Design and implementation of Vision Guidance System for unmanned ground vehicle

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Abstract*–An unmanned ground vehicle (UGV) is a vehicle that operates while in contact with the ground and without an onboard human presence. UGVs can be used for many applications where it may be inconvenient, dangerous, or impossible to have a human operator present. UGV system solves tasks of periodical surveillance in indoor environments using vision technique, vision is a simple and accurate navigation method in indoor environment, UGVs also can be used in military and also in civilian fields like Agriculture, Manufacturing, Mining and Emergency response. This paper includes a designing simulation of GNC "navigation, guidance and control "system using two cars, using vision guidance algorithms with camera mounted on stabilized platform which is placed on a vehicle which represent guide object and it is free in two dimensions yaw and roll. Then we use and image processing to detect one of two cars which represent the target (destination) and determine its position then using navigation algorithm to track it, with achieving minimum miss distance between two cars.

I. Introduction

A working remote-controlled car was reported in the October 1921 issue of RCA's World-Wide Wireless magazine.

An unmanned ground vehicle (UGV) is a vehicle that operates while in contact with the ground and without an onboard human presence. the vehicle will have a set of sensors to observe the environment, and will either autonomously make decisions about its behavior or pass the information to a human operator at a different location who will control the vehicle through teleoperation, an autonomous UGV (AGV) is essentially an autonomous robot that operates without the need for a human controller on the basis of artificial intelligence technologies. The vehicle uses its sensors to develop some limited understanding of the environment, which is then used by control algorithms to determine the next action to take in the context of a human provided mission goal. This fully eliminates the need for any human to watch over the menial tasks that the AGV is completing. there are a wide variety of UGVs in use today. Predominantly these vehicles are used to replace humans in hazardous situations, such as handling explosives and in bomb disabling vehicles, where additional strength or smaller
size is needed, or where humans cannot easily go. Military applications include surveillance, reconnaissance, and target acquisition. They are also used in industries such as agriculture, mining and construction. Based on its application, unmanned ground vehicles will generally include the following components: platform, sensors, control systems, guidance interface, communication links, and systems integration features.

This paper includes designing of a small indoor unmanned ground vehicle using computer vision to detect red color as car "target" using python and OpenCV [3] then determine its location with respect to field of view, Camera stream is displayed as a video, stabilized platform using two servos for camera is used to make camera frame stable due to obstacles which counter vehicle in its path, using Arduino as micro controller and IMU [6].

The UGV navigation is based on monocular vision and odometry [2].

Inertial navigation system is used to track the position and orientation of vehicle relative to a known starting point, orientation and velocity. The representation of relative orientation using Euler angles is easy to develop and to visualize. But computationally intense.

Also, a singularity problem occurs when describing attitude kinematics in terms of Euler angles. So that, the widely used method for attitude determination is "quaternion calculation" which is based on Euler's rotation theorem.

In guidance we use Pure pursuit guidance [1] [5] method is used it is a two-point guidance method. which having one range r and one line of sight λ, along which r is directed.

II. Problem Statement

It is desired to detect desired vehicle and determine its position with respect to field of view, then sending it periodically to microcontroller and centre detected vehicle in centre of screen and direct other vehicle toward the other using suitable guidance method "pure pursuit guidance method"

III. Image Processing

A. vision

Computer vision is the automated extraction of information from images. Information can mean anything from 3D models, camera position, object detection and recognition to grouping and searching image content, Practical computer vision contains a mix of programming, modeling, and mathematics and is sometimes difficult to grasp.

B. detection

use computer vision to detect red color as car "target" using python and OpenCV, Programming computer vision needs representations of vectors and matrices and operations on them. This is handled by Python's modules. This is also the representation we will use for images, the array object lets you do important operations such as matrix multiplication, transposition, solving equation systems, vector multiplication, and normalization, which are needed to do things like aligning images, warping images, modeling variations, classifying images, grouping images.

Camera stream is displayed as a video. Video with pure Python is hard. There is speed, codecs, cameras, operating systems and file formats to consider. There is currently no video library for Python. OpenCV with its Python interface is the only good option, as shown in Fig (1).

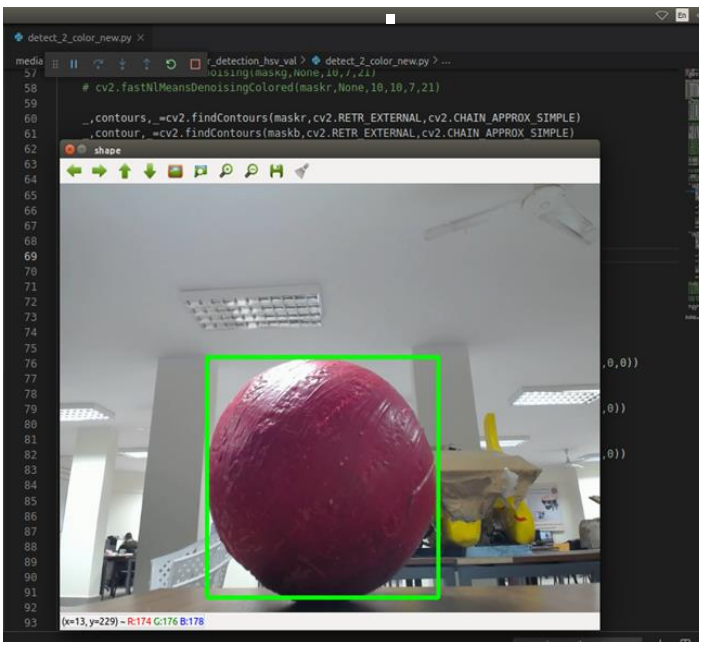

Fig. 1 detection of red color.

C. tracking

Two servos are used to design and implement stabilized platform for the camera and make camera frame stable due to obstacles which counter vehicle in its path, using Arduino as micro controller and IMU.

Inertial navigation is a self-contained navigation technique in which measurements provided by accelerometers and gyroscopes are used to track the position and orientation of an object relative to a known starting point, orientation and velocity. Inertial measurement units (IMUs) typically contain three orthogonal rate-gyroscopes and three orthogonal accelerometers as shown in Fig (2), measuring angular velocity and linear acceleration respectively.

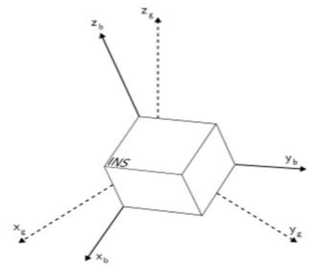

Fig. 2 The body and global frames of reference

Nearly all IMUs fall into one of the categories, the difference between the two categories is the frame of reference in which the rate-gyroscopes and accelerometers operate, IMU pinout and its configuration is shown in Fig (3).

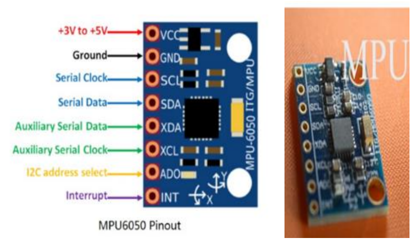

Fig. 3 MPU pinout and configuration

D. QUATERINION CALCULATION

The representation of relative orientation using Euler angles is easy to develop and to visualize. But computationally intense.

Also, a singularity problem occurs when describing attitude kinematics in terms of Euler angles. So that, the widely used method for attitude determination is "quaternion calculation" which is based on Euler's rotation theorem, a quaternion is a (4x1) matrix consists of a scalar part S and a vector part V.

Quaternion Calculation Properties

– No singularities.
– Convenient product rule for successive rotation.
– Computationally less intense compared to other parameters such as Euler angles or direction cosine matrix.
– Widely used as attitude representation parameter of rigid bodies such as space crafts.

IV. Guidance

A. Guidance method

Guidance is the process for guiding the path of an object towards a given point, which in general may be moving. The guided object may be a vehicle (a car, a boat, a missile, a spacecraft), The process of guidance is based on the position and the velocity of the target relative to the guided object, there are many guidance methods like:

- Pure pursuit guidance method.
- Proportional navigation guidance method.
- Parallel navigation guidance method.

Pure pursuit guidance method is used it is a two-point guidance method. which having one range r and one line of sight λ, along which r is directed as shown in Fig (4).

The geometrical rule of pure pursuit (PP) is simply, Let the pursuer M direct itself at the target T. More precisely, Let the velocity vector V_m coincide with r, i.e., with the LOS

In mathematical terms, PP requires that the vector product V_m x r be zero (but such that V_m *r > 0, otherwise one would have 'pure escape' rather than pure pursuit.) Note that PP is instantaneously planar by definition, the engagement plane being defined by r and V_T. If T is not maneuvering, then this plane is fixed md the engagement is planar. It is no wonder that the first generation of two-point guided weapons utilized this simple rule.

Fig. 4 An illustration for the definition of pure pursuit

One of the big problems involved with pure pursuit guidance is that accuracy deteriorates with range [4].

Guidance Law for Pure Pursuit.

Define an 'error' that quantifies the way the state of the guided object M differs from what it should be according to the geometrical rule, and apply control to reduce it. The most obvious guidance law for ordinary (i.e., σ= 0) pure pursuit would have the control proportional to the angle between V_m and r, in the direction of (V_m x r) x V_m. Alternatively, the (vector) error e would be proportional to the cross range which is the component of r across the flight line vector V_m - and also across the axis of M if the angle of attack a is negligible.

B. *Experiment*

In this application a TV camera was mounted on stabilized plat form. Via a USB link as shown in Fig (6), the operator saw the target at decreasing ranges, which greatly improved the accuracy, and transmitted commands to vehicle, such that the image of the target would remain at the center of the TV field-of-view Fig (7).

Then vehicle is directed toward the target with specific speed

Until reach certain limit then stop, let our plane be the z = 0 plane of a Cartesian frame of coordinates (FOC). Without loss of generality we assume that T moves along the line $x_T(t) = c$, $y_T(t) = v_T t$. Suppose M starts pursuing T from the origin, i.e., $x_M(0) = y_M(0) = 0$, and that the velocity ratio $K = v_M/v_T$ is constant. Bouguer has shown that M's trajectory yM(xM), or y(x) for the sake of brevity, is given by the equation (2).

$$\frac{K}{K^2-1}\left\{1+\frac{1}{2}\left[(K-1)\left(1-\frac{x}{c}\right)^{\frac{K+1}{K}}-(K+1)\left(1-\frac{x}{c}\right)^{\frac{K-1}{K}}\right]\right\}$$
(2)

If v_T is constant, the total time of guidance from equation (3) is:

$$t_f=\frac{y_f}{v_T}=\frac{k}{k^2-1}\frac{c}{v_T} \quad (3)$$

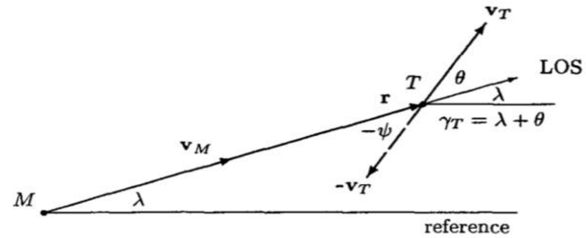

Fig. 5 Geometry of planar pure pursuit

The trivial case of head-on encounter is an exception on which no time need be wasted. Note. In all PP trajectories, the LOS MT is tangent at M to the trajectory of M. This property is an immediate result of the definition of this geometrical rule. Implementation of vehicle is shown in Fig (6) with field of view in Fig (7).

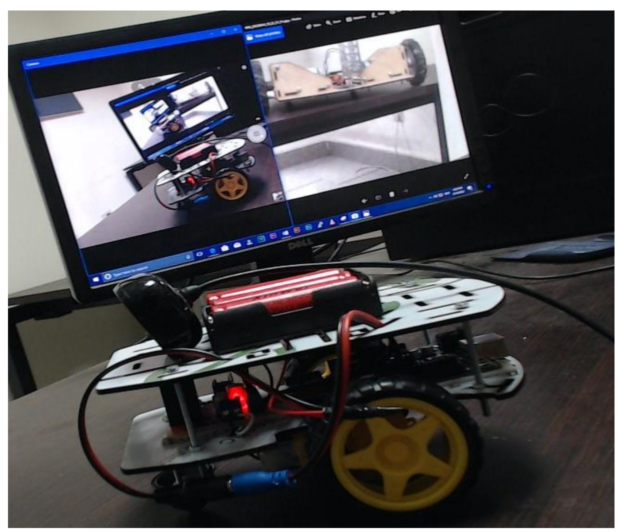

Fig. 6 implementation

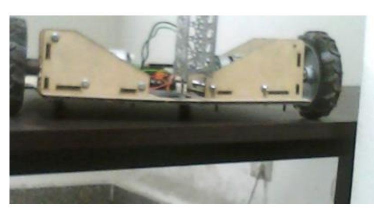

Fig. 7 camera field of view

V. RESULT

Camera successfully detect red object Fig (8), and determine its position, Fig (9).

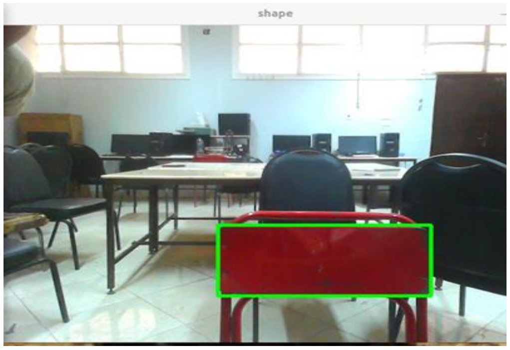

Fig. 8 detecting object

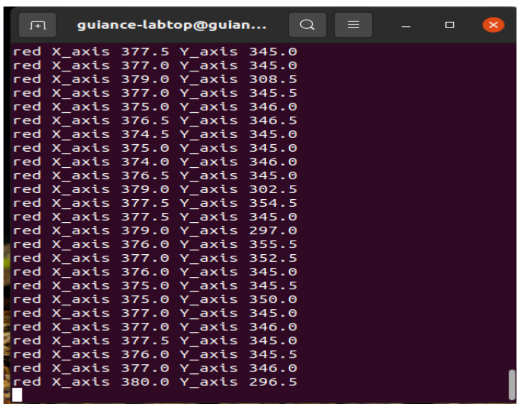

Fig. 9 position of detected object

IMU implementation and measurements is obtained as shown in Fig (10) and Fig (11) respectively to determine tilt angle in pitch and roll to achieve stabilization of camera platform.

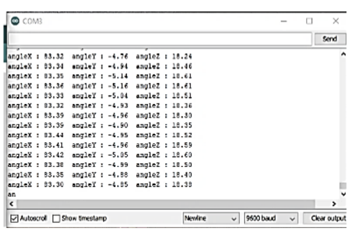

Fig. 10 IMU measurements

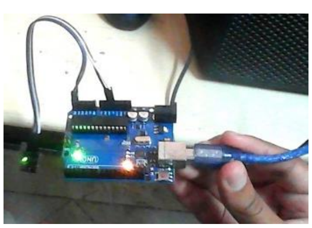

Fig. 11 IMU implementation

Then guidance method takes place and direct vehicle toward detected object (vehicle).

VI. CONCOLUSION

We can simulate a small GNC system by using low cost and low weight components with good accuracy performance by computer vision using small USB camera connected to computer, mounted on stabilized platform which is autonomously drifted using IMU , centering detected object with respect to field of view of camera to apply pure pursuit guidance method to direct vehicle toward detected vehicle in straight line with constant speed , applying what we learn in Guidance theory (I, II) in 4th year and Advanced Guidance and Control in 5th year to choose and apply an effective and suitable guidance law “Pure pursuit” to have best performance

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