Implementation of Adaptive Movement Control for Waiter Robot using Visual Information

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ABSTRACT

Robovie-R2 [1], developed by ATR, is a 110cm high, 60kg weight, two wheel drive, human like robot. It has two arms with dynamic fingers. It also has a position sensitive detector sensor and two cameras as eyes on his head for recognizing his surrounding environment.

Recent years, we have carried out a project to integrate new functions into Robovie-R2 so as to make it possible to be used in a dining room in healthcare center for helping serving meal for elderly. As a new function, we have developed software system for adaptive movement control of Robovie-R2 that is primary important since a robot that cannot autonomously control its movement would be a dangerous object to the people in dining room. We used the cameras on Robovie-R2's head to catch environment images, applied our original algorithm for recognizing obstacles such as furniture or people, so as to control Roboie-R2's movement. In this paper, we will focus our algorithm and its results.

Keywords: Adaptive motion control, Server-robot, Computer vision, Image processing, Digital images, 3D Graphical data

1. Introduction

In Japan, the population of people of advanced age has been increasing rapidly, conversely, the population of younger keeping decreased. This is called a society composed largely of elderly people and with a low birth rate. More and more elderly people may ask for the help of nursing care, however, might not be satisfied because of the short of hands.

As one of the national measures against this problem, the application of robotics techniques to the area of healthcare is considered an effective and realistic solution. Based on the remarkable technologies of electric, mechanics and materials, Japanese have made it possible to construct various human like robots that looks similar to human and can behave like human beings.

For example, Toshiba's small talking robot ApriPoko [2] is able to recognize human voices, learn a range of instructions, and do the remote control of TV for elderly people. Toyota's Mobiro [3], a sort-of motorized wheel chair, can scoot people around their neighborhood and is able to cope with uneven surfaces. Toyota's Robina has been designed for face-to-face communication with humans. The robot can serve as a guide at the Toyota Exhibition Hall. It can automatically navigate a route through obstacles and, by holding a pen in one hand and a piece of card in the other, sign its signature on the card. Toyota's highly intelligent robots are even capable of playing the trumpet, or playing the violin. Honda developed ASIMO [4] that can do stepping back and walk based on the predicted movement of oncoming people. ASIMO can also perform tasks such as carrying a tray and pushing a cart. All these robots are expected to be useful for the people of advanced aged in the near future.

As a human-like robot on the market, Robovie [1] is the center of attention. Robovie is a robot published by the Media Information Science Laboratories of the Advanced Telecommunications Research Institute International (ATR). It is a humanoid robot that has a head, two arms, and two wheels for moving. It has an overhead camera and two eye cameras for catching the images of surrounding environment. It also has ultrasonic distance sensors and voice dialog capability.

Since ATR started to sale Robovie to public, many researchers have used Robovie in different areas for different purposes. For the purpose of healthcare and wellness, we have carried out a project of integrating new functions to Robovie-R2, so as to make the robot be adaptable for carrying a tray in a dining room in healthcare centers. We decided to use Robovie-R2 because of its excellent mechanism. The robot can do various dynamic movement of the upper body while moving and balancing on its two wheels. Even pushed by somebody, the robot could still stand safely. Such ability is necessary as a serving robot.

However, working as a serving robot, Robovie-R2 is still functionally impossible and with problems that have to be solved. Basically, Robovie-R2 cannot decide its movement by itself. It can move forward or backward but always need the instruction from human being. It cannot automatically navigate a route through obstacles in the environment. Also, it cannot prevent itself from colliding with oncoming people by predicting their movement.

2 Proposed System

Therefore, our research is aimed at solving this problem. We used two types of visual information:

- Digital images that are from the three cameras on Robovie-R2's body. One camera is over its head, another two are on its eyes.
- Three dimensional graphical data that describes the dining room by representing the room's size, layout, tables, chairs in geometrical data.

Based on the above visual information, we are able to construct an adaptive movement control system for Robovie-R2 through following processes:

- Construct 3D graphical data of dining room.
- Construct 3D graphical data of furniture, such as tables, chairs, cards, or desks.
- Integrate 3D furniture data together with the dining room's data. As a result, the layout of the dining room is represented with geometric data. Based on the data of the layout of dining room, calculate the possible routes from a specified starting position to a specified ending position. Make order of the possible routes according to the length, select the shortest route as the best choice.
- Let Robovie-R2 move along the chosen route. While moving, detect obstacles and oncoming people. When an obstacle appears, control the Robovie-R2 to make a stop or adjustment of moving direction.

In the following sections, we will describe the route choice algorithm and the obstacle detection algorithm in detail.

2.1 Construction of Robot Navigation

Figure 1 shows the block diagram of the system about implement. The robot takes out the information in the dining room that becomes its environment from two or more cameras. The subsequent procedure is shown as follows.

1. In the image recognition processing part, the situation of the real world is understood from the obtained camera images.
2. In the robot inducement system, the transmission of understood information is received from the image recognition processing, and the reflection has been done on the virtual space map.
3. In the action decision rule part, a strategic action of the robot is decided by using the virtual space map.
4. In the algorithm part for the robot locomotion, details of a consecutive path are formed.
5. The operation that acts on the real world by the work such as spreading a table is done by transmitting the route guidance information of the robot to the actuator part of the robot.

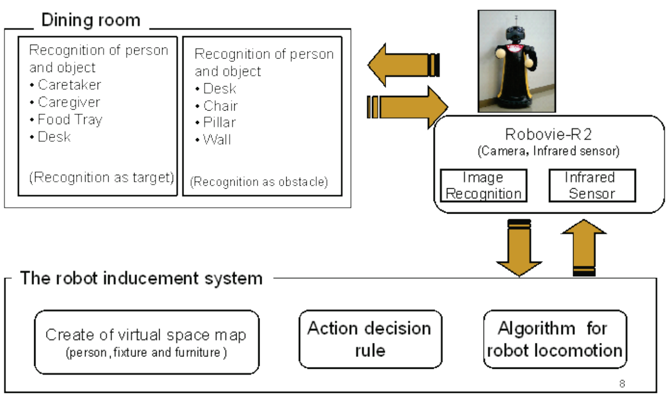


Fig. 2 Construction of Robot Nagivation

2.2 About the robot

An experimental robot is Robovie-R. ver.2.

The reason to adopt Robovie-R ver.2 is as follows.

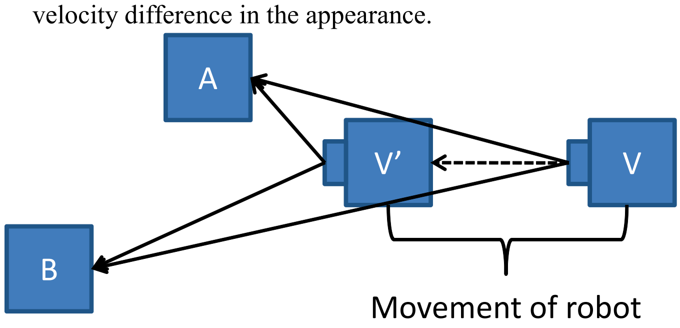
- The platform of the robot operates by Windows XP.
- The development environment for the robot has been already provided
- Tactile sensor, range sensor by infrared rays, image sensor with camera, voice input/output with mike and speaker
- The wireless LAN base station is built into the robot.
- It is possible to remotely control.
- The demonstration as the communications robot has been possible by some medical facilities.

3 Recognition system by robot

In this Paper, it chiefly explains the recognition system that uses the visual information using the robot vision. We have explained about the robot inducement systems with other papers.

3.1 Obstacle avoidance

The optical flow with the compound eye was used as a technique for acquiring 3-dimentional information that became a mission-critical information source when the robot acted. In addition, we have used seeming the movement of the object by the robot's moving by a relative velocity difference in the appearance.



$$\frac{AV}{AV'} > \frac{BV}{BV'}$$

Fig. 1 Acquisition of artificial three-dimensional information

For instance, forward object seems to move earlier than rear object when there are two objects as shown in Figure 2.

First, the image of the robot is used, the optical flow by the Lucas&Kanade method is used, the entire image is processed, and the size of the movement of the image is acquired. The entire image is assumed to be a block image of 8×8, and the median of the value of the movement is acquired.

When you assume the environment such as assumed robots and dining rooms, as shown in Figure 3, it is thought the obstacle that should be avoided to a right, left and upper area in the emergency in consideration of the course of the robot is not found. However, when the distance with the camera is short, a very big optical flow is detected. Then, an optical flow outside the course decided to be ignored because of the course provided by the camera and the robot. As a result, it became possible to reduce the amount of the image processing that became an object to the half. In addition, a big place of the detected optical flow was detected. It has been possible to detect the direction and the place that became an obstacle for the robot by this technique.

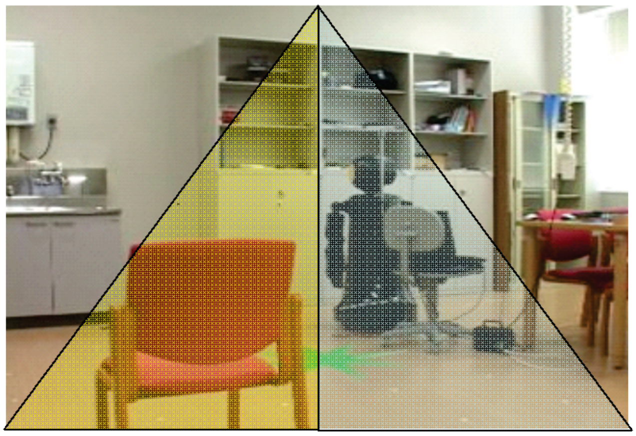


Fig. 3 Image and course

Next, we aim to recognize the position of the obstacle. It becomes possible to detect a rear object by doing mask processing and the template matching again to the optical flow of the detected forward object.

The recognition of the state of the 3-dimentional becomes possible by the stereovision because it executes similar processing with another camera.

The accuracy improves by increasing of the number of detection successes of future requested by the optical flow of the image in the same point for this system to obtain the minimum square solution of the 3-dimentional value.

However, when future detections are one camera image, the state of the 3-dimentional cannot be recognized. In this case, the 3-dimentional feature detection that should be restored is forecast. It forecasts with the kalman filter.

3.2 Kalman Filter

The kalman filter used in this system is described.

The state variable of the extraction point of the object at time t is defined by the vector that consists of the following six parameters.

$$X_t = [x_t \;\; y_t \;\; z_t \;\; vx_t \;\; vy_t \;\; vz_t] \quad (1)$$

x, y, and *z* show three dimension position of the object. *vx, vy,* and *vz* show *x, y,* and *z* direction element at the speed respectively.

Moreover, the state transition model is defined as follows.

[Transition from t to t+1]

$$X_{t+1} = FX_t + w_t$$

$$P_{t+1} = FP_tF^t + Q_t \qquad F = \begin{bmatrix} 1 & 0 & 0 & \Delta t & 0 & 0 \\ 0 & 1 & 0 & 0 & \Delta t & 0 \\ 0 & 0 & 1 & 0 & 0 & \Delta t \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

W_t is a disturbance vector of the 4th Dimension added to the axis. The average assumes and already-known of 0 and the covariance is the values of Q_t. F shows the transition procession in the state, and this system uses the model of the uniform motion. Δ t shows the timeing between frames.

[Observation in t+1]

$$Y_{t+1} = HX_{t+1} + V_t \quad H = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix} \quad (3)$$

The value of v_t is an observation error vector of the 3th Dimension, and it becomes 0 on the average. The covariance assumes already-known with R_t. Both w_t and v_t are discrete gaussian white noises. At each other, and no correlation to state quantity X_t, the algorithm of the kalman filter by the above-mentioned model becomes the following expression.

[Filtering]

$$X_{t+1} = \left(\overline{P}_{t+1}{}^{-1} + H^T R_t{}^{-1} H\right)^{-1} \bullet \left(\overline{P}_{t+1}{}^{-1}\overline{X}_{t+1} + H^T R_t{}^{-1} Y_{t+1}\right)$$

$$P_{t+1} = \left(\overline{P}_{t+1}{}^{-1} + H^t R_t{}^{-1} H\right)^{-1}$$

The state vector is updated by the above-mentioned expression, and the forecast is calculated by expression (2).

It becomes possible to recognize the state of the obstacle of 3D robustly by the above-mentioned technique about the constant velocity rectilinear motion.

3.3 Object tracking function

As it was the above-mentioned, the object tracking function to always specify the moving destination is needed at the same time as recognizing the obstacle avoidance with two cameras. The object tracking is done by using the following procedures.(Figure 4)

1. The pursued object is decided by using the PC's mouse.
2. The object is specified by using dynamic contour methods (Snake) as outline extraction processing.
3. The pursuit object in the image shown by RGB color specification has been converted into the HSV color specification.
4. The pursuit color element image has been made from a present frame.
5. The moving object is pursued by using the pursuit color element image.

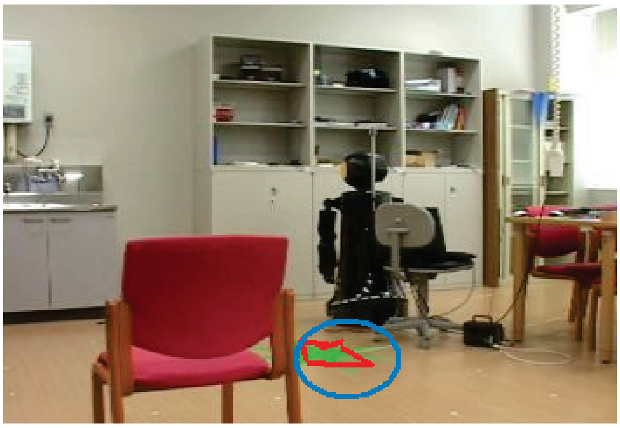


Fig. 4 Object tracking function

4 Routing Planning Program

It is necessary to plan the path that the robot should move by using the obstruction detection and the object tracking function as explained in the previous chapter.

In this chapter, it pays attention to the route planning problem to use the potential approach.

That is, the robot needs the potential function that receives the repulsive force from obstacle and attracting force from goal. If the robot is moved in a maximum likelihood direction of the designed potential function, the robot becomes possible to reach the goal while avoiding the obstacle it. Concretely, potential energy ($U_G(x)$) until reaching a goal and attracting force ($F_G(x)$) are generated by using the following expressions.

$$U_G(x) = \frac{1}{2}k_G(x - x_G)^2$$

$$F_G(x) = -\nabla U_G(x)$$

At this time,

- x: Present place of the robot.
- x_G: Position vector to the target.
- k_G: A constant parameter

x is a position of the robot, F_G works as attracting force, and the movement of the robot is controlled.

On the other hand, the action that avoids the obstacle can be formulated by using decreasing potential field proportional to parting.

$$U_O(x) = \frac{1}{2}k_O\left(\frac{1}{d} - \frac{1}{d_0}\right)^2 \quad if\ d \le d_0\ else\ 0$$

$$F_O(x) = -\Delta U_O(x) \quad if\ d \le d_0\ else\ 0$$

At this time,

- O:Subscript that shows the obstacle.
- d:Shortest distance from the robot to the obstacle.
- d_0:The limitation distance of the contribution area.
- k_O: A constant parameter

The potential field can be overlapped linear. If the movement of the robot was controlled according to the following equation, the action toward the target point and the action that avoid the obstacle were combined.

$$F_A = F_G + F_O$$

5 Conclusion

In this paper, we proposed the obstacle discovery function that used the optical flow and the object tracking function that used a dynamic contour method by using the visual information that the robot had. Moreover, we explained the route planning algorithm of the robot.

In the future, we plan to do the implementation and the evaluation of these proposal items.

Acknowledgment

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