Visual Perception In Hexapod Robot

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Abstract: The purpose of this paper is to explain a real time vision system for position determination and vision guidance to navigate a Hexapod robot on terrain surface. Visual understanding is a rapidly maturing approach to the control of robot manipulators that is based on visual perception of robot and work piece location. Visual understanding involves the use of one or more cameras and a computer vision system to control the position of the robot’s end effectors relative to the work piece as required by the task. The camera may be stationary or held on the hexapod head.

Keywords: hexapod, perception, vision system

1. INTRODUCTION

Technological advancement is widening up by the advent of new inventions. Robot is one such invention to overcome the ever present challenges of high cost of labor, third world combination, and consumer demand for higher quality and greater variety at a lower cost. It is an interdisciplinary field that ranges in scope from the design of mechanical and electrical components to sensor technology, computer systems, and artificial intelligence. It is the science of designing and building robots suitable for real life applications in manufacturing and other non-manufacturing environment. In non-manufacturing environment robots act as computer controlled camera that allows it to see its environment and respond accordingly is known as its vision.

In the current scenario, the robot vision system is basically used for inspection purposes in industries such as gauging, verification of presence of components, detection of flaws, etc. After experience with large and heavy commercial mobile robot systems, we decided to develop completely new mini-robots which is useful and suitable for a variety of tasks in research and education. This robot was designed to be versatile for a number of different perception or action tasks and not be too specialized for any event in particular [1]. A wireless transmission allows the robots to exchange information regarding their positions, sensor data, as well as their intended actions and plans. Since the earliest days of this field, computer vision researchers have struggled with the challenges of effectively combining low-level vision with classical artificial intelligence. Some of the earliest work involved the combination of image analysis and symbolic AI to construct autonomous robots. These attempts met with limited success because the vision problem was hard and the focus of vision research shifted from vertically integrated, embodied vision systems to low-level, stand-alone vision systems. Current general purpose processors have been enhanced with new features and explicitly dedicated to the efficient handling of multimedia (audio and video) data; in order to exploit the high intrinsic spatial parallelism of low-level image processing. It can be observed that most of the image processing operators exhibit natural parallelism in the sense that the input image data required to compute a given area of the output is spatially localised. The use of vision with robots has a long history and today vision systems are available from major robot vendors that are highly integrated with the robot's programming system [2]. Capabilities range from simple binary image processing to more complex edge- and feature-based systems capable of handling overlapped parts. The common characteristic of all these systems is that they are static and typically image processing times are of the order of 0.1 to 1 second. In such systems visual sensing and manipulation are combined in an open-loop fashion, 'looking' then 'moving'. The accuracy of the 'look-then-move' approach depends directly on the accuracy of the visual sensor and the robot manipulator. An alternative to increase the accuracy of these sub-systems is to use a visual-feedback control loop which will increase the overall accuracy of the system. Taken to the extreme machine vision can provide closed-loop position control for a robot end-effectors — this is referred to as visual servoing [3].

![Visual Servoing](image)

Figure 1. General structure of robot vision
2. LITERATURE SURVEY

With a plethora of different graphics and robotics applications that depend on motion-tracking technology for their existence, a wide range of interesting motion-tracking solutions have been invented. Surveys of magnetic, optical, acoustic and mechanical robot positioning systems are available now days. Visual techniques for detecting and tracking main scene features have been notably improved over the last few years and applied to robot navigation solutions. Zhou and Li (Zhou and Li, 2006) detected ground features grouping all coplanar points that have been found with the Harris corner detector (Harris and Stephens, 1988). Lowe (Lowe, 2004) developed the Scale Invariant Feature Transform (SIFT) method to extract highly discriminative image features, robust to scaling, rotation, camera view-point changes and illumination changes [4].

Genghis, one of the most famous walking robots from MIT, uses hobby servomotors as its actuators. Thrun et al. developed the museum tour-guide robot MINERVA that employs EM to learn its map and Markov localisation with camera mosaics of the ceiling in addition to the laser scan occupancy map [5]. The idea behind the creation of the six-legged mobile robot called FOBOT was to design a robot i.e. when placed in a specific geographic location it will be able to explore its unknown environment and send visual information from the area to the remote PC.

3. LEGGED LOCOMOTION

A legged robot is well suited for rough terrain; it is able to climb steps, to cross gaps which are as large as its stride and to walk on extremely rough terrain where, due to ground irregularities, the use of wheels would not be feasible [6]. To make a legged robot mobile each leg must have at least two degrees of freedom (DOF). For each DOF one joint is needed which is usually powered by one servo. Because of this a four legged robot needs at least eight servos to travel around. Figure 2 shows the energy consumption of different locomotion concepts. It strikes that the power consumption of legged locomotion is nearly two orders of magnitude more inefficient than of wheeled locomotion on hard, flat surface (e.g. railway wheel on steel). One reason for this is that wheeled locomotion requires in general fewer motors than legged locomotion.

When the surface becomes soft wheeled locomotion offers some inefficiency, due to increasing rolling friction then more motor power is required to move. As Figure 2 shows legged locomotion is more power efficient on soft ground than wheeled locomotion because legged locomotion consists only of point contacts with the ground and the leg is moved through the air. This means that only a single set of point contacts is required, so the quality of the ground does not matter as long as the robot is able to handle the ground. But exactly the single set of point contacts offers one of the most complex problems in legged locomotion and the stability problem.

4. CAMERA AND SENSOR TECHNOLOGIES

Early computer vision work was based on vidicon or thermionic tube or image sensors. These devices were large and heavy, lacked robustness and suffered from poor image stability and memory effect. Since the mid 1980s most researchers have used some form of solid-state camera based on an NMOS, CCD or CID sensor. Most visual servo work has been based on monochrome sensors, but colour has been used for example in a fruit picking robot to differentiate fruit from leaves [7]. Given real-time constraints the advantages of colour vision for object recognition maybe offset by the increased cost and high processing requirements of up to three times the monochrome data rate.

Visual features may be used to guide a robot manipulator or mechanism. The camera contains a lens which forms a 2D projection of the scene on the image plane when the sensor is located. This projection causes direct depth information to be lost, and each point on the image plane corresponds to a ray in 3D space [8].

We classify sensors using two important functional axes into (i) proprioceptive or exteroceptive and (ii) passive or active.

**Proprioceptive** sensors measure values internal to the system(robot) for example motor speed, leg load, robot leg joint angles, battery voltage.

**Exteroceptive** sensors acquire information from the robot’s environment, for example, distance measurements, light intensity, and sound amplitude.

**Passive** sensors measure ambient environment energy entering the sensor.

**Active** sensors emit energy into the environment then measure the environment reaction. Because active sensors can manage more controlled interaction with the environment, they often achieve superior performance.

5. CONTROL DESIGN & PERFORMANCE

Legged locomotion is characterised by a series of point contacts between the robot & the ground. The key advantage includes adaptability & maneuverability in rough terrain. Advantage of legged locomotion is the
potential to manipulate objects in the environment with great skill. Figure 3 shows six legged insect structure. The leg which may include several degrees of freedom must be capable of sustaining part of the robot’s total weight.

Figure 3. Insects six leg

The most obvious characteristics are slowness of motion, lag with respect to target motion and often significant jitter or shakiness. The performance achieved is a consequence of the detailed understanding of the dynamics of the system to be controlled (the robot) and the sensor (the camera and vision system).

Our robots have a number of on board sensors, including vision and do not rely on global sensor systems. This enables our robots to perform several different tasks such as navigation, map generation and intelligent group behaviour [9].

Figure 4. System block diagram of a visual feedback control system showing target motion as disturbance input.

The compensator design approach has followed classical linear principles of increasing system Type and positioning the closed-loop poles by means of PID or pole placement control. The system’s Type is important to the steady-state tracking error and at least Type 2 is necessary to adequately track sinusoidal or parabolic motion.

6. Body structure

The main tasks of a walking robot’s body are to support legs and to accommodate sub-systems. Therefore, the body must be big enough to contain the required sub-systems such as an onboard controller, electronics, drivers and batteries. “Alternating tripods” means those two non-adjacent legs on one side and the central leg on the opposite side alternate in supporting the robot. That means for a given foot position, the central leg in its support phase is carrying about half the robot’s weight, whilst the two collateral legs in their support phase are carrying about one-fourth of the robot’s weight. This is especially significant in traditional hexapod configurations, where legs are placed at the same distance from the longitudinal axis of the body. If the robot has similar legs, then the non-central legs will be over-sized and to optimize the mechanism the central leg’s design should differ from that of the rest of the legs. However, using just one leg design has many advantages in terms of design cost, replacements, modularity and so on. Satisfactory force distribution and system homogenization can be achieved by shifting the central leg slightly from the body’s longitudinal axis so that the central leg support less weight and the corner legs increase their contribution to support the body. This effect is illustrated in Figure 5, which shows a legged robot supported on three legs. The equilibrium equations that balance forces and moments are given by (Klein 1990):

\[
\begin{bmatrix}
    x_1 & x_2 & x_3 & F_1 \\
    y_1 & y_2 & y_3 & F_2 \\
    1   & 1   & 1   & F_3 \\
\end{bmatrix}
= W
\]

The condition for sharing the weight of the robot evenly among the supporting legs is:

\[
\begin{bmatrix}
    X & -X & 0 & W/3 \\
    Y & -Y & 0 & W/3 \\
    1 & 1 & 1 & W/3 \\
\end{bmatrix}
= W
\]

Rows 1 and 3 are always satisfied and row 2 is satisfied if:

\[ 2Y = Y_i \]

This last condition produces an unusual configuration that does not look very suitable for our application. In any case, the farther the central foot is from the body’s longitudinal axis, the more homogeneously the forces are distributed.

Figure 5. Force distribution for a tripod configuration

The onboard controller is a distributed hierarchical system comprising a PC-based computer, a data-acquisition board and three-axis control boards based on
the PIC microcontroller, interconnected through an ISA bus [10]. Every microcontroller commands a servo motor-joint driver based on the PWM technique. An analogue data-acquisition board is used to acquire sensorial data from the range of external equipment (sensors, locators, etc.). A Bluetooth is provided for network communication with the Host computer.

![Figure 6. Block diagram of developed system](image)

Figure 6. Block diagram of developed system

The abovementioned figure shows the control environment currently implemented. The user interfaces have control over the running of the microcontroller and are fed back information about the status of the robot. The onboard controller is a PIC operator station and connects via Bluetooth to the host computer. The microcontroller reads the information and controls the movements of the robot. The drive system consists of servo motors. The motor is driven by a high powered PWM controller board; it gets the signal from the microcontroller. The controller has to perform a number of tasks in time shared parallel mode. This includes handling timer interrupts, sensor inputs & actuators output. Robot should understand the data from the visual sensor and force sensor according to that it should change its movement. The complete body structure is shown in Figure 7.

![Figure 7. Virtual body structure.](image)

Figure 7. Virtual body structure.

7. CONCLUSION AND FUTURE WORK

If properly designed, the robot’s visual behaviors can be matched to human expectations and allow both robot and human to participate in natural and intuitive social interactions. In this paper we are pleased to present a hexapod robot vision navigation system. It uses salient regions to navigate the robot as well as to direct its heading. By having both mobile capabilities, our system can perform a user-specified command to go to a goal location. This is an extension to most available systems which are either just a vision localisation system (with the movement controlled by a user) or a vision navigation system (which can only perform navigation from pre-specified starting and ending locations).

The next step to improve the system is to have robot visually navigate itself without localisation during those times. Moreover, the proposed system can be easily expanded to localise more than one robot. Future extensions of the paper are interactive dynamic path planning and intelligent inference mechanism for the integration of pose estimates from multiple cameras to increase the accuracy of pose estimates.

Acknowledgement

The authors acknowledge the valuable technical contributions of Mr. Hiwale A.S. and the members of the Mechanical and Electronics Departments at the G. S. Moze College of Engineering, Pune, Maharashtra, India.

REFERENCES


[4] “Vision-Based Global Localization and Mapping for Mobile Robots” Stephen Se, Member, IEEE, David G. Lowe, Member, IEEE, and James J. Little, Member, IEEE


[8] Active Vision for Sociable Robots
Cynthia Breazeal, Aaron Edsinger, Paul Fitzpatrick, and Brian Scassellati,

Using Gist and Saliency
Chin-Kai Chang* Christian Siagian* Laurent Itti

select for competent controllers in evolutionary 
robotics, Robotics and Autonomous System, Vol. 54, 
2006, pp. 840-857

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