Embedded Systems Lab, CS-308 Project

Hexapod Locomotion

Group 17

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1. Introduction

Hexapod is a bot which has six legs like a spider and uses them in a coordinated fashion to aid its movement.

Hexapods are of a variety of use in these days. Whether it be simple dancing hexapods or as important as military rescue bots, hexapods are today very important.

The project aims at implementing functionality in **FirebirdV Hexapod** which can enable it to move fast, smooth and stable. FirebirdV Hexapod has 6 legs built on a Firebird bot, each leg containing 3 servo motors. So, in total, the bot has 18 degrees of freedom.

2. Problem Statement

The project aims at developing the following:

- Moving the hexapod fast and smoothly in all the directions.
- Turning the hexapod in both clockwise and anticlockwise direction.
- Controlling the locomotion with keyboard using ZigBee module for wireless communication.
- Implementing various gaits which are suited for different terrain and situations.

3. Requirements

A. Hardware Requirements
   a. FireBirdV Hexapod
   b. Zigbee: To control hexapod from the keyboard

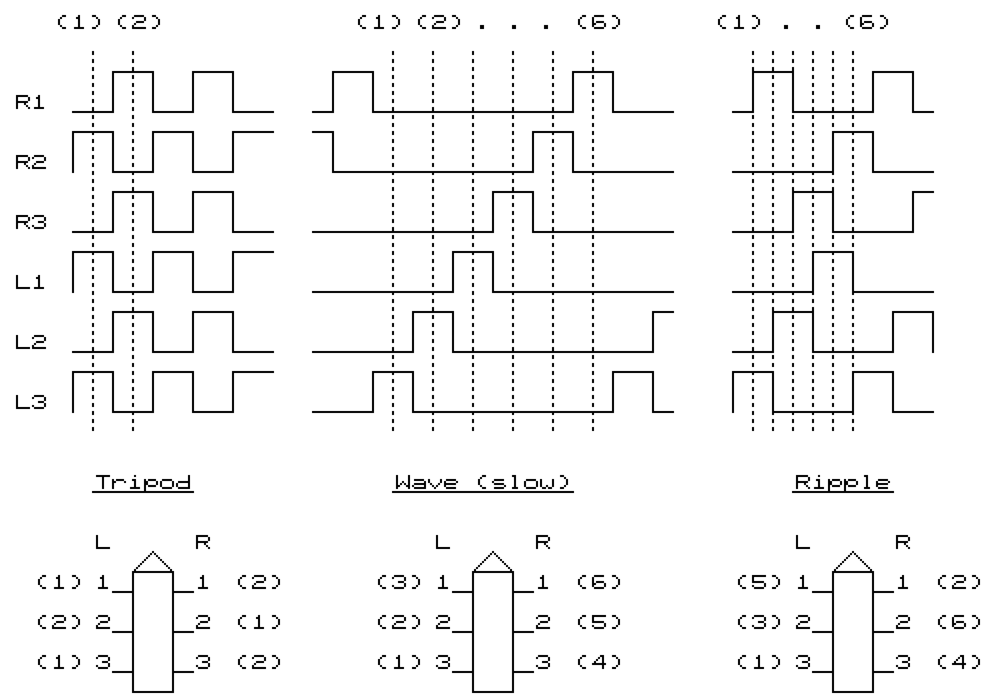
B. Software Requirements
    a. IAR Embedded Workbench: The environment in which the code is executed.
    b. X-CTU: To implement ZigBee communication.

4. Task Specification and Implementation

There are 3 major tasks handled

- **Motion:** There are 12 different directions of motion (6 corresponding to its 6 legs and the other 6 for movement in direction between two legs). Various gaits have been implemented for hexapod's motion which are briefly described as follows:

    1. Tripod Gait: If the legs of hexapod are numbered from 1 to 6, then legs 1, 3 and 5 form one tripod and legs 2, 4 and 6 form the other. During walking, hexapod uses its 2 tripods from one foot to the other. Stable state is reached after one complete cycle.
    2. Tripod Continuous Gait: This is like tripod gait given that it never reaches stable state while in motion i.e. when one tripod is moving forward, the other is preparing for it.
    3. Tripod Insect Gait: It is similar to how insects walk with three legs to the right and rest three to the left.
    4. Two Legged Gait: Two legs are moved at a time in this gait.
    5. Wave Gait: In the Wave Gait, all legs are moved forward in succession. This is then repeated on the other side.
    6. Ripple Gait: On each side a local wave comprising non-overlapping lift phases is being performed, and that the 2 opposite side waves are exactly 180 degrees out of phase with one another. For instance, if 1^{st}, 2^{nd}, 3^{rd} leg forms a wave, a wave 180 degrees out of phase is there on the 4^{th}, 5^{th} and 6^{th} leg.



- **Turning:** Hexapod can turn either clockwise or anticlockwise. Gaits implemented for turning are the following:
    1. Tripod Turn Gait: Uses three legs at a time to rotate and comes intermittently in stable state in each cycle.
    2. Tripod turn continuous: Turns similar to the above gait with the exception that it does not come to a stable state.
    3. Two legged turn: Uses two legs to turn.

- **Zigbee Communication:** Motion of the bot can be controlled by a keyboard through ZigBee module for wireless communication.

5. Testing of various gaits

Test criteria are the following:

- Speed (quantitative)
- Stability (qualitative)

- Smooth motion (qualitative)

Test description:

- Measured time taken to travel a fixed distance by the bot for various gaits.
- Measured the angular distance traveled for measuring rotational speed.
- Other criteria qualitatively judged from tests done.

The data collected from testing is shown in the following statistics.

Motion Gates:

Gait	Speed	Stability	Smoothness
Tripod (simple)	6.22 cm/s	Moderate	High
Tripod Continuous	10.02 cm/s	Low	Moderate
Tripod Insect	8.54 cm/s	Low	Moderate
Two Legged	3.96 cm/s	Moderate	Moderate
Wave	1.33 cm/s	High	Low
Ripple	1.88 cm/s	High	Low

Turning Gates:

Gait	Speed	Stability	Smoothness
Tripod (simple)	1 rotation in 8.6 s	High	High
Tripod Continuous	1 rotation in 5.2 s	Moderate	Moderate
Two legged	1 rotation in 9.5 s	High	Moderate

Stability increases with the number of legs supporting the bot during its motion.

Smoothness increases with simultaneous movements of servos in various legs.

6. System Description

a) What are worked as per plan?

I. Increasing the speed of hexapod: With Tripod continuous gate, a much greater increase in speed has been obtained mainly because of avoiding the useless stable state in the cycle of motion and preparing the other trio of legs for movement while one is doing its task.

II. Implementation of Gaits for movement of hexapod, both translational and rotational: Various gaits have been implemented as described above.

III. Wireless control: Using ZigBee, wireless communication via keyboard is facilitated.

b) What we added more than discussed in SRS?

I. Implementation of gaits which aid in the stability of motion: Gaits like wave and ripple have been implemented which increase the stability of the movement to a greater extent.

II. Making the turning of hexapod faster: There has not only an increase in translational speed but also in the rotational speed of the bot.

c) What was not done as promised in SRS?

I. RTOS framework: Code was initially decided to be executed in RTOS framework but the unavailability of resources and inability to write ISRs (Interrupt Servicing Routines) in RTOS properly has hampered our plan to export the code in RTOS framework. The entire code of hexapod movement works on the principle of timer interrupts and there is a lot of difficulty in dealing with them in RTOS.

7. Challenges faced and their solutions

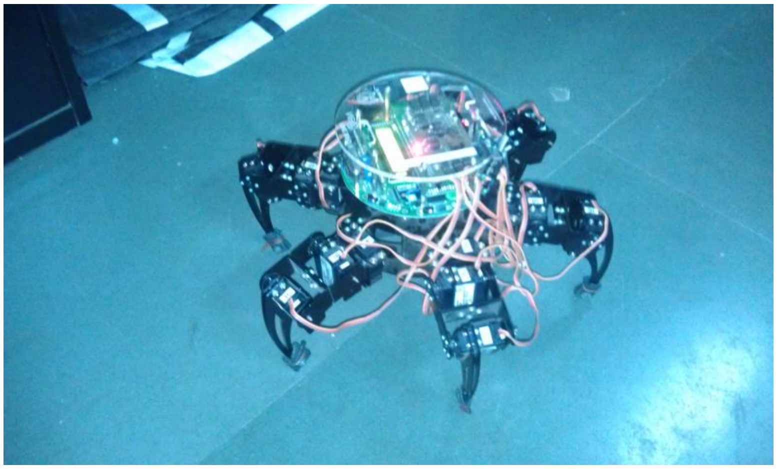
- Motion both fast and stable
  - Developing coordination between 18 servos: This was handled by implementing various gaits for movement of hexapod.
  - Slow movement of hexapod: By varying the time delay and angular extremities of servos, we were able to achieve greater speed.
  - Instability in hexapod movement: This was handled by using specific gaits like ripple and wave.

- Rotation both fast and smooth
  - Slow rotation speed: We used variations of tripod gait to increase the rotational speed.
  - Collision of neighboring legs: We carefully studied the motion of servos and decided on the angular motion to be imparted.

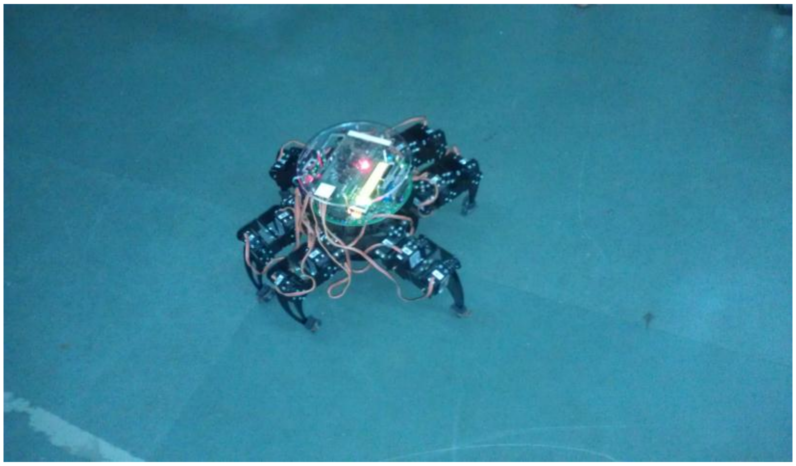
- Zigbee, a user friendly interface
  - Incapability of calling movement modules from ISR for Zigbee communication: Since all movement modules work using timer interrupts, calling them from the ISR for Zigbee communication stops their execution. To handle this, we defined different modes corresponding to different states of hexapod. These modes could be changed by the user through keyboard and communicated via Zigbee module.

- RTOS, a multi-tasking and parallel processing environment
  - Non-working ISRs in RTOS: Due to unavailability of resources, we were unable to define ISRs in RTOS which made the code non-functional.

8. Snapshots



Hexapod in its calibrated (ready) state



Hexapod in its movement state

9. Future Modifications

- Possible extensions
  - Implementation in RTOS to aid multi-tasking
  - Obstacle avoidance
  - White line follower

- There are a lot of applications of hexapod which involve its speedy and sturdy motion. Using our modules (which are well documented, divided and written so as to reduce hardware dependence), user can select the type of motion he wants. For example
  - All terrain bot.
  - Military hexapods for unmanned missions.

10. Conclusion

So, we have developed many forms of motion a hexapod can have which have different metrics in terms of speed and stability.

Also, the code we have written is divided into functions and modules which can be taken by a future group to develop further on it. The code is written to aid its movement to other hardware because besides the basic functions, no other functions are based on hardware specifications.

11. References

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