ON INTELLIGENT IMAGE PROCESSING METHODOLOGIES APPLIED TO NAVIGATION ASSISTANCE FOR VISUALLY IMPAIRED

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ABSTRACT

The main objective of this thesis is to develop a computer based Navigation Assistance for Visually Impaired (NAVI) as a vision substitutive system. The hardware of the system includes a Vision sensor mounted on a headgear, a set of Stereo earphones and a Single Board Processing System (SBPS) with batteries, duly placed in a vest. The Vision sensor is a digital video camera. The video camera captures the image of the environment. The captured image is processed, mapped on to specially structured stereo sound patterns and sent to the earphones. A set of image processing requirements for vision substitution is identified and incorporated in the NAVI system. The image processing, developed in this thesis, is designed to work as a model of the human vision system. To model the human vision system in image processing, two properties of human eye, namely lateral inhibition and domination of the object properties rather than background are incorporated. The image processing methodologies applied in NAVI are developed using artificial intelligent techniques. The property of lateral inhibition is incorporated using neural network based Canny edge filter. In vision substitutive system, definition of objects and background is not easy as compared to industrial object recognition system. Therefore, three methods for object enhancement and background suppression are proposed in NAVI using fuzzy logic and neural network. The edge image and the object enhanced image with background suppressed are integrated to produce a resultant image. The resultant image is sonified to produce stereo acoustic patterns. Blind volunteers were trained with the developed NAVI system and they were tested to identify the environment. They were able to understand the logic behind the sound in discriminating the object from background. It was also verified that the discrimination of objects by the blind through the proposed image processing methodologies is effective and easier than that of earlier efforts in this direction.

ABSTRAK

Objektif utama tesis ini adalah untuk merekacipta alat bantuan navigasi berasakan komputer bagi mereka yang cacat penglihatan atau NAVI 'Navigation Assistance for Visually Impaired' sebagai satu sistem pengganti pengalihatan. Sistem perkakasan yang telah dihasilkan merangkumi penderia penglihatan yang dipasang pada 'headgear', fontelinga stereo dan sistem pemprosesan papan tunggal ('single board processing system'). Bateri disimpan dalam baju yang direka khas. Penderia penglihatan adalah sebuah kamera video digital yang digunakan untuk merakam imej persekitaran. Imej yang dirakam akan diproses dan ditukarkan kepada isyarat bunyi stereo berstruktur khas dan dihantar kepada fontelinga. Satu set keperluan pemprosesan imej telah dikenal pasti dan digunakan dalam system NAVI ini. Pemprosesan imej yang dibangunkan dalam tesis ini berfungsi sebagai satu model sistem penglihatan manusia. Untuk memodelkan sistem penglihatan manusia dari segi pemprosesan imej, dua ciri mata manusia iaitu penekanan untuk mengenalpasti bahagian hujung dan dominasi sifat-sifat objek berbanding dengan latarbelakang telah digunakan. Dalam tesis ini, kaedah pemprosesan imej adalah berasaskan teknik-teknik kecerdikan buatan. 'Canny Edge Filter' berasaskan rangkaian neural digunakan untuk mengenalpasti bahagian hujung dan sifat objek. Di dalam sistem pengganti penglihatan, definisi sistem pengesan objek dan latar belakang adalah tidak semudah untuk dilakukan berbanding dengan industri. Jadi, tiga kaedah untuk menguatkan paparan objek and mengurangkan latarbelakang dengan menggunakan kaedah fuzzy logik and rangkaian neural buatan telah dicadangkan. Gabungan bahagian tepi imej ("edge image") dengan kesan objek yang dikuatkan dan latarbelakang yang telah dikurangkan membentuk imej yang lebih menonjol. Imej yang dihasilkan ini ditukar kepada bentuk isyarat bunyi stereo. Sukarelawan-sukarelawan yang cacat penglihatan telah dilatih dan diuji untuk mengenalpasti persekitaran dengan menggunakan NAVI. Mereka berupaya memahami logik di sebalik bunyi yang dihasilkan untuk membezakan objek daripada latarbelakang. Di samping itu, diskriminasi objek menggunakan kaedah pemprosesan imej yang dicadangkan ini adalah lebih berkesan dan mudah berbanding dengan kaedah-kaedah sebelum ini.

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LIST OF ILLUSTRATIONS

G_{obj} : Gray level of object in FLIPS

G_o : Gray level of object in pattern clustering

G_b : Gray level of background in pattern clustering

G_x : First derivative of Gaussian function in x direction

G_y : First derivative of Gaussian function in y direction

H_i : Monochrome of 4 levels

H_{in} : Input to FLIPS; this is the normalized histogram of preprocessed image.

h_1 : Monochrome value of BL

h_2 : Monochrome value of DG

h_3 : Monochrome value of LG

h_4 : Monochrome value of WH

I : Preprocessed image

I_1 : Edge Image

I_2 : Object enhanced and background suppressed image

I_3 . Image with edge and object enhanced with background suppressed.

I_{BS} : Background suppressed image matrix

I_x : x component of image

I_y : y component of image

I_L : Left half of image I

I_R : Right half of image I

J : Objective function in clustering

K_1, K_2 : Chosen scalar constants

K_G : Constant gain.

k : Updation parameter

LVQ : Learning Vector Quantization

M(x,y) : Magnitude of pixel value in edge detection

M_c : Hard partition space of X

M_{fc} : Fuzzy partition matrix

M : Number of rows in the image I

N : Number of columns in the image I

n_1 and n_2 : image dependent constants

n : Number of data

q : Slope parameter

R_T : Ratio of the lower to higher thresholds

$S(j)$: Sound pattern for column j of the image

S_L : Sound pattern to the left earphone.

S_R : Sound pattern to the right earphone

s : Standard deviation of image.

T : Class of the training vector

T_h : High threshold

T_l : Low threshold

t : iteration count

U* : Optimum partition

v^* : Final cluster center

v_i : Cluster center

w_j : Weight vector for j^{th} output unit

X_1, X_2, X_3 : Object enhancement gains

$X_{BL}, X_{DG}, X_{LG}, X_{WH}$: Feature vector from BL, DG, LG and WH gray levels

X : Training vector

$[x_1, x_2, x_3, x_4]$: Feature vector.

z : weighting parameter

z_0 : Initial z

z_f : Final z

α : initial learning rate in LVQ

α_t : Learning rate, where t is iteration number in LVQ.

β : A chosen parameter to distinguish background as light or dark color

δ : Object occurrence factor

ε : Termination criterion

μ : Mean of image

μ_{ik} : Membership of k^{th} data point in the i^{th} cluster

μ_r : Mean of iris area

θ_1, θ_2 and θ_3 : Enhancement decision factors

σ : Gaussian spread parameter

τ : Threshold of image

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Orientation, Navigation and Mobility are perhaps three of the most important aspects of human life. Most aspects of the dissemination of information to aid navigation and cues for active mobility are passed to human through the most complex sensory system, the vision system. This visual information forms the basis for most navigational tasks and so with impaired vision an individual is at a disadvantage because appropriate information about the environment is not available. The loss of eyesight is one of the most serious misfortunes that can befall a person. The term blindness refers to people who have no sight at all as well as to those whose sight is so seriously impaired that their vision cannot be corrected to what is generally considered normal. Approximately three-quarters of those considered as blind have limited vision, which cannot be corrected to normal vision with standard eyeglasses or contact lenses. These people are said to be severely visually impaired, (WHO. 1998). The major causes of blindness are age-related macular degeneration, cataracts, glaucoma, diabetic retinopathy, trachoma, onchocerciasis, by birth, lack of eye care and accident (Times of India, 2000).

Mobility is an ability of movement within the local environment. It is also the ability to move with the knowledge of objects and obstacles in front. Blind individuals find their mobility difficult and hazardous, because they cannot easily identify the obstacle for a comfortable navigation. The autonomous navigation without collision and with discrimination of objects becomes the major task for them to face their daily life requirement.

1.2 BLIND POPULATION - AN OVERVIEW

Visual impairment is one of the most common disabilities worldwide. WHO reported that due to the lack of epidemiological data, especially from the developing and under developed countries, the exact number of blind persons in the world is not known. In 1994, WHO estimated that it was around 38 million with a further 110 million cases of low vision, that are at risk of becoming blind. In 1998, the total population of visual impairment was more than 150 million people (WHO, 1998). Currently, there is a total of about 45 million blind people in the world and a further 135 million have low vision and this number is expected to double by 2020 (Times of India, 2000). The number of people who become blind each year is estimated to be 7 million. Over 70% of the people with vision problem receive treatment and their vision is restored. Thus, the number of blind persons worldwide is estimated to increase by up to 2 million per year (WHO, 1997). Eighty percent of these cases are ageing-related. In most countries of Asia and Africa, it accounts for over 40% of all blindness. It is also estimated that, currently, there are approximately 15 million blind people in South East Asia Region or one-third of the blind population of the world. China accounts for about 18% of the world's blind and is estimated to have the largest number of blind people in the world. There are a quarter of a million people in the UK who are registered as visually impaired. However, the UK actually has nearly one million people entitled to register as a visually impaired person, and 1.7 million with the vision difficulty. This represents over three percent of the UK population (NFB, 2002). In Britain, more than twenty thousand children grow up with visual impairment, and there are two hundred vision-related accidents per day in the UK alone (Leonard and Gordon, 1999; Viisola, 1995). There are approximately 10 million visually impaired people in the United States (AFB, 2001). In addition, statistics state that for every seven minutes, someone in America is becoming visually impaired (Blasch, 1999). In Malaysia, alarming increment in blind population is noted with about 46.9 % from 1990 to 1999. By September 2000, there were about 13,835 registered in Blind associations and it is predicted that, it might be less than 50 % of the total blind population in the country (JKM, 2000; ERM, 2001).

The largest number of visually impaired people falls into the senior citizen category; in fact sixty-six percent of people with impaired vision are over seventy-five year old (Papenmeier, 1997; Lacey and Dawson-Howe, 1998; WHO, 1997a).

1.3 ELECTRONIC TRAVEL AIDS

Orientation and mobility are two of the main confront that visually impaired individuals face every day. Basic independent mobility is vital throughout all sections of society. Mobility, the ability to navigate in a complex environment, enables human to accomplish many different physical goals. Electronic Travel Aids (ETA) are the electronic equipment that help to present visual information to visually impaired people, so that they can have interaction with the environment. Many devices exist to assist visually impaired people in navigation (Duen, 1998). A number of research institutes and software companies are working on solutions to the problems of navigational information for visually impaired people.

Since early 1950's several efforts in providing travel aids for visually impaired people had been on development. They ranged from the simple cane to advanced electronic aids (Löfving, 1998). The development of other assisting devices to aid visually impaired people in their everyday life has been increasing. In some cases, solutions to providing sensory supplementation such as Braille through to electronic reading machines have been very effective. However, truly adequate solutions for navigation assistance for visually impaired have not yet been achieved. A number of devices have already been developed to address some of the difficulties faced by visually impaired people with regard to travel (Baldwin, 1998).

Most of the early ETAs are based on ultrasonic sensors for obstacle detection. Later, due to the advancement in high sensitive sensors and computing devices, the research had been focused to video camera based ETAs and Global Positioning Systems. In this thesis, a video camera based ETA is developed. The image is captured using a digital video camera, processed in a computing device and is mapped on to specially structured sound patterns.

1.4 OBJECTIVE OF THE THESIS

The main objective of this thesis is to design a navigational system for blind people that is portable and has all necessary software to sonify the image in real time. The system is named as Navigation Assistance for Visually Impaired (NAVI). The objective of the thesis in developing the NAVI system has five folds: