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Visual Tracking of Objects for a Mobile Robot using Point Snake Algorithm

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Abstract

Path Planning is one of the important fields in robot technologies. Local path planning may be done in on-line modes while recognizing an environment of robot by itself. In dynamic environments to obtain fluent information for environments vision system as a sensing equipment is a one of the most necessary devices for safe and effective guidance of robots. If there is a predictor that tells what future sensing outputs will be, robot can respond to anticipated environmental changes in advance. The tracking of obstacles has a deep relationship to the prediction for safe navigation. We tried to deal with active contours, that is snakes, to find out the possibilities of stable tracking of objects in image plane. Snakes are defined based on energy functions, and can be deformed to a certain contour form which would converge to the minimum energy states by the forces produced from energy differences. By using point algorithm we could have more speedy convergence time because the Brent's method gives the solution to find the local minima fast. The snake algorithm may be applied to sequential image frames to track objects in the images by these characteristics of speedy convergence and robust edge detection ability.

1. Introduction

Since 1960's robots have started to give munch benefits to human world in many industrial field. Nowadays robots for hospitals, homes that have closer relationships to human are being researched, developed, and produced. Unlike manipulators applied to many industrial fields, mobile robots may give other sides of advantages such as exploring dangerous fields to human, automatical moving certain objects from one side to the other, and driving a car by intelligent devices instead of human driving for convenience and safety.

Path Planning is one of the important fields in robot technologies. That may be divided into two major categories ; global path planning, local path planning. Based on the perfect knowledge on the environment in which robot will be operated global path planning is executed in off-line modes. Local path planning may be done in on-line modes while recognizing an environment of robot by itself. In dynamic environments there may be lackness of information of those because many moving obstacles such as men, moving carts, and other mobile robots may exist in there. So local path planning have to be done for supplements of dynamic environmental information to the results of global path planning to make mobile robots more reliable devices for human world.

One of the typical mobile robots is AGV, that is Autonomous Guided Vehicle, and AGVs are used for automatical moving certain things, goods, and raw materials in industry. In a certain industry of Japan there are fixed tracks or rails made of magnetic guiding lines or reflecting tapes on the floor in a industry to guide AGVs safely for avoiding the complexity generated from designs of paths and control problems. But this fixed track method for guiding AGVs needs more money for installing, managing and changing pre-designed tracks. If a AGV goes on wrong way from the track by certain causes, the recovery to the track is not easy problem. Because of these problems of fixed track method path planning using software base method has been more important. To obtain fluent information for environments vision system as a sensing equipment is a one of the necessary devices for safe and effective guidance of robots.

Many studies on motion planning in uncertain and static environment have been done by many researchers. But operations in real world are not stationary problems. Much lackness of information for environment may request controller larger safety margins and shorter sampling periods. Because the trajectories of obstacles can't be known before planning a global trajectory, a method of using on-board sensors for handling immediate moving obstacles must be needed for safe navigation. The refining robot's motion to deal with moving and unexpected obstacles have to be made based on sensing information. If there is a predictor that tells what future sensing outputs will be, robot can respond to anticipated environmental changes in advance[4]. Though this research doesn't cover a prediction idea, a tracking of obstacles or certain objects has a deep relationship to prediction for safe navigation. We tried to deal with active contours, that is snakes, to find out the possibilities of stable tracking of objects in image plane more systematically.

2. Architecture of a car-like mobile robot

We have been researching on path-planning, navigation and control of a car-like mobile robot which has a vision system with single CCD camera as a main environment sensor. Fig.1 is a picture of our mobile robot and Fig.2 is its configuration diagram.

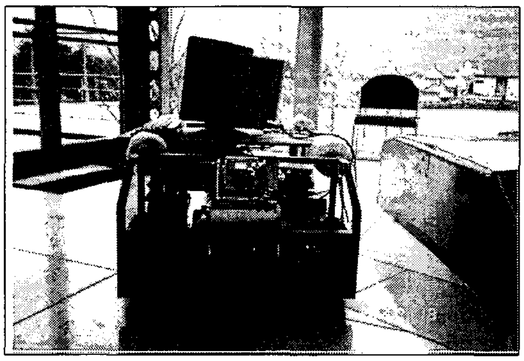

Figure 1. Our car-like mobile robot

There are two front wheels for steering and two rear wheels for locomotion by DC electric motor. The front wheels can be controlled by controller board using stepping motors. Stepping motor controlling boards are interfaced to main controller board, that is 486 NEC PC. They are commanded to control steeping motors and give steering angle data to main controller. Another stepping motors and their controllers are existed for the controls of tilt angle and fan angle of

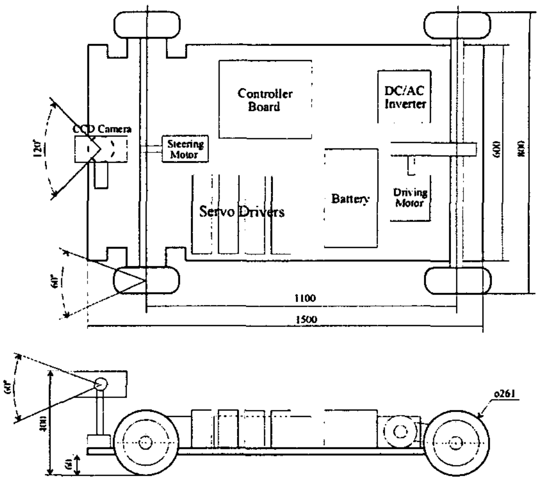

Figure 2. A configuration diagram for our car-like robot

CCD camera system. There are image grabber and processor in the main controller to process visual information. there is a Ni-Cd battery package to supply DC power for servo-drivers, DC motor for locomotion and stepping motors, and a DC/AC converter to supply AC 220V power for PC and monitor.

3. Active contour for tracking objects

The tracking methods such as difference image method and spatio-temporal descent method have been researched by many researchers. These methods have some demerits those are long calculation time and the possibilities of successful identification of objects.. Snakes, that is active contour models, are deformable contours that have been used in many image analysis applications, including the image-based tracking of rigid and nonrigid objects. The snake equations of motion provide flexible tracking mechanisms that are driven by simulated forces derived from time-varing images[2].

Snakes are defined based on energy functions, and can be deformed to a certain contour form which would converge to the minimum energy states by the forces produced from energy differences. Snakes were introduced by Kass in 1987, and he modelled objects by snake functions. He optimized the energy states by using variational calculus. In 1988 Amini solved some problems such as the phenomenon of concentration of snakes points to a ceratin point and instability through active contour model by using dynamic programming method. Laurent suggested 'Balloons model' which gives a kind of expansion force to prevent contraction phenomenon[1].

Snake is a kind of optimal energy spline that can be expressed equation (1) which has arc length 's' as a parameter.

$$\vec{v} = (x(s), y(s)) \qquad (1)$$

Using this snake, active contour, the edges of objects can be extracted because snake has a tendency of natural moving to the boundaries of objects due to energy difference. So the definition of energy function is more important subject in active contour problems because snake moves along this energy difference. At the 1st stage Kass configured energy functions comprised of internal energy, image energy and external energy like equation (2).

$$\begin{aligned} E_{snake} &= \int_0^1 E_{snake}((\vec{v})(s))\, ds \\ &= \int_0^1 (E_{\text{int}}(\vec{v})(s) + E_{\text{image}}(\vec{v}(s)) \\ &\quad + E_{ext}((\vec{v})(s)))\, ds \end{aligned} \qquad (2)$$

3.1 Internal energy

This energy term make the energy contour have smooth curved form and have no discontinuous points in a snake. Kass defined his internal energy as the function that can be divided into two sub energy terms like equation (3).

$$\begin{aligned} E_{\text{int}} &= \frac{1}{2} (E_{cont} + E_{curv}) \\ &= \frac{1}{2} (\alpha(s) \, |\vec{v_s}(s)|^2 + \beta(s) \, |\vec{v_{ss}}(s)|^2) \end{aligned} \qquad (3)$$

where subscript letter 's' means the derivative of 's', and α, β are the weighting coefficients. The first term of above equation prevents the discontinuity of snake because it was gained by differentiating its snake. If a snake has discontinuities on its contours or radical variation then this energy term should have relatively big values. So by the characteristics of snake for finding the minimum state of energy snake doesn't have any tendency to have discontinuity.

The second term is called the curvature energy term because it prevents radical curvature on its contour. It can be produced by second derivatives.

3.2 Image energy

The image energy term is comprised of 3 terms such as line energy, edge energy, and terminal energy like equation (4).

$$E_{\text{image}} = \gamma_{\text{line}} E_{\text{line}} + \gamma_{edge} E_{edge} + \gamma_{ter} E_{ter} \qquad (4)$$

The line energy term may be gained easily using the intensities, I(x,y), from each pixel point of image, and likes bright or dark areas. The edge energy term, E_{edge} , is a function for the consideration of edge of the objects in the image. E_{edge} have great values at the points at which the difference of intensities are more big than surrounded ones. Above equation (4) may be changed to equation (5) by considering discrete system.

$$\begin{aligned} E_{snake} = \sum_{i=1}^{N} (& \alpha_i(s) \, |\vec{v_i} - \overrightarrow{v_{i-1}}|^2 \\ & + \beta_i(s) \, |\overrightarrow{v_{i-1}} - 2\vec{v_i} + \overrightarrow{v_{i+1}}|^2 \\ & + \gamma_i(s) (- |\nabla I(x,y)|^2)) \end{aligned} \qquad (5)$$

Kass used variational calculus for finding the minimum energy states, and configured some Euler's equations. But his solution should find the inverse of N by N matrix for a snake of N points. There are much computational time for finding his solution. By the way snake forces have somewhat small magnitude at the area in which the derivatives of gradient term is zero, so snake would move to the edges very slowly.

4. Application of the Point algorithm[1]

The energy function of Kass may have much computation time and instability, and a method using dynamic programming method gives somewhat complex calculation strategies. To overcome this mathematical complexity and instability of snake Jin-Woo Yi proposed the point algorithm using the steepest descent method and Brent's method. He gained the directions of snake forces from the application of steepest descent method, and the minimum energy point by using Brent's method at the directions of snake forces. So he had a more fast convergence speed for a calculation of the minimum energy point, and could exclude mathematical instability due to noise and the differentiation of the energy function. Also he used recursive Gaussian filtering method to filter the noise in the image and to gain the gradients of image intensity without direct differentiating the energy function

4.1 Energy function of point algorithm

The energy function is comprised of 3 major terms such as continuous energy, curvature energy, and image energy like equation (6).

$$E_{snake} = \sum_{i=1}^{N} (\alpha_i E_{conti} + \beta_i E_{curvature} + \gamma_i E_{image}) \quad (6)$$

E_{conti} is a energy function for the continuous formation of snake contour, and maintains the distance between the nodes of snake within the average distance of all the nodes. It can be

$$E_{conti} = \left(\frac{\bar{d} - |\vec{v}_i - \vec{v}_{i-1}|}{\bar{d}} \right)^2 \quad (7)$$

represented by equation (7).

where v_i and d mean the ith node, the average distance between two nodes respectively.

$E_{curvature}$ are designed to maintain smooth curved form of contour using two vectors made of three surrounding nodes like equation (8).

$$E_{curvature} = \beta_i \left| \frac{\vec{u}_i}{|\vec{u}_i|} - \frac{\vec{u}_{i+1}}{|\vec{u}_{i+1}|} \right|^2 \quad (8)$$

$$where\ \vec{u}_i = \vec{v}_i - \vec{v}_{i-1},\ \vec{u}_{i+1} = \vec{v}_{i+1} - \vec{v}_i$$

E_{image} may be the lowest value when the gradient of the pixel positioned (x,y) has maximum value. With this characteristics he can find edges of the objects easily. E_{image} can be expressed as equation (9). Threshold value should be selected a value above the maximum gradient value squared in the image for the exclusion of minus values of the energy function.

$$E_{image} = \frac{Threshold - |\nabla I(x,y)|^2}{Threshold} \quad (9)$$

4.2 Snake forces of point algorithm

Snake forces can be generated using the energy function. to maintain the average distance between two surrounding nodes, to make snake's form smoothly curved and to find the edges of the objects in the image. The magnitudes of the snake forces don't be used to find the minimum energy points but the directions of the snake's forces would be used to give the directions of the steepest descent gradient. If the directions of the snake forces are determined, then the minimum of the energy points may be calculated by using the Brent's method rather fast.

5. Simulation

To know the possibilities of using the snake algorithm for visual tracking in sequential images we apply the point snake algorithm to find the edges of a ball on the green grass in figure 3. We assigned 8 nodes as a discrete points on the snake contour, chose appropriate weighting parameters heuristically such as α, β, γ .

Figure 3. A figure for simulation

In figure 4 (a) an object, a ball on grass, is represented, and in figure 4(b) eight snake points surrounded a ball at first gradually moves to the edges of a ball by the snake forces. It converged to the edge at all time through another iteration steps after the arrival of the edge.

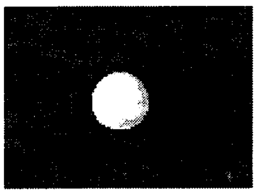

Figure 4(a) an object

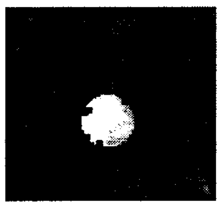

Figure 4(b) Moving Snake

6. Conclusion

We applied the snake algorithm to find the edge of the object in the image using point method for the speedy convergences to the minimum energy points and the stability of the mathematical stability because of no use of the differentiation. Energy function can be formulated based on image information to maintain the average distance between two surrounded nodes, to make snake's contour smooth form and to make snake move to the maximum gradient values for reaching the edge points. We can make image processing to find the edges more systematically and analytically because of using mathematical energy function rather than using heuristic approach though some parameters have to be determined by heuristically through simulations in snake methods. By using point algorithm we could have more speedy convergence time because the Brent's method gives the solution to find the local minima fast. The snake algorithm may be applied to sequential image frames to track objects in the images by these characteristics of speedy convergence and robust edge detection ability.

But if the object in the image moves so faster that the snake's contour can't follow the movement of the object then the tracking may be failed. So the Kalman snakes may be a candidate for more speedy tracking of the objects in the images because Kalman filter consider the movement of the objects. Initial snakes in the sequential images may be selected based on the consideration of the objects. This concept may be extended to the prediction of the motion of the objects, and this prediction may result in safer navigation for moving obstacles.

7. References

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