ENVIRONMENT INDEPENDENT DIRECTIONAL GESTURE RECOGNITION TECHNIQUE FOR ROBOTS USING MULTIPLE DATA FUSION

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Abstract

A technique is presented here for directional gesture recognition by robots. The usual technique employed now is using camera vision and image processing. One major disadvantage with that is the environmental constrain. The machine vision system has a lot of lighting constrains. It is therefore only possible to use that technique in a conditioned environment, where the lighting is compatible with camera system used. The technique presented here is designed to work in any environment. It does not employ machine vision. It utilizes a set of sensors fixed on the hands of a human to identify the direction in which the hand is pointing. This technique uses cylindrical coordinate system to precisely find the direction. A programmed computing block in the robot identifies the direction accurately within the given range.

Keywords: *gesture recognition, cylindrical coordinates, direction of arrival, line segment, position of point*

Abstrak

Sebuah teknik yang disajikan di sini untuk arah pengenalan gestur oleh robot. Teknik yang biasa digunakan saat ini menggunakan *camera vision* dan pengolahan citra. Salah satu kelemahan utama dengan teknik itu adalah keterbatasan lingkungan. Sistem *machine vision* memiliki banyak kendala pencahayaan. Oleh karena itu, teknik tersebut hanya mungkin digunakan dalam lingkungan yang telah dikondisikan sebelumnya, di mana pencahayaan cocok dengan sistem kamera yang digunakan. Teknik yang disajikan di makalah ini dirancang untuk bekerja dalam lingkungan apapun dan tidak menggunakan *machine vision*. Sistem yang diusulkan ini menggunakan satu set sensor tetap di tangan manusia untuk mengidentifikasi arah di mana tangan menunjuk. Teknik ini menggunakan sistem koordinat silinder untuk secara tepat menemukan arah. Sebuah blok komputasi diprogram pada robot mengidentifikasi arah secara akurat dalam kisaran yang diberikan.

Kata kunci: *pengenalan gestur, koordinat silinder, arah kedatangan, segmen garis, posisi titik.*

1. Introduction

The demand for human interaction with robots is increasing with time. One of the most challenging and interesting field of research in this direction has been developing technologies for robots to understand human gestures. This paper presents a technique for robots to sense directional gestures. There are similar techniques that employ machine vision for the same purpose, but they have their own constrains due to environment. The paper technique presented here overcomes that constrain to a great extend.

A set of sensors along with transmitters and receivers are fixed on the robots and on the hands of the human whose gesture should be recognized.

2. The Basic Working Principle

The system uses two points on the human hand as two ends of a line segment. One point is close to the elbow and another point is close to wrist. The direction in which this line segment points with reference to the location of the robot can be calculated by the processing unit in the robot. The precise sensing of the two points is done by a pair of set of three sensors. To locate each point in space with respect to the robot, a set of three sensors are used. Cylindrical coordinate system is used for the calculation of the direction with respect to the point where the robot is located. Once the direction where the hand is pointing is found out, the direction in which the robot needs to move can be decided by the processing unit.

The robot is assumed as the centre of the cylindrical coordinate. The two points are defined in space using cylindrical coordinates. Three sensors are used to find the three cylindrical coordinate points: A Direction of Arrival (DoA) sensor for finding the angle, a simple electromagnetic transceiver for finding the distance between the point and robot and a height detecting sensor (preferably laser sensor) to detect the height of the point above the ground. Thus all the three coordinate values required to define a point in cylindrical coordinate are obtained. In Fig 1., the robot is located at point O. One of the two points is P. OP is the distance between the robot and the sensor point. The distance can be obtained by electromagnetic transceiver. The height-detecting sensor will give the height PQ. From OP and PQ, the distance OQ can be found. The angle is given by DoA sensor. Thus a point P in the cylindrical coordinate can be defined with respect to the robot (origin). Thus the co-ordinates of the two points on the hand of the person who is pointing are found out using the above explained technique. Let the two points be P_1 and P_2. Here point P_1 is the point closer to the elbow and P_2 is the point closer to the wrist. The robot is located at point O. Thus the direction in which the robot has to go is a projection of the line segment joining point P1 and P2. Thus the robot is programmed to reach the point on the ground that is the vertical projection of the point P_2. Then the robot proceeds from P_2 in the direction of P_1P_2.

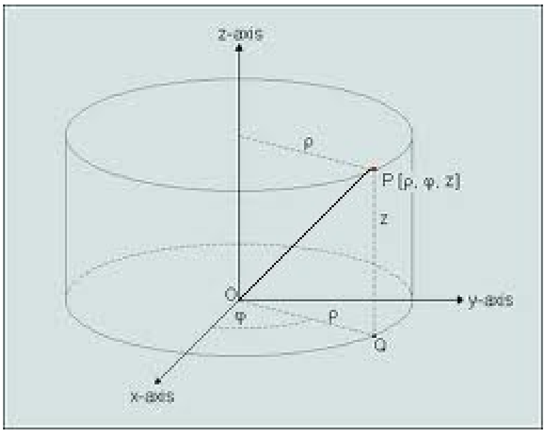

Fig 1. Cylindical coordinate of point P

3. Acquisition of Coordinate Values

3.1 Direction of Arrival

The most important coordinate value required in terms of precisely acquiring the position of the point is angle "**φ**". This angle is obtained by a DoA sensor. To eliminate ambiguity of whether the obtained signal is stray or not, a pair of DoA sensor can be used for a single point. In this case the DoA sensor is positioned on the robot. It is a simple electromagnetic receiver with precise narrowband frequency range. The corresponding electromagnetic transmitter is positioned on the hand of the person whose gesture is to be sensed and it generates the matching narrowband signal.

3.2 Distance Between Origin and Point

The distance between origin and the point is "u" and it is obtained by employing an electromagnet or acoustic transmitter and receiver and measuring the strength of the received signal. The strength of the signal received is inversely proportional to the distance between the transmitter and receiver.

3.3 Height of The Point Above Ground

The height "h" of the point above the ground is measured either by a high precision ultrasonic sensor or by a laser sensor. There are also other mechanisms for measuring height above the ground, which can be employed based on factors like size, compatibility and cost.

4. Calculations To Find The Coordinate Values

The algorithm presented here takes only the x and y coordinates the two coordinates on ground, into consideration for calculation and determination of which direction is gestured. The same algorithm can be extended for three-dimensional directional gesture recognition by just taking into consideration the height coordinate. The obtained cylindrical coordinates are first converted into Cartesian coordinates for the sake of simplified and understandable mathematical calculation. In Fig 2., the known quantities are D, h and ɵ, which are values obtained from sensors. The three cylindrical coordinates are angular coordinate "ɵ", radial distance "u" and vertical height "h". The only unknown value of the three cylindrical coordinate values is radial distance "u". This value can be found by a simple Pythagoras formula:

$$u = \sqrt{(D^2 - h^2)} \quad (1)$$

Thus after all three cylindrical coordinate values are obtained, it is converted into corresponding Cartesian values x, y and z by conventional formula. As shown in Fig 2., the Cartesian coordinates of the points P_1 and P_2 are found.

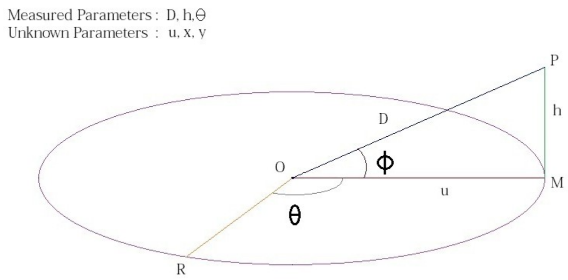

Fig 2. Known and Unknown parameters in the cylindrical coordinates of point P

5. Algorithm To Find The Directional Vector

The ultimate objective of the proposed mechanism is to make the robot to identify the direction pointed by the human controller or instructor. Therefore the directional vector of the line segment joining P_1 and P_2 is required to be found. In Fig 3., the top view of the robot and the points P_1 and P_2 are shown. The values of all the three Cartesian coordinates of both the point P_1 and P_2 are known. Only the x and y coordinate values of point P1 and P2 are sufficient to find the two dimensional directional gesture for land roving robots. Three-dimensional calculation is required only for flying robots. Since the x and y coordinate values of both P_1 and P_2 are known, the directional vector of the line segment P_1P_2 is found out by simple geometrical formula. The robot now has to reach any point close to point P_2 and then proceed moving in the direction P_1P_2. The directional convention is that the robot should move only from P_1 to P_2 and further and not from P_2 to P_1. This is done by assigning a prefixed tag on any values acquired from the sensor corresponding to any one point.

6. Algorithm To Find The Clearance Point

In the case of a practical land robot, the robot is expected to reach a point on the extended part of the line segment P_1P_2. The robot should reach the point P_3, which is the clearance point, typically as shown in Fig 3. The clearance distance "*n*" should be very small when compared to the length of P_1P_2. The mathematical algorithm to find out the coordinate of P_3 is simple. First, the clearance distance that is desired, that is the value "*n*" is required as input. This length or clearance distance *n* may vary from system to system. The first step is to find the equation if the circle with point P_2 as the center and the length *n* as radius. The obtained equation of the circle is solved with the equation of the line joining P_1P_2 to find the two points where the circle intersects with the line P_1P_2. These points are P_3 and P_4. The point P_3 is farther from point P_1 when compared to point P_4. Thus the point P_3 is selected as the point where the land roving robot should come. The above algorithm is explained with an illustration below.

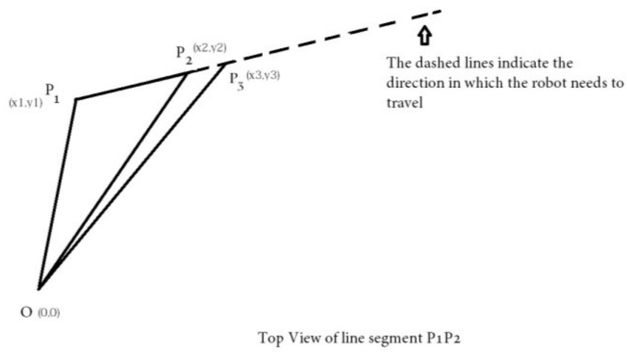

Fig 3. Representative top view of robot and direction of pointing

In Fig 4., the point P_1 and P_2 have coordinates (-4, 7) and (3,5) respectively. The clearance distance assumed in this case is 0.5 units. The equation of the line joining the two points is obtained since the coordinates of the two points are known. The obtained equation of that line is:

$$2x+7y=41 \tag{2}$$

The equation of circle with P_2 as center and 0.5 as radius is obtained. That equation is:

$$(x-3)^2 + (y-5)^2 = (0.5)^2 \tag{3}$$

When Eqn.(2) and Eqn.(3) is solved we get two coordinate values. The two coordinate values corresponding to P_3 and P_4 respectively. The two point coordinates are (2.538, 5.132) and (3.465, 4.876). The point P_3 is assigned to the point which does not lie on the line segment P_1P_2. Therefore, within the two points P_3 and P_4, the point whose x and y coordinate values lays within the x and y coordinate values of P_1 and P_2 is eliminated. The eliminated point is P_4. The other point whose x and y coordinate value lies outside the x and y coordinate value of P_1 and P_2 corresponds to point P_3. Therefore, the robot is expected to come to position P_3. The robot now has to proceed from point P_3 in the direction along line segment P_1P_2 away from point P_2.

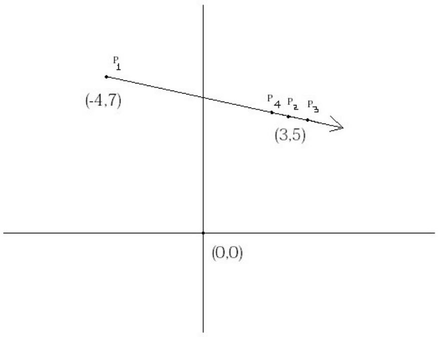

Fig 4. Illustration to find clearance point P_3

7. Setup of The Direction of Arrival Sensor

The DoA sensor consists of an array of sensing elements placed close to each other. Since in this case, the signal is expected from any direction, that is 360 degrees, a minimum three arrays is mandatory In Fig 5., the DoA shown uses four array sensors. The DoA, as mentioned above senses from which direction the signal arrives. As shown in Fig 4., the source emits radiation which is first received by the sensing element closest to the source.

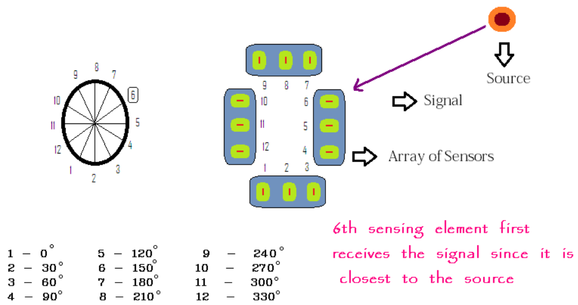

Fig 5. Representative diagram of Direction of Arrival sensor working

In this case, it is the top most sensing element (6^{th} sensing element) of the right side array that first receives the signal. All the other sensing elements receive the signal after that sensing element. Therefore by using conventional time delay analysis, it is possible to detect which sensing element first receives the signal and which one receives following the first reception. If the time gap between the consecutive receptions of the signal by the sensing elements is measureable, then by employing a simple algorithm it is possible to deduce the Direction of Arrival with great accuracy. A simple convention of DoA sensor is presented in presented in Fig 4. There are twelve sensing elements, which are numbered from 1 to 12. Here the sensing element 1 corresponds to 0^0 and 360^0. Since there are 12 sensing elements, the angle between two sensing element is 30^0. In this illustration, it is assumed that the 6^{th} sensing element is closest to the source. Therefore, it is the first element that receives the signal. The reading of the DoA sensor is therefore 150^0. It is obtained as the product of the number of sensing element and the angle between two sensing elements, which in this case is 150^0 ($6*30^0$).

8. Conclusion

This mechanism presented here is an inchoate form of the idea. The overall system can be made very compatible and precise if the best in class building components are used. A small computing device should be attached to the sensing and transmitting components to control and synchronies them for better results. The system can be dynamically used to control server robots in hotels, offices if the two dimensional algorithm for land roving robots is employed. The three dimensional algorithm is employed for flying robots. For this the height dimension is taken into calculation. In both the cases the robot can be dynamically controlled on how fast the sensing elements receive the transmitted signals, how fast the transmitting signals transmit the signal and how fast the signals can be conditioned and processed. Timing is the most important factor when it comes to practical implementation of this mechanism.

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