–like snake.

The bottom sides of the casing have the contours seen in Fig.3. These contours were cut from 4mm thick Plexiglas material using FAWOO 700-S CNC ENGRAVER.

As a first step, the 3D model of the robot’s housing was designed taking into account the user specifications and requirements mentioned in chapter 3.

For this, SolidWorks 2007 software was used. In the picture bellow you can see the outlines of the parts that need to be realized for the prototype.

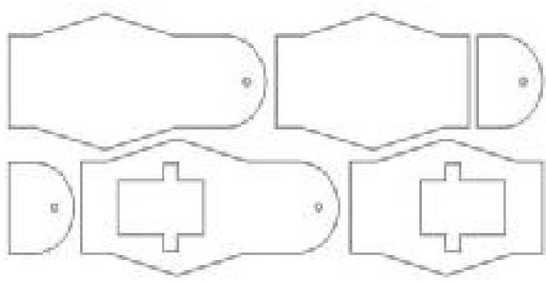


**Fig.2.**_Contour of the bottom sides for the snake-like robot_

These contours are then rebuild with the help of vector graphics using CorelDraw. Using ArtCAM Pro software, we can set the cutting process. In figure 3, we have the menu for toll dimensions and the process parameters:

- Cutting tool: end mill 3 mm;
- Tool step-over: 1.5 mm;
- Tool step-down: 0.5 mm;
- Feed rate: 400 mm/min;
- Plunge rate: 400 mm/min;
- Spindle speed: 8.000 rpm;

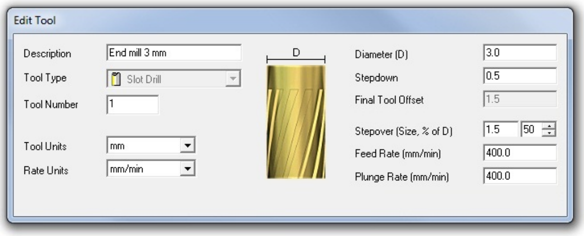



**Fig.3.***Machining parameters for the 3mm end mill;*

After the parameters are set, the CAM software generates the tool path necessary for guiding the tool. For this kind of machining the tool path is in 2.5 dimensions, as seen in fig.4

**Fig.4.***Generated tool path*

From here we export the tool path to the machine software. The work piece is fixed on the work table, and the machining can start. In figure 5 we have an overall view of the equipment and in figure 6 a close-up to the tool in process.

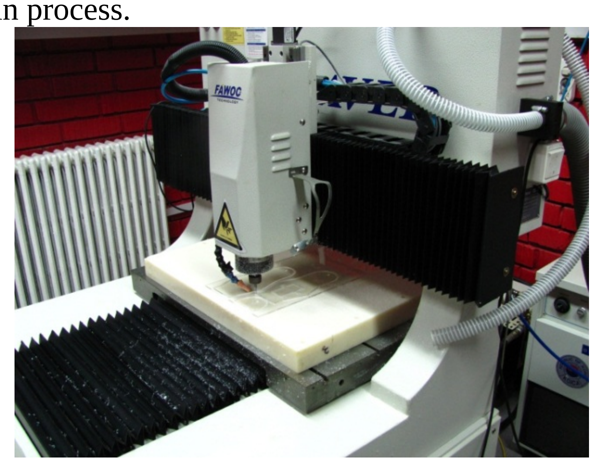


**Fig.5.***TheFawoo 700S-CNC equipment;*

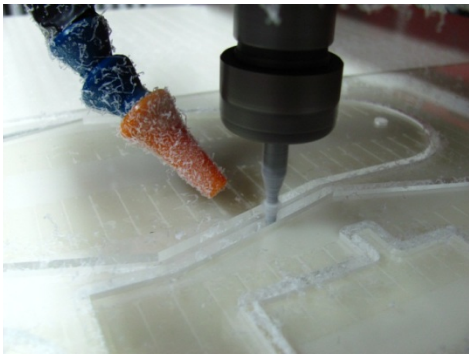
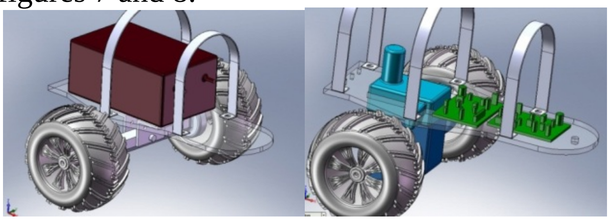


**Fig.6.***TheFawoo 700S-CNC equipment;*

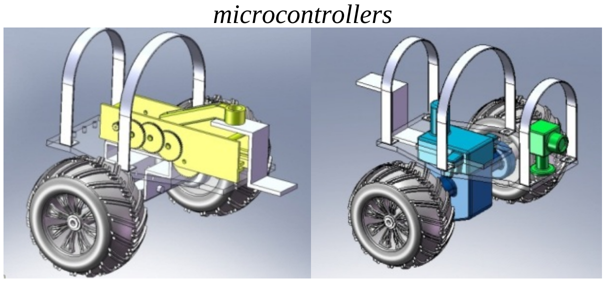
## 4.2. CAD Prototype Design

For the CAD design of the platform, SolidWorks was mainly used. Each individual module was designed and then assembled together. The individual modules can be seen in figures 7 and 8.



a. b.

**Fig 7.a.** *Module 4 – The accumulator,* **b.** *Module 3 – The microcontrollers*



a. b.

**Fig 8.a.** *Module 2 – the lifting mechanism,* **b.***Module 1- Audio and video recording*

## 4.3. Robot Mockup

Based on the steps presented so far, a mockup of the resulted concept was built. The mockup is presented in figure 9.

**Fig. 9.** Mockup of the concept

## 5. FINAL OBSERVATIONS

In this paper we went through the stages of designing and developing a snake-like teleoperated modular robot.

To get to this final stage, we had to follow some Competitive design and development techniques, we have successfully determined the client needs, prioritized them with the AHP method and extracted the importance of each one. As a result, we were able to use the first 3 phases of the QFD method and determined the correlation between the needs and the Critical To Quality characteristics; the CTQ's and the functions; and the functions and the modules.

The robot is constructed by chaining together a number of independent links. This makes it resistant to failure, because it can continue to operate even if parts of its body is damaged.

The 'head' of the robot snake is equipped with an IR camera. Microcontrollers are used tocontrol the 5 actuating DC motors placed throughout the body. The electronics and gear boxe ofeach module will be protected by a clear polycarbonate plexigalss housing.

The snake like structure is most useful in situations where its unique characteristics give it an advantage over its environment. The small cross-section to length ratio allows it to move into, and maneuver through environments that tend to be long and thin, like pipes or highly cluttered, like rubble.

This type of modular robot is a very good candidate to assist search and rescue teams or to be used for pipe inspection, as it is capable of operating on ruff terrain as well as on smooth surfaces.

If you want to add a little diversity to the range of applications, it can also be used for wildlife spotting or even in the military for reconnaissance.

## 6. ACKNOWLEDGEMENTS

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# ROBOT MODULAR TELEOPERAT DE TIP SARPE

***Abstract:*** *Robotii de tip sarpe, sau corect denumiti roboti giper-redundanti, sunt, dupa cum le spune si numele, dispozitive robotice lungi, care sunt proiectate sa imite corespondentii lor biologici, nu doar ca si forma, ci si ca functionalitate. Aceste tipuri de roboti sunt foarte manevrabili, poseda o redundanta mecanica marita si sunt flexibili. Acest lucru permite robotilor sa traverseze zone complexe cu multe obstacole. In general robotii hiper-redundanti sunt compusi din mai multe elemente rigide conectate prin legaturi.*

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