Design & Development of Robotic Vehicle using Origami Concept

Mohak Sharma[1] Md. Saif Ali[2] Bhushan Patil[3] Imteyaz Alam[4] Prof. S. R. Burkul[5]
[5]Guide
[1,2,3,4,5]D.Y. Patil College of Engineering Ambi, Pune, India

Abstract— Origami is the traditional Japanese art of paper folding. Due to its fascinating properties, several attempts are being actively made to expand applications of origami-inspired designs in engineering. This paper presents the design of a deformable wheel based on an origami structure that was integrated with a small-scale mobile robot. All segments of the structure are connected by links-i.e., folding lines-and this linked structure provides advantages in terms of maintaining geometry and force transmissibility. These two advantages enable control of the shape or size of the wheel by activating a certain portion of the structure. With this property, the wheel diameter of the robot is reduced from 11 cm to 4 cm by four SMA coil spring actuators. Two plate springs are embedded in the wheel to maintain stiffness and allow the wheel to recover from contraction. With the deformable wheel, the robot can pass through a 5 cm gap despite having an 11 cm wheel in its normal state. This deformable wheel concept can be used to build mobile robots that can move quickly with large wheels and move through small gaps when required.

Key words: Origami, Deformable Wheels

I. INTRODUCTION

Origami is the traditional Japanese art of paper folding. A paper can be folded into thousands of different three-dimensional shapes depending on the positions of the folding lines, order of folding, and way of the folding. This fascinating property has attracted many artists and mathematicians. Not only artists and mathematician, but engineers are also fascinated by these unique properties of origami and actively attempt to expand the application of origami designs in engineering.

A robot with a deformable wheel has the potential to overcome different types of obstacles, from narrow gaps to high steps. There have been studies about deformable wheel to achieve these advantages. The two important issues in deformable wheel design are building an effective wheel deforming mechanism and guaranteeing the stiffness in various states of the wheel. One approach that can provide a solution to these issues is to use origami concept.

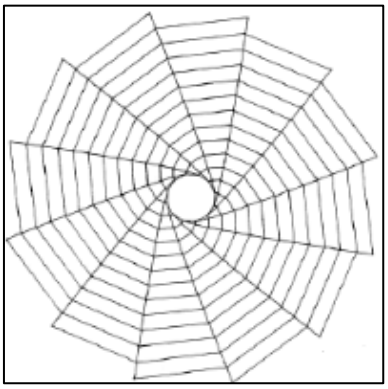


Fig. 1: Designed Folding Pattern When the Hub Has 12 Vertices

The wheel is built using paper reinforced with carbon fiber at the edges and two plate springs are embedded in the wheel to maintain stiffness and allow it to recover from contraction. Four SMA spring actuators are installed for contraction. The diameter of the wheel is 11 cm in its normal state and reduced to 4 cm when contracted. This deformable wheel concept can be used to build mobile robots that can move quickly with large wheels and move through small gaps when required.

II. LITERATURE REVIEW

1) P. H. Le, J. Molina, [1]

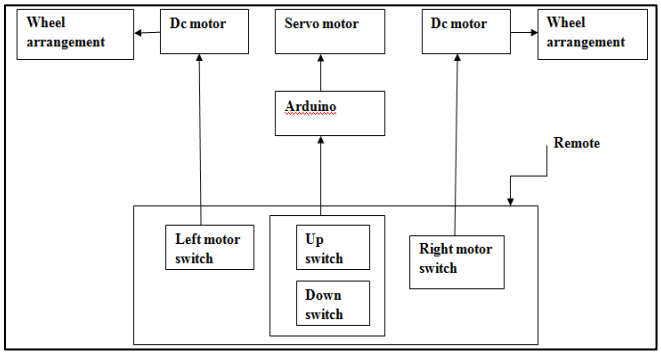
In this work, we propose the application of Japanese "Origami" art for a floating function of a small aerial vehicle such as a hexa rotor. A preliminary experiment was conducted using Origami magic balls mounted under a hexa rotor. This magic ball can expand and shrink using an air pump during free flying. Using this interesting and functional concept, it promises to reduce the resistance of wind as well as reduce the energy consumption when the Origami balls are deflated. This approach can be particularly useful in rescue emergency situations. Furthermore, there are many unexpected reasons that may cause the multi-rotor has to land on the surface of water due to problems with the communication between the aircraft and the ground station. In addition, a complementary experiment was designed to prove that the hexa rotor can fly maintaining the stability and also, takes off and lands on the surface of water using air balloons.

2) Gowtham Rajan R , Rajanish N [2]

The utilization of origami in materialistic engineering designs has fascinated engineers and researchers. The structural stability provided by the 3D origami design can be applicable as a wheel for the robot. The origami structure is used as a deformable wheel, which aids in increasing and decreasing the height of the robot. A special ball bearing and cable driven mechanism is used in deforming the wheel. A mobile robot with deformable origami wheel has been built and tested to show its ability to deform and maneuverability to overcome obstacles.

III. SYSTEM DESCRIPTION

A. *Working Diagram*



B. Wheel Design

1) Wheel Structure

This structure has two main advantages. First is the shape maintenance; all of the wheel segments are linked together and enable the structure to maintain a circular shape independent of whether it is folded or not. This is one of the main reasons why this structure was selected to be used as a wheel. Second is the force transmissibility and the stiffness maintenance. A wheel that supports the entire body of the robot usually encounters a stiffness problem. How much weight the wheels can endure is the main issue of the wheel, and it is even more important for deformable wheel which usually has a certain degree-of-freedom for deformation. Since the entire wheel structure is linked together, controlling the stiffness of every segment is not required. The wheel stiffness can be easily controlled by controlling a certain portion of the structure. This property also reduces the number of actuators: that is, an actuator is not needed in every segment to control the entire structure. This reduces complexity of the system and increases the power efficiency when changing the shape.

2) Actuation Mechanism

There are two main issues that should be considered for actuation; maintaining stiffness of the wheel at a certain shape, and actuation. With regard to the first issue, the wheel should bear the weight of all components such as electronics, batteries, and transmission. To maintain the desired shape under the loading condition, a component to maintain stiffness is required to prevent the wheel from unwanted deformation.

These two plate springs support and maintain the stiffness of the whole structure. The other issue is how to actuate the wheel. Actuators for wheel deformation require a large linear stroke. In addition, a light-weight and simple structure is required for embedment. We used SMA coil spring actuators to satisfy these requirements.

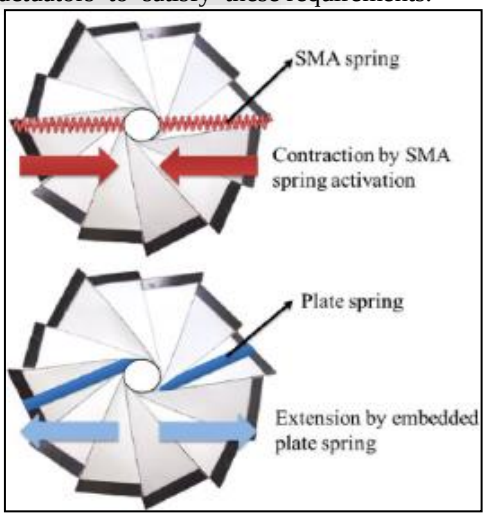


Fig. 2: Concept of The Wheel Actuation Mechanism

Contraction forces are generated by the SMA spring actuators and extension force are generated by the plate spring.

C. Components Description

1) Dc Motor

– Specification

100RPM 12V DC motors with Gearbox
6mm shaft diameter with internal hole
125gm weight
Stall Torque = 1.5kgcm torque
No-load current = 60 mA(Max), Load current = 300 mA(Max)

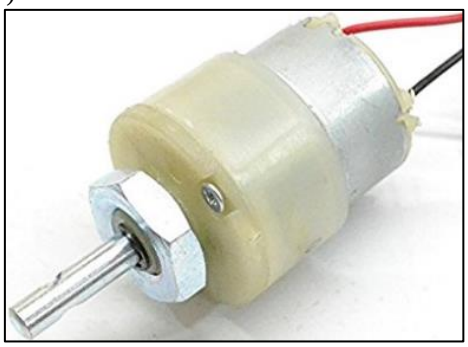


Fig. 3:

2) Servo Motor

– Specifications & Features

Operating Voltage:3.0-7.2 Volts
Operating Speed (4.8V no load): 0.10sec/60 degrees
Dimensions: 31 x 13 x 33 (LxWxH) mm.
Weight: 9 gm
Stall Torque: 1.2kg / 42.3oz(4.8V); 1.6 kg / 56.4oz (6.0V)
Temperature Range: -30 to +60 Degree C
Dead Band Width: 7usec
Gear type: POM gear set
All Nylon Gear
Connector Wire Length 150mm
Rotational Degree: 180 degree
Power Supply: Through External Adapter
servo wire length: 25 cm

Fig. 4:

3) Ardunio

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

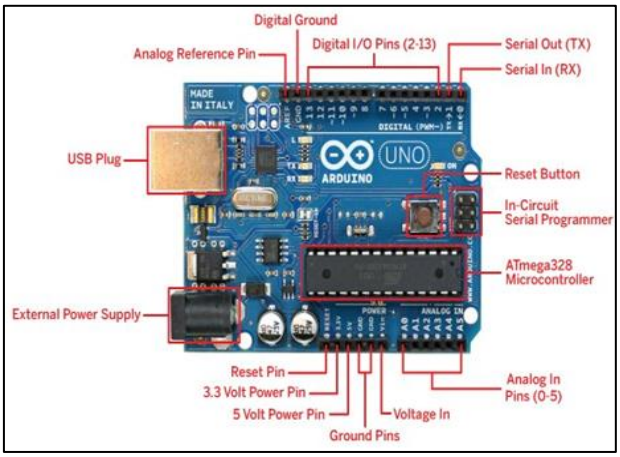


Fig. 5:

4) Calculation & CAD Model

Motor selection for wheels
Given
Diameter for shaft=7mm
Weight of assembly with frame is=2 kg
Torque required for motor
Torque=force*radius of wheel
=1*9.81*3.5
=68.67 Nmm
=0.06867 Nm
=0.6867kgcm
We are using two motors
So torque required for one motor is half of total torque=0.3433kgcm
Therefore we are selecting motor with 1.2kgcm torque.
Power output of DC motor is =voltage *current
=12*0.3
=3.6 watt
Power=2*pi*N*torque/60
3.6=2*pi*N*0.3433/60
N=100
We are selecting motor with 100rpm.

5) Cad Model

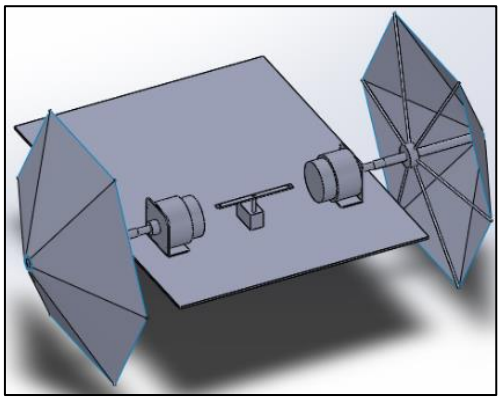


Fig. 6:

IV. ADVANTAGES & FUTURE SCOPE

A. Advantages

- The adjustable wheel diameter aids in better manoeuvr ability through different terrains.
- Suitable to work under hazardous environments, where other conventional methods cannot afford to risk.
- Provides a continuously varying speed transmission system by adjusting the wheels rather than manipulating the motor speed.
- Changeable height of the robot without any external mechanical modification.

B. Future Scope

- More rugged memory retaining fabrics can enhance the stability of the wheel.
- Thermal imaging camera can enable in identifying the victims more precisely.
- 3D printed body design will reduce the overall dimension of the robot.

V. CONCLUSION

Design and development of deformable wheeled robot based on an origami structure is successfully implemented. The origami structure is used to replace a conventional linked mechanical system with a simple one-layer origami structure. The wheel can deform with only two plate springs and four SMA coil spring actuators.

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