Wireless Underwater Mobile Robot System Based on ZigBee

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***Abstract*— In this paper, a wireless underwater mobile robot system is designed in order to study the behavior of Artemia group. A new idea has been presented for underwater mobile robot system which is consists of two parts, first is the underwater mechanical robot and the second is ZigBee wireless based mobile robot which controls and moves the first part. By this system different patterns motion control (Linear, Circular, Zigzag, etc.) has been performed and proved the ability to control group of robot by controlling the group of Artemia.**

Keywords-component (Robotics, ZigBee, Artemia Motion)

I. INTRODUCTION

Understanding and modeling the relative mechanisms and operational principles of collective behavior of animals have been a source of inspiration for multi-agent control strategies based on decentralized algorithms. The study of flocking may therefore provide useful ideas for developing formation control, distributed cooperative control and coordination of multiple mobile autonomous agents/robots [1].

Artemia Salina is a crustacean smaller than insects in size and mass. The hatched Artemia is called nauplius, has a length typically less than 0.4 mm and shows an anatomical structure different than that of adult Artemia. The nauplius has only one eye, containing a photo receptor, and uses a pair of antennae as fins for swimming as shown in Fig. 1 [2]. Collective behavior of Artemia is good model for the development of useful distributed control systems (DCS) for robot applications [3].

Figure 1. A photo of a nauplius.

The direction of Artemia motion is highly sensitive to intensity of light especially the short waves of light [3]. Wireless control based on spot of light which is moved by underwater mobile robot system will be achieve in order to populate Artemia. Artemia is widely affected by internal draughts which generated by swimming robot because Artemia is small in size and has weak motion torque. The challenge of internal draughts has been solved by using small size underwater robot which consists of mechanical parts only. Wireless micro swimming robot which is controlled by the magnetic field is more close to natural and free state, in which it is more convenient to study biomimetic swimming principle. In the meantime, being characterized with high reliability and safety, it could reach deep cavern by the medium of body fluid inside organism with flexibility, thus micro swimming robot, as a new important approach on therapy in term of interposition, has a widespread prospect in the field of biosystems engineering [4].

In this paper, a new idea for underwater mobile robot system which consists of two parts has been presented, first is the underwater mechanical robot and the second is ZigBee wireless based mobile robot which controls and moves the first part. By this work three types of wireless control has been achieved, first, the Artemia motion control by light [3], second wireless control using magnetic field for underwater mechanical robot, and the third is wireless sensor (ZigBee standard) based mobile robot as shown in Fig.2.

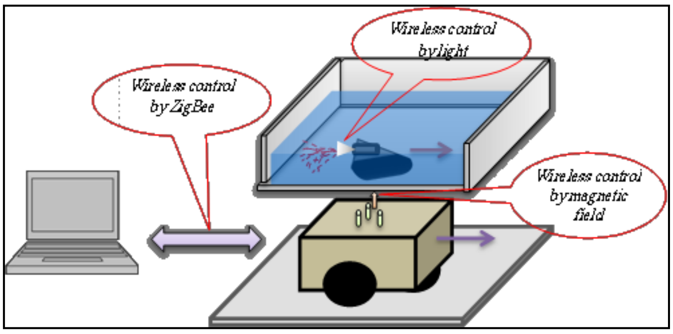


Figure 2: Underwater robot system.

II. MOBILE ROBOT MOTION CONTROL

In two-wheeled mobile robot control, many motion control design methods [5-10] are proposed in order to move efficiently in a two-dimensional space. One motion control problem of two-wheeled mobile robot is how to communicate with mobile robot through personal computer (PC) in order to control the motion of mobile robot.

In this paper, a design of two-wheeled mobile robot controlled by PC through ZigBee standard based wireless sensor network is suggested. A two-wheeled mobile robot is considered and its structure is described in Fig. 3 [11], where X-Y is the global coordinates and x_m-y_m is the local coordinates which is fixed to the robot with its center p as the origin.

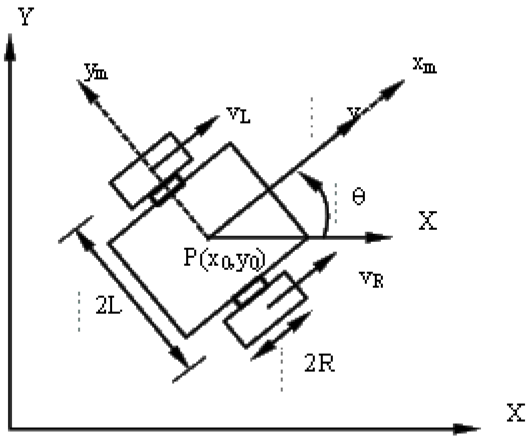


Figure 3: Schematic diagram of a two-wheeled robot for the motion control.

The mobile robot body is of symmetric shape and the center of mass is at the geometric center p of the body. R is the radius of the wheel and L is the displacement from the center of robot to the center of wheel. The set (x0, y0) represents the position of the geometric center p in the world X-Y coordinates, and the angle θ indicates the orientation of the robot.

The two fixed wheels are controlled independently by two motors. The direction of mobile robot depending on velocity of each motor since the formation of different patterns (linear, circular, zigzag, etc.) depend on the variation of the velocity of each robot wheel.

According to the schematic design of the two-wheeled mobile robot indicated in Fig. 3, its kinetic equation can be described by

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v \\ w \end{bmatrix} \quad (1)$$

where $\dot{x}$ and $\dot{y}$ denote the velocity of the robot in the direction of X-axis and Y-axis, respectively. v denotes the linear velocity of the robot in the head direction of the robot and $\dot{\theta}$=w denotes the rotational angle velocity of the robot. The robot's motion controlled by its velocity v and angular velocity w, which are function of time.

Two wheels are fixed in mobile robot and each wheel is controlled independently by each motor, so the forward velocity of the robot and the wheel angular velocity are described by

$$\begin{bmatrix} v \\ w \end{bmatrix} = \begin{bmatrix} \frac{1}{2} & \frac{1}{2} \\ \frac{-1}{2L} & \frac{1}{2L} \end{bmatrix} \begin{bmatrix} v_L \\ v_R \end{bmatrix} \quad (2)$$

where L is the displacement from the center of robot to the center of wheel. v_L =Rw_L and v_R = Rw_R are the linear velocities of the left wheel and right wheel, respectively. R is the radius of the wheel and w_L and w_R are angle velocities of the left wheel and right wheel, respectively. Based on equations (1) and (2), we can obtain the following equation:

$$\begin{bmatrix} v_L \\ v_R \end{bmatrix} = \begin{bmatrix} cos\theta & sin\theta & L \\ -cos\theta & -sin\theta & L \end{bmatrix} \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} \quad (3)$$

The velocity and direction of rotation of wheel motor is controlled by pulse width modulation (PWM) which is generated by the main board of mobile robot. Mobile robot receives PWM parameters from PC through ZigBee wireless network as indicated in Fig. 4.

III. MOBILE ROBOT MAIN BOARD

Robot main board is the brain of mobile robot which receives the motion pattern parameters from PC through ZigBee wireless connection and processes these parameters to perform pattern motion control. The main part in the robot main board is AVR ATmega162 microcontroller which generates two PWM signals for each wheel motor.

The two active wheels of the robot are actuated by two independent servo motors modified for continuous rotation. In particular, we used ZS-F135 sub-micro servo motors with the following specifications: speed 0.16 s/60° at 4.8 V; torque 1.2 kg cm at 4.8 V; weight 8 g, size 22.8 mm× 11.6 mm× 22.6 mm. The robot is powered by three 1.5 V batteries.

IV. ZIGBEE WIRELESS SENSOR NETWORK

ZigBee is a standard that defines a set of communication protocols for low-data-rate short-range wireless networking [12]. ZigBee-based wireless devices operate in 868 MHz, 915 MHz, and 2.4 GHz frequency bands. The maximum data rate is 250 K bits per second. ZigBee is targeted mainly for battery-powered applications where low data rate, low cost, and long battery life are main requirements.

The ZigBee standard is developed by the ZigBee Alliance [13], which has hundreds of member companies, from the semiconductor industry and software developers to original equipment manufacturers (OEMs) and installers. The ZigBee Alliance was formed in 2002 as a nonprofit organization open to everyone who wants to join. The ZigBee standard has adopted IEEE 802.15.4 as its Physical Layer (PHY) and Medium Access Control (MAC) protocols [14]. Therefore, a ZigBee-compliant device is compliant with the IEEE 802.15.4 standard as well. ZigBee wireless networking protocol layers are shown in Fig. 5. ZigBee protocol layers are based on the Open System Interconnect (OSI) basic reference model [15].

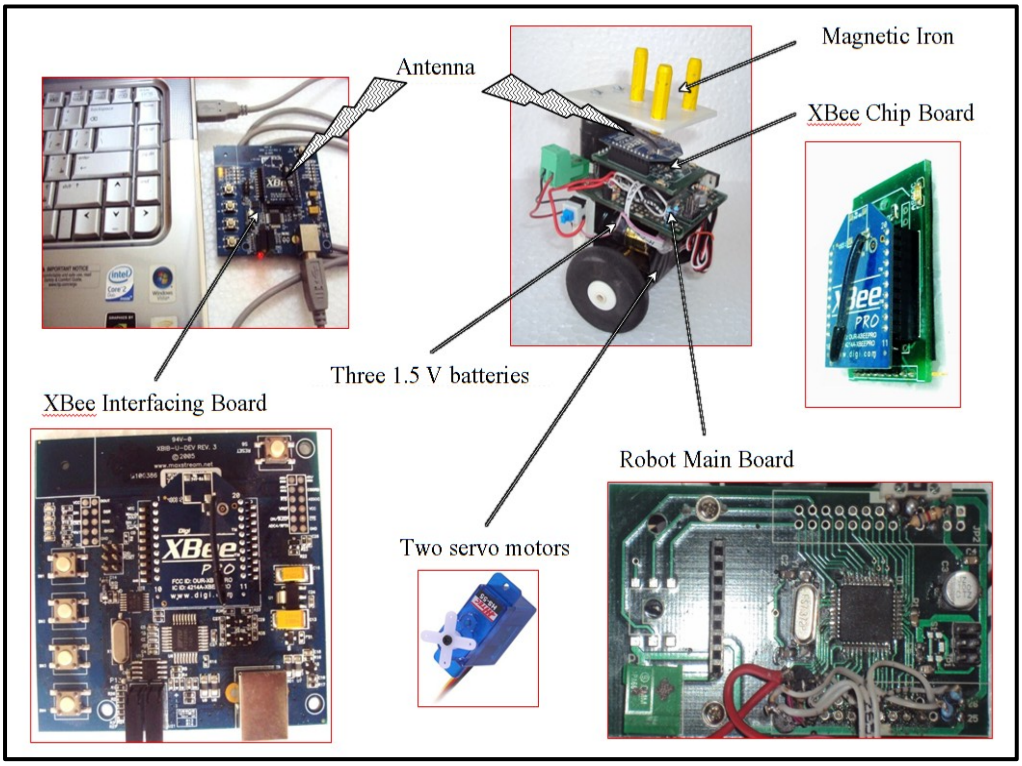


Figure 4: Circuit diagram of wireless based mobile robot.

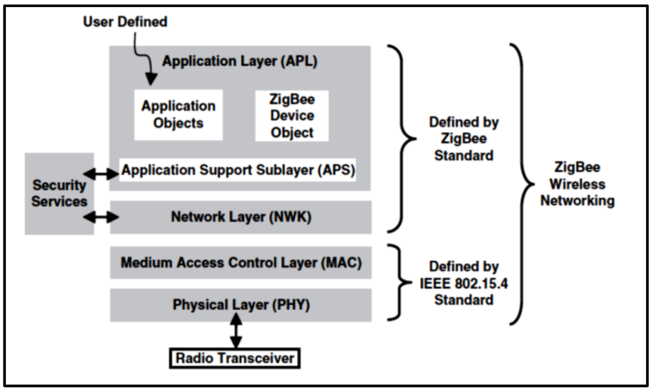


Figure 5: ZigBee Wireless Networking Protocol Layers.

XBee ZigBee/Mesh RF module has been used for support ZigBee wireless network. For the applications where robust mesh networking topologies are preferred, XBee ZigBee/mesh modules provide developers with both ZigBee mesh and the soon-to-be-released proprietary DigiMesh™ topologies [16]. These networks allow devices to harness the entire network of RF modules to effectively extend range beyond that of a single module, and create a more stable and reliable network. Employing dynamic self-healing, self-discovery functionality for reliable communications, XBee ZigBee/mesh RF modules make mesh networking simple and easy to deploy. The XBee module is very easy to use, and the interface is based on a simple dialogue with a serial port, which can be easily handled by a microcontroller or a PC as shown in Fig. 6.

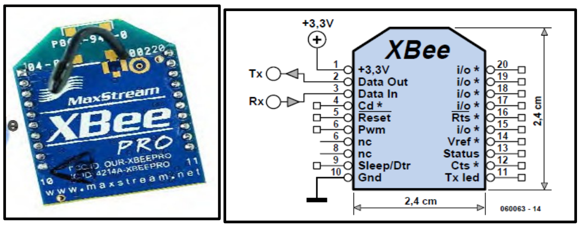


Figure 6: XBee ZigBee/Mesh RF module.

V. Underwater Mechanical Robot

Motion control of Artemia inside water needs wireless swim robot to form several types of fixed pattern (linear, zigzag, circular, etc.). This swim robot will be large compared with Artemia body size and the motion of this robot inside water make waves affected on the Artemia motion. To overcome the above difficulties, we need a very small size swimming robot or a micro robot (3 cm^3 or less) controlled by wireless sensor network. This is very complicated, so to solve this problem, a simple mobile robot has been designed. The suggested robot consists of three iron ball wheels which are moved by applying a magnetic field source from outside water as shown in Fig. 7.

The mobile robot shown in Fig. 4 contain three magnetic iron sticks fixed on the top of robot, each one of these magnetics attracted one of iron boll wheel of mechanical robot then the motion of mobile robot attracted exactly to the motion of mechanical robot by this way the motion of mechanical robot can be controlled by controlling the motion of mobile robot as shown in Fig. 2.

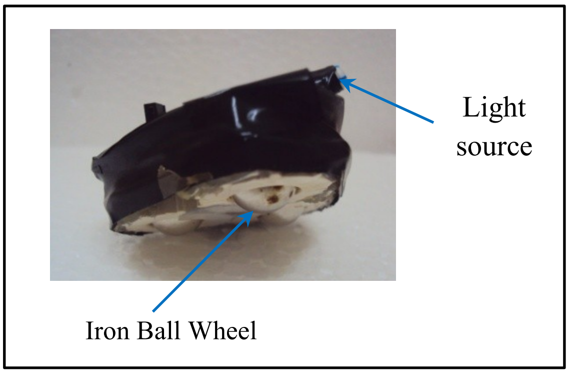


Figure 7: Underwater mechanical robot

VI. EXPERIMENTAL RESULTS

In experiments, wireless underwater robot system has been used in order to control the motion of Artemia population to form three types of motion patterns (liner, circular and zigzag). By these experiments, we proved Artemia group can be controlled to move in any direction based on sensing to movable light spot. Also information extracted from these experiments are a good source for deriving complete wireless control system for multi mobile robot system based on external guide.

Several videos have been recorded for Artemia group motion. To process Artemia videos, a moving objects detection algorithm has been used in order to extract data like position, and number of individuals in Artemia group. The video split into a sequence of images and each image has been converted into gray scale image and then converted to binary image. Sequence of binary images processed by morphology algorithms in order to remove noise and unwanted objects and then labeling has been perform in order to find the position of individuals. Then, these data are used to compute the velocity of individuals and to plan a path of Artemia group.

A number of difficulties solved for processed video of small individuals of Artemia: All experiment done inside laboratory then experiments can be repeated several times to get good videos and suitable for image processing, the semitransparent orange color of Artemia body problem solved by using black environment, the well-defined spacing of the group, and the high contrast provided by individuals against the black background, permit mostly automatic detection of individuals in images, and the videos are acquired indoor without disturbing nature behavior like wind, waves, etc.

About 75 individuals have been used for wireless control of Artemia group in all motion pattern control and the average number of individuals have been follow the movable light spot are 19 in case of linear motion at 0.3 cm/s light spot speed, and 17 individuals in case of circular motion at 0.15 cm/s light spot speed, while 12 individuals in case of zigzag motion at 0.175 cm/s light spot speed.

Some frames of experiments videos referring to a straight line, circular, and zigzag trajectory are reported in Fig. 8. Path trajectory of Artemia group motion with respect to no. of frames for three types of motion pattern are shown in Fig. 9.

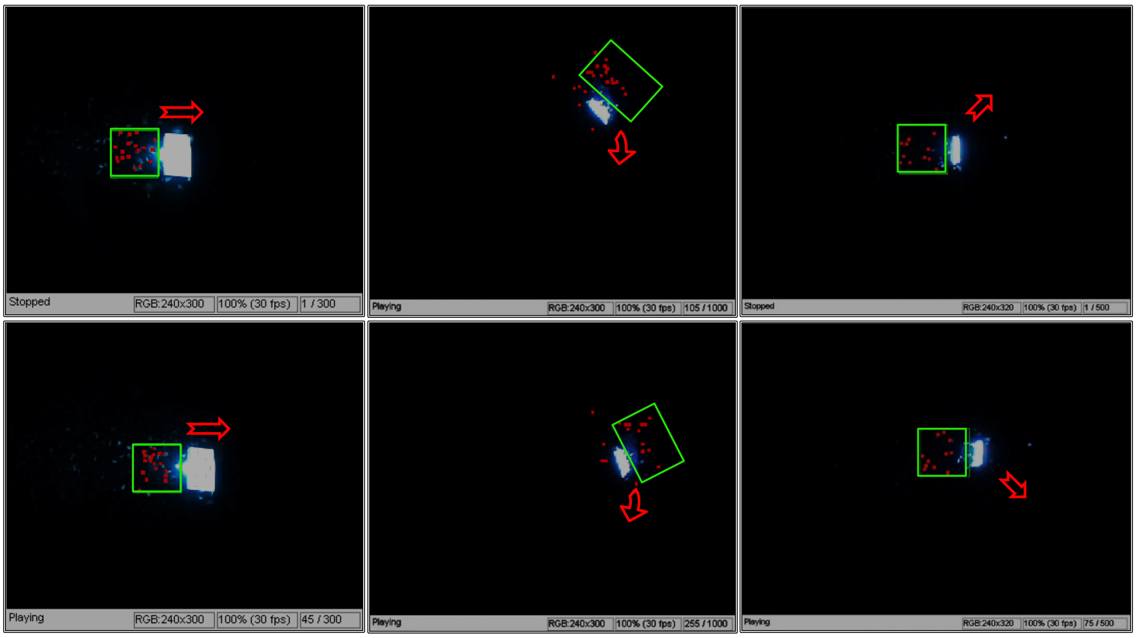


Figure 8: Frames showing motion control of an Artemias population through a robotic system.

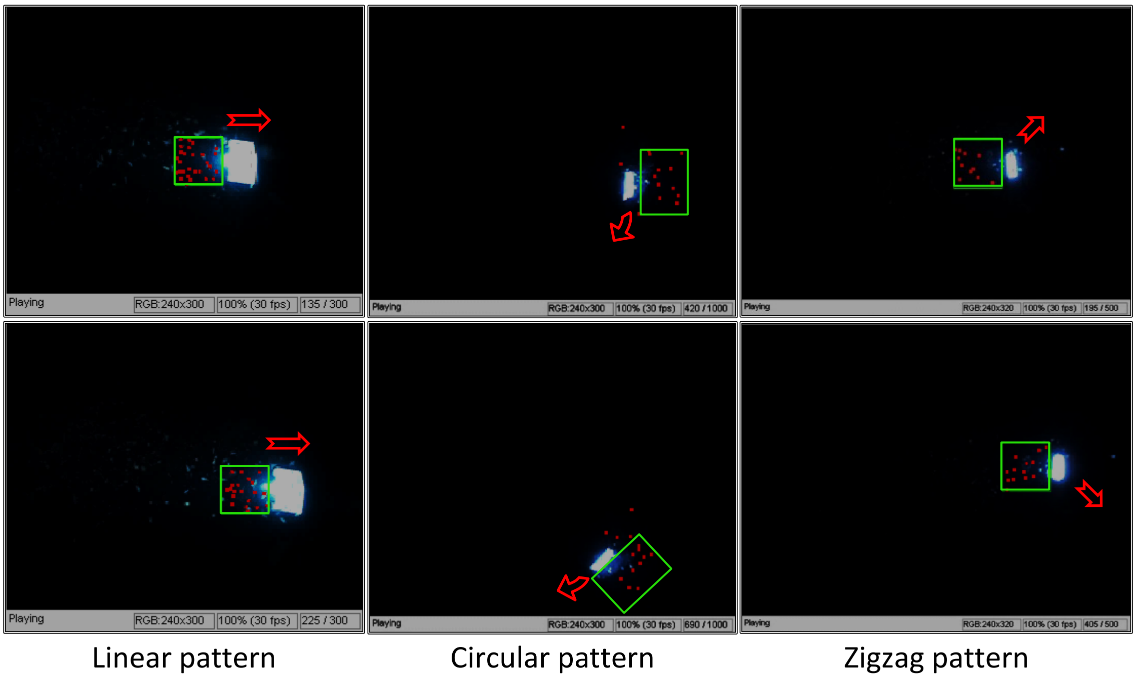


Figure 8: Continue.

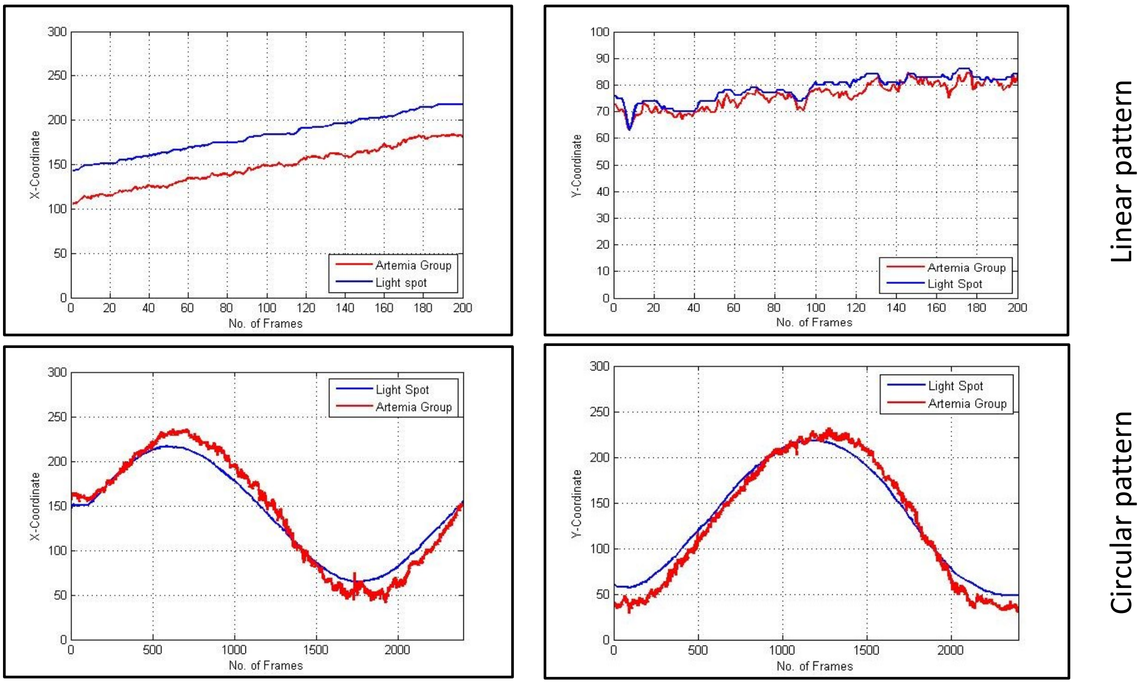
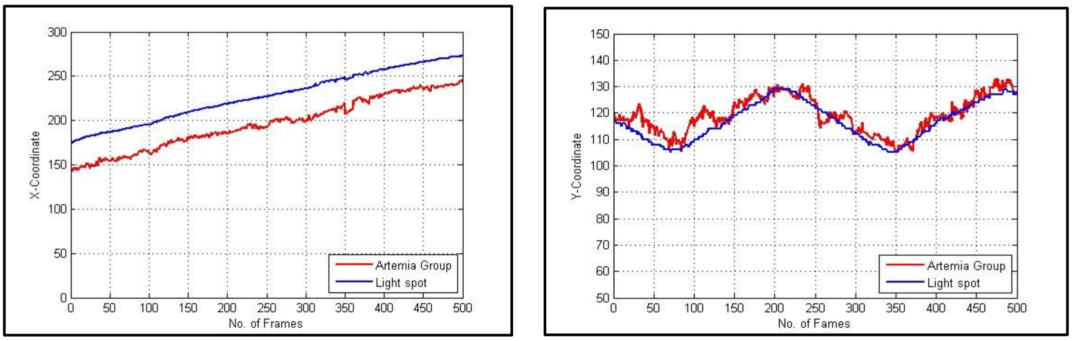


Figure 9: X-coordinate and Y-coordinate positions of group center vs. no. of frames.



Zigzag pattern

Figure 9: Continue.

VII. CONCLUSIONS

In this paper, we introduce new idea for wireless robot control system which is used as a tool to perform a wireless control on a group of Artemia to achieve several patterns to extract behavior of these organisms.

The wireless robot control system contain three types of wireless control, first is used light to control the motion of Artemia group, second is used magnetic field to control the motion of underwater mechanical robot while the last one is used ZigBee standard to control the mobile robot by PC. This system is easy to construct, low cost and can control small organisms in small area with perform several patterns.

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