Optical Sensor based Navigation of a Mobile Robot Using Optic Flow

Benjamin Arul .S

#*Assistant Professor, Dept. of Electronics & instrumentation Engg.,*
Jeppiaar Engineering college, Chennai, Tamilnadu, India

benjamin.gjf@gmail.com

Abstract--- Robotic Navigation means its ability to determine its position in its frame of reference and then to plan a target path towards some particular goal location. In order to navigate the robot in its environment, it require some representation in a particular form. Navigation can be defined as the addition of the three fundamental concepts: Self-localisation, Path Planning and Map-interpretation. The main thing is to calculate the optical flow of any image in an unknown environment. Based on the appearance and identifying the object the navigation has to be achieved for unstructured environments. This navigation uses optical sensors include laser-based range finder and photometric cameras using CCD arrays to extract the visual features required to the localization in the environment. However , there are a range of techniques for navigation and localization using vision information. Here ,we have calculate the optical flow for an image taken using optical flow algorithm with the help of image processing of matlab software.

Index terms: .Navigation, Optical flow, motion of camera,obstacle detection.

I.INTRODUCTION

Robotic Navigation is a very quickly developing field in the science of robotics.. It is very important to be able to determine with the position of a robot in its environment as well as to manage all the related mechanical, electronics and software constraints. The main aim of our work is to develop algorithms that will be used for robust visual navigation of autonomous mobile robot .The input given as a sequence of images that are continuously used by the navigation system while the robot is in motion. The image sequence is provided by a single vision system for a real physical robot. The robot has to be given instruction to understand its environment by extracting the important features from this image sequence ,in our case the optical flow is the principle value for navigation. The adopted strategy to avoid obstacles during navigation is to balance between the right and left optical flow vectors. The figure 1 shows the block diagram of the navigation algorithm

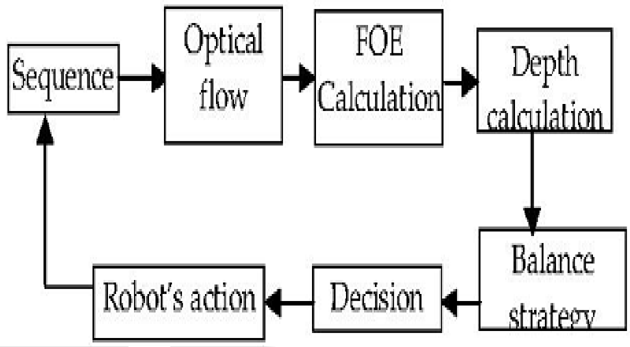


Fig 1. Obstacle avoidance svstem

First optical flow vectors are computed from an image sequence. In case of robot orientation, computation of FOE position in the image plane is essential and we have to analyze whether the obstacle is near or far away from the robot to avoid collision to achieve proper navigation.

II . MOTION ESTIMATION

The motion of an image sequence produced by the camera is achieved by the object movement in 3-D scene or by camera in motion.

The motion of the objects and the camera produces 2-D motion on the image plane through some suitable projection system. This 2-Dimensional motion, also called as apparent motion or optical flow that needs to be recovered from intensity and colour information of a video sequence. We have chosen Horn and Schunck technique to calculate the optical flow, and then we use it for navigation options such as trying to balance the flow of left side and right side to avoid obstacles

III. HORN AND SCHUNCK ALGORITHM

The **Horn–Schunck method is** a global method of calculating optical flow which produce a global constraint of *smoothness* to solve the *aperture problem* .In our project we chose Horn and schunck algorithm to estimate the optical flow to detect the obstacle using matlab.

A. *Mathematical Details*

The Horn- Schunck algorithm prefers smoothness in the flow over the entire image. Thus, it reduces the change in its occurrence of flow and prefers solutions which show more smoothness.

The flow is considered as global energy which is need to be minimized. This function is given for two-dimensional image streams as:

$$E = \iint [(I_X\ u + I_Y\ v + I_t\ ))^2 + \alpha^2\ (\ \| \nabla_u\ \|^2 + \| \nabla_v\ \|^2)]dxdy$$

where *Ix ,Iy and It* are the derivatives of the image intensity

$\vec{V} = [u(x,y), v(x,y)]^T$ is the optical flow vector, and the parameter α is a constant. Maximum values of α lead to a smoother flow. This functional values of vectors can be reduced by solving the Euler–Lagrange equations. These are

$$\frac{\partial L}{\partial u} - \frac{\partial}{\partial x}\frac{\partial L}{\partial u_x} - \frac{\partial}{\partial y}\frac{\partial L}{\partial u_y} = 0$$

where *L* is the integrand of the energy equation, giving

$$I_x\left(I_x\ \ u + I_y\ \ + I_t\ \right) - \alpha^2\ \Delta u = 0$$

$$I_y\left(I_x\ \ u + I_y\ \ + I_t\ \right) - \alpha^2\ \Delta v = 0$$

where subscripts again denote partial differentiation and $\Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$ denotes the Laplace operator .Normally the laplacian is calculated numerically using finite differences and may be written as $\Delta u(x,y) = \bar{u}$(x,y)-u(x,y) where $\bar{u}$(x,y) is a weighted average of *u* calculated in a neighborhood around the pixel at location (x,y). Using this notation the above equation system may be written

$$(I_x^2 + \alpha^2\ )u + I_x\ I_Y\ v = \alpha^2\ \bar{u} - I_x\ I_t$$

$$I_x\ \ I_y\, u + \left(I_y^2\ \ + \alpha^2\ \right)v = \alpha^2\ \bar{v} - I_y\ I_t$$

which is linear in *u* and *v* and may be solved for each pixel in the image. However, the solution depends on the values of the flow field, it must be repeated until the values have been updated. The following function can be derived as :

$$u^{k+1} = \bar{u}k - I_X \frac{(I_x\ \ \ \bar{u}k + I_y\, \bar{v}k + I_t)}{\alpha^2\ + I_x^2\ + I_y^2}$$

$$v^{k+1} = \bar{v} - I_y \frac{(I_y\ \ \bar{u}k + I_y\, \bar{v}k + I_t)}{\alpha^2\ + I_x^2\ + I_y^2}$$

Where the superscript *k+1* refers to the next iteration, which is to be calculated and *k* is the last calculated result. This can be used with the help of Jacobi method when analysing all pixels of an image comparatively.

B. *Properties*

Advantages of the Horn– Schunck algorithm include that it gives a high density of flow vectors. On the negative side, it is more worse to noise than local methods.

IV. DESCRIPTION

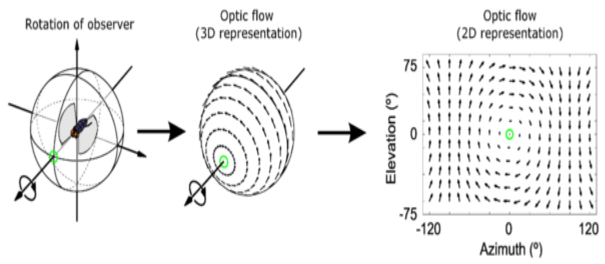
As an observation point directed towards the environment, the pattern of light reflected to that point changes continuously, creating optic flow. This optical flow contains information about both observation called the Focus of expansion (FOE), the Time To Contact (TTC), and the depth.

Optical flow or **optic flow** is the pattern of apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer (an eye or a camera) and the scene. Optical flow was used by scientific researchers in many areas such as detecting object and tracking, extracting plane, detecting moving objects, robot navigation and visual scenes of total distance of vehicle travelled .An information obtained from optical flow has been considered as being very useful for controlling air vehicles. The application of optical flow includes the problem of referring not only the motion of the observer and objects in the allocated scene, but also the structure of objects as well as the environment. image. If the sum of the magnitude of the flow reaches a certain threshold, it is assumed that there is an obstacle in front of the robot.

Based on this optical flow field, we have to calculate the both left and right half of the observed

A.*Representation of optical flow*

Motion estimation and video compression have developed as a main aspect in the research of optic flow. Based on the motion estimation techniques, the optical flow is more or less similar to a motion field. It refers not only to determine the flow itself but also to estimate its structure.



Motion estimation and video compression have developed as a main aspect in the research of optic flow. Based on the motion estimation techniques, the optical flow is more or less similar to a motion field. It refers not only to determine the flow itself but also to estimate its structure.

The application of optical flow includes the problem of including not only the observer's motion and objects in the scene, but also the structure of objects and the environment around it. Since awareness of motion and the generation of mental maps of the structure of our environment are critical components of vision, the conversion of this inward ability to a computer capability is similarly crucial in the field of machine vision.

V.PROPOSED METHOD

Consider an image sequence and the optic flow vector has to be calculated. The calculation of FOE of a particular image is essential to take an appropriate decision in an image plane so that the control law will get estimated

Finally the depth map is to be calculated to know ,whether the obstacle is nearer or it is at a distance to give an alarm of attention or it is far away from the robot so that it may get aware of it. Here we calculate the optical flow with an particular point of focus of expansion.

A.*Focus of expansion*:

For *translational* movement of the camera, the motion of the image everywhere is directed away from a singular point corresponding to the projection of the translation vector on the plane of the image. This point, is called the Focus of Expansion (FOE) and it is computed based on the principle that flow vectors are oriented in specific directions relative to the FOE.

The horizontal component hL of an optic flow vector L to the left of the FOE points leftward while the horizontal component hR of an optic flow vector R to the right of the FOE points rightward, as shown in fig.

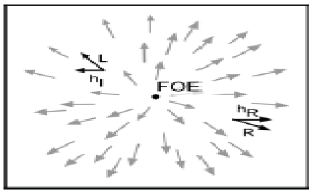


Fig:2 FOE Calculation.

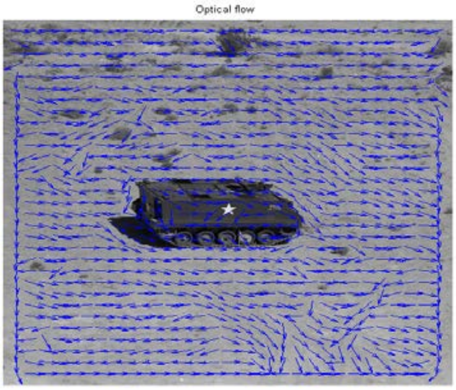
In a full optic flow field the horizontal path of the FOE, corresponding to the position about which a majority of horizontal components separate from its initial position , can be estimated using a simple counting method totally the signs of the horizontal components centered on each image location. At a particular point whenever the divergence is maximized, the difference between the number of hL components to the left of the FOE and the number of hR components to the right of the FOE will be minimized. Similarly we can calculate the vertical location of the FOE by identifying the position about which a majority of vertical components (vu and VD)diverge from a singular point.

The image velocity can be defined as a function of the camera parameters and divide into two terms mainly based on the rotational *(Vt)* and translational components *(Vr)* of camera velocity *(V)* respectively. The rotational part of the flow field can be computed from appropriate data (e.g. the camera rotation) and the focal length.

B. *Methods for determining optical flow*

- Phase correlation – deals with an inverse of normalized cross-power spectrum.
- Block-based methods – reduces the sum of squared differences or sum of absolute differences, or maximizing normalized cross-correlation.
- Differential methods of estimating optical flow, based on partial derivatives of the image signal and or the sought flow field and higher-order partial derivatives.
- Lucas–Kanade method – mainly refers image patches and an affine model for the flow field.
- Horn–Schunck method – optimizing a functional based on residuals from the brightness constancy constraint, and a particular regularization term expressing the expected smoothness of the flow field.
- Buxton–Buxton method – depend upon a model of the motion of edges in image sequences.
- Black–Jepson method – deals with the coarse optical flow through correlation.
- General variation methods – a range of modifications/extensions of Horn–Schunck, using other data terms and other smoothness terms.

VII. IMPLEMENTATION OF WORK



Here we are considering a tanker image .By using Horn -Schunck algorithm we can estimate the optic flow. Using this image sequence with the help of camera optical flow can be calculated by diagnosing the smoothness in the flow vectors we achieved.

VII .CONCLUSION & FUTURE WORK

The paper describes how, the optical flow provides a robot the ability to avoid obstacles, using the control laws , the main goal is to detect the presence of objects close to the robot based on the information of the movement of the brightness and consistency of an image. The major difficulty to use optical flow in navigation, is that it is not clear what causes the change motion vector or change of illumination. Further improvement of the developed method is possible by including other sensors (sonar, infra red,...) in addition with camera as a sensor. Navigation can be improved with the usage of optimization techniques in future by using the depth of an image calculated and can be implemented.

REFERENCES

[1] J. Santos-victor and A. Bernardino, 'Visualbehaviors for binocular tracking', Robotics and Autonomous Systems, pp. 137-148, 1998.

[2] D.J. Braunegg, “Marvel: A System that Recognizes World Locations with Stereo Vision,” IEEE Trans. Robotics and Automation, vol. 9, no. 3, pp. 303-308, June 1993.

[3] .[Giachetti et al., 1998] Andrea Giachetti, Marco Campani, and Vincent Torre. The use of optical flow for road navigation. IEEE Transactions on Robotics and Automation., 14(1):34–48, February 1998.

[4] A. Dev, B. Krose, and F. Groen, “Navigation of Mobile Robot on the Temporal Development of Optical Flow” in Intelligent robots and systems. vol.II, 1997, pp.558-563.

[5] G. N. DeSouza and A. C. Kak, “Vision for mobile robot navigation:A survey,” IEEE Trans. Pattern Anal. Mach. Intell., vol. 24, no. 2, pp. 237–267, Feb. 2002.

[6] M. Mata, J. M. Armingol, A. de la Escalera, and F. J. Rodriguez, “A deformable model-based visual system for mobile robot topologic navigation,” in Proc. IEEE/RSJ Int. Conf. Intell. Robots Syst., Las Vegas, NV, Oct. 2003, pp. 3504–3509.

[7] S. Atiya and G.D. Hager, “Real-Time Vision-Based Robot Localization,” IEEE Trans. Robotics and Automation, vol. 9, no. 6, pp. 785-800, Dec. 1993.

[8] J. Borenstein and Y. Koren, “The Vector Field Histogram–Fast Obstacle Avoidance for Mobile Robots,” IEEE Trans. Robotics and Automation, vol. 7, no. 3, pp. 278-288, June 1991.

[9] H.I. Christensen, N.O. Kirkeby, S. Kristensen, and L. Knudsen, “Model-Driven Vision for In-Door Navigation,” Robotics and Autonomous Systems, vol. 12, pp. 199-207, 1994.