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Solar Cell Powering with Integrated Global Positioning System for SWARM Robot System

Dr S.N.Singh[1*] Hirak Mazumdar[2] Rakesh Kumar[3]
1. National Institute of Technology, Jamshedpur, Jharkhand (India)
2. RVS College of Engineering and Technology, Jamshedpur, Jharkhand (India)
3. Research Scholar, National Institute of Technology, Jamshedpur, Jharkhand (India)
snsnitjsr@gmail.com, hirakm.tech.ece@gmail.com, surakesh@gmail.com

Abstract

A new concept of a Solar Cell powering with integrated Global Positioning System (GPS) for SWARM (Small World Autonomous Robots for Micro-manipulation) is proposed. The main idea is to use a projector to transfer energy and to provide global positioning information to the robots that are equipped with photodiodes on their top. We project a white image showed a scavenged power of 100 to 200 watts normally tungsten bulbs commercially available in market. Based on the global positioning system, the projector sends regularly a sequence 17 images and the robots decodes them using two photodiodes in order to calculate its own position and orientation inside a defined arena.

KEY INDEX: Photodiodes, Powering (Normally 100W – 200watts tungsten bulbs), GPS-Here called EGO-Positioning and Swarm Robotics

1. Introduction

In nature, the sun is an important source of energy. Its electromagnetic energy is converted into thermal energy and can be utilized to produce electricity. The energy obtained from nature has been used to power robotic system.

The paper presents to develop such system and technical viability has been studied using simulation approach where a virtual sun has been created with using beamer that illuminates the arena in which robots are placed. This paper focuses on the energy scavenging system with its optimal power output using global positioning system, called here EGO-positioning. This paper highlights following three main elements of system.

- Energy Scavenging.
- Global Positioning System (GPS) (T Bandyopadhyay, A Guha 1997).
- Supervisory parallel communication (Beamer to Robot communication)
  - Programming to the robots.
  - Generic data transmission.

All the measurements presented here were carried out projecting a white image on a rectangular surface corresponding to the size of the arena defined for the SWARM robot. Now a day's high pressure lamps (Xenon, Mercury) are useful for beamers due to its high irradiance. Here we used simple tungsten lamps (100W/200W) to use them as an energy source for the SWARM Robot (E. Sahin and W.M. Spears 2005).

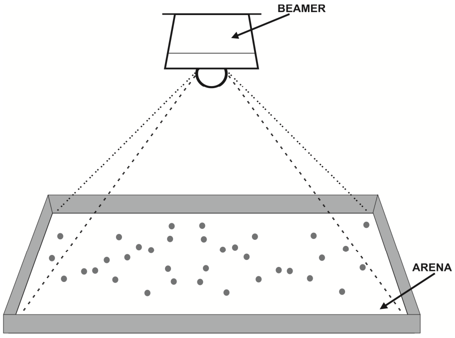

Figure 1. A beamer illuminating the arena and the robots

Position of Robert system is determined with technique known as ODOMETRY. The word odometry (Edwin Olson, December 4, 2004) is composed from the Greek words Hodos (meaning "travel", "journey") and Metron (meaning "measure"). Odometry is used by some robots, whether they be legged or wheeled, to estimate (not determine) their position relative to a starting location. This method is sensitive to errors due to the integration of velocity measurements over time to give position estimates. Dead Reckoning System is another technique for the process of estimating one's current position based upon a previously determined position, or fix and advancing that position based upon known or estimated speeds over elapsed time, and course.

In the proposed system combining both the above system a novel technique based on new concept designated as EGO - Positioning system has been used. A disadvantage of dead reckoning & odometer is that since new positions are calculated solely from previous positions, the errors of the process are cumulative, so the error in the position fix grows with time.

Due to constraints including physical size and the large number of robots, positioning systems well known in mobile robotics are not applicable here. Hightower et al. (J. Hightower 2001) give an overview of various solutions for indoor localization of autonomous robots ranging from IR detection to ultrasounds systems. None of the cited works address the issues of extreme miniaturization or high number of robots. Even more recent research, e.g. (Eltaher *et al.* 2005; Yuqiang Zhang 2005) are concerned about accuracy rather than applicability for 1000 mm^3size robots.

The proposed EGO-Positioning (Achim Brakemeier 2009) procedure allows the micro-robots in the SWARM to know their own position and orientation inside the arena. Every robot identifies its positioning exactly at the same time, without any delay.

2. Working Principle

EGO- Positioning work with linear prediction techniques. Each & every X & Y sequence is divided into multiple clusters of same sequence. This increases the overall resolution. Furthermore odometry in a localize clustered of SWARM Robotics is maintained the boundary value of the grids of the arena well localize will keep the robots inside the arena boundary.

The principle of the proposed EGO-Positioning system is to use the beamer to project on the arena a sequence of images corresponding to a position code. This code is detected by the two photodiodes of the each robot. Applying then a decoding algorithm on the obtained position code, the robots calculate their own "X" and "Y" co-ordinates from a defined origin of the arena. Only one centered photodiode would be sufficient to determine the robots position, two is allows calculating also its orientation (Figure 2).

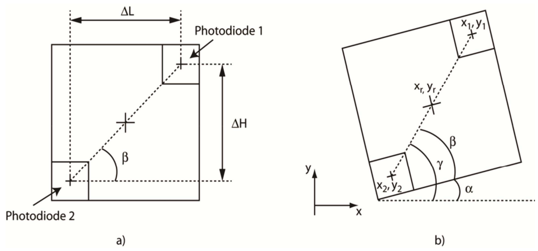

Figure 2. Configuration of the solar module: a) initial angle β,
b) arbitrary position of the robot x_r, y_r and orientation α

3. Design

$$X_r = \frac{x_1 + x_2}{2} \quad (1)$$

$$Y_r = \frac{y_1 + y_2}{2} \quad (2)$$

$$\alpha = (\gamma - \beta) = \arctan_2 \frac{y_1 - y_2}{x_1 - x_2} - \arctan\left(\frac{\Delta H}{\Delta L}\right) \quad (3)$$

Where

$\arctan_2$ defines an angle between - 180˚ and 180˚ ΔH & ΔL are the robot height & length respectively. The algorithm for position calculation is very simple since the obtained positioning code corresponds to the binary position of the photodiodes (Figure 6). Every zone of the arena is coded by a sequence of bits from the most significant to the less significant. Figure 3 shows an example of binary positioning code.

The 1st and 5th image correspond to the most significant bit of the "X"-position and "Y"-position respectively. Here binary "1" corresponds to white and "0" corresponds to black.

- Photodiode-1, X = 1000; Y= 1010…… (8, 5), (Decimal code)

- Photodiode-2, X = 0101; Y= 0010…… (5, 2), (Decimal code)

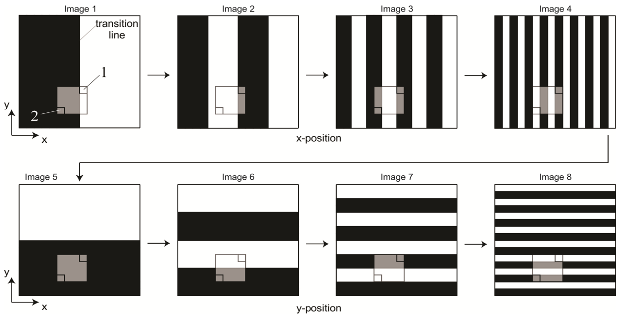

Figure 3. Image sequence giving binary positions

4. Transmission of Block diagram

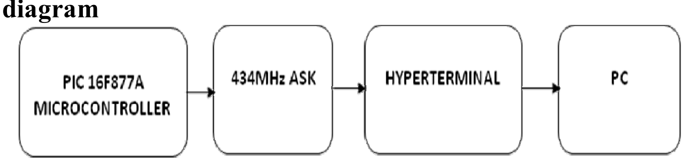

Figure 4. Work Flow

The major workflow for the hardware integration will be based on the algorithm as follows:

- Initiation of EGO Sequence generation.
- X sequence image projection.
- Y sequence image projection.
- RF feedback from swarm robots.
- Calculation of local co-ordinates based on feedback data.

In order to calculate their correct position, the SWARM robots have to stop moving at the beginning of the EGO-positioning procedure and have to hold their position. A specific start code is project when the EGO-positioning procedure will be complete successfully. The start code can be used in used in addition to stop the robots with the EGO - positioning sequence. There is several start codes are used to determine other robot behaviors.

A sequence of flashing full beam image will be sent by the beamer projector. The frequency of beamer operation will be calculated by the swarm robots. The frequency will determine the control codes for operation like EGO- positioning start or stop. The swarm robots must be stopped at track for the EGO initiation. So we propose a EGO initiation scheme of 5 beam projection, which when determined by the swarm robots will initiate the swarm "on track stop" sequence, thus paving the path for the EGO initiation procedure (Figure 7).

The X sequence images, which are nothing but a sequence of images with alternative black and white pillared patches will be projected on the arena with different degrees of resolution. For the time being we propose to concentrate only on 4 digit sequence or resolution. Hence a method has been devised for the X position beam scanning. For the above sequence generation, we propose the use of grated parallel openings (ex: window blinds) which will be placed on a 360^o degree rotary base. The base will rotate to accommodate full X and Y rotary beam projection (Figure 5).

For the Y sequence images to be projected on the arena, we need to rotate the rotary base by 90 degrees. The same grating thus can be used for dual axis operation over X and Y sequence of images. The swarm robots need to send a feedback to the beamer controller as to where the status of the swarm robot stands (stop, GO codes). The RF linkage that we propose here will be based on ASK 434 MHz transceiver operated by a PIC 16F877A microcontroller. The Port A and Port B of the microcontroller will send out the feedback codes to the beamer controller via the ASK transceiver. The GO codes will be then send back to the swarm robot thru the same ASK linkage (RF) once the EGO positioning system has finished (Figure 4).

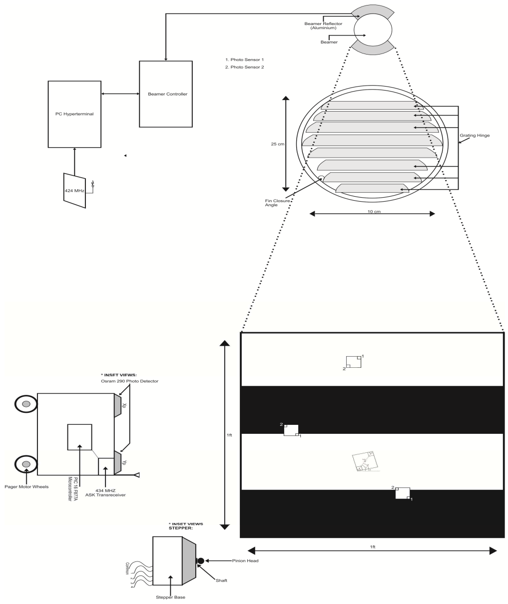

Figure 5. The grating methodology

5. Calculation of the X & Y coordinates

The calculation of the X-Y positioning will solely be based on the binary sequence monitoring method (Clayton & Satoshi Kagami 1994).

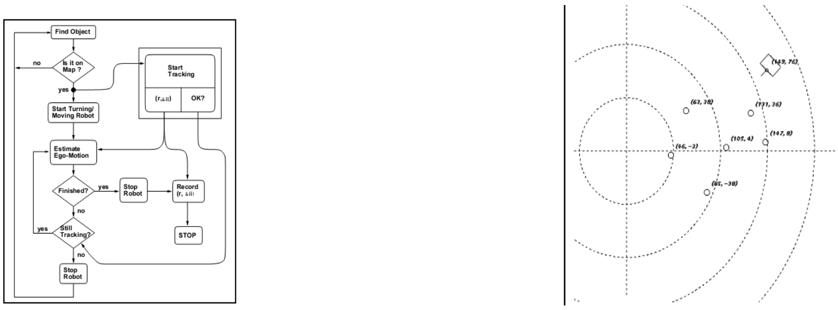

Figure 6. (a) Schematic Algorithm for EGO-Positioning. (b) Topological Matching for EGO-Positioning.

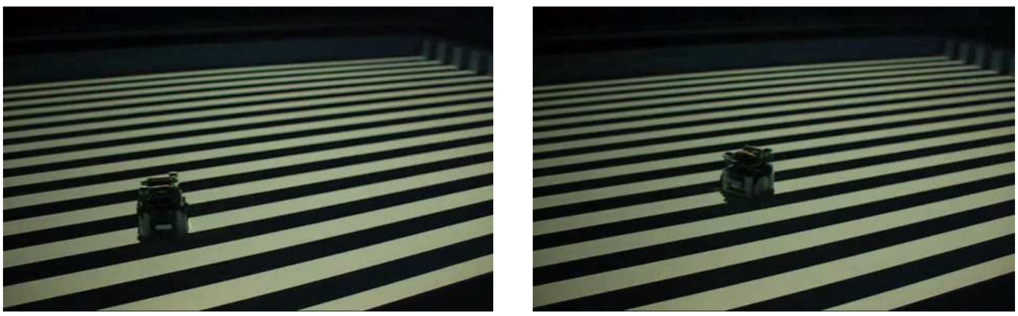

Figure 7. Various Image sequence giving Binary Position

6. Discussions and Conclusion

The proposed methodology will lead in the general behavioral pattern study of swarm robots under clustered AI sequence generation algorithms such as ANN or Fuzzy Logic. The swarm robots will behave on the different location pattern as determined by the EGO positioning system, and will interact with each other with above mentioned approaches. The study of Genome patterns like Genetic Algorithms can be viewed on real scale by the swarm EGO positioning method. The K-Means clustering of node points in a constrained arena can be studied with the proposed method. The EGO positioning system can elevate the process of further research in localized transport methodologies in human transitions.

7. Future Work

- Implementation of fully automated solar charger inbuilt with every micro-robot in a swarm.
- Change of sensors for light detection. A visible light source is not sufficient to direct the bots as a beamer as they incur more interference due to RF and environmental ambient changes. So we propose IR based EGO system in future.
- Instead of a differential drive, a skid drive system is more practical approach, which we like to implement in future.
- The resolution of EGO can be increased by utilizing more grids in one block, which will require an extensively illuminated beamer. Such a beamer can be constructed using high power SMD LED's.

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Biographies

Dr S.N. Singh had completed M.tech and doctoral PhD degree at the Department of Electrical Engineering, National Institute of Technology Jamshedpur (India). He obtained his B.Tech degree in Electronics and communication engineering from BIT Mesra (A Deemed university), Ranchi - Jharkhand (India) in 1979/80. Presently his area of interest is *solar energy conversion technology.* He had published more than 60 papers in National and International journals based on his research work. He had remained *Head of Department of Electronics and Communication Engineering for* two terms and presently heading Govt. of India Deptt of IT sponsored VLSI SMDP-II Project

Mr. Rakesh Kumar had completed M.Sc. Engineering Degree in Power Electronics from the Department of Electrical Engineering of National Institute of Technology Jamshedpur (India) in the year 2003. He obtained his B.E degree in Electronics & Communication Engineering from RIT Islampur–Maharastra (India). Presently he is Research Scholar in National Institute of Technology Jamshedpur (India) in the Department of Electronics & Communication. His field of Specialization is in Industrial Electronics & control. He has completed several projects on Holography and allied field and published 5 papers in international journals.

Mr. Hirak Mazumdar had completed Master of Technology Degree in Electronics & Communication Engineering (Modern Communication Engineering) from Dr. B. C. Roy Engineering College, Durgapur under West Bengal University of Technology, Kolkata (India) in the year 2011. He has also obtained his M.Sc degree in Physics (Electronics) from Guru Ghasidas Central University, Bilaspur, C.G (India) in the year 2009. Presently he is working as Lecturer in the Department of Electronics & Communication of R.V.S College of Engineering & Technology, Jamshedpur. His field of Specialization is in solar energy conversion technology, Artificial Intellengce & SWARM Robotics. He has attended several seminar based on Solar cell technologies.