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VISION TRACKING AND VOICE-CONTROLLED FOYER SERVICE ROBOT

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Introduction

Machine –human interaction based on voice control and vision tracking features is one of world main focuses in the robotic industry. The integration of voice control and vision tracking features is expected to deliver its usefulness to support normal daily activities and services. This paper presents vision tracking algorithm, voice control algorithm, interface circuit controller and the implementation of integrated system on prototypical foyer service robot. The main parts of the robot are head equipped with a video camera, a five degrees-of-freedom manipulator, and a mobile base as shown in Fig.1.

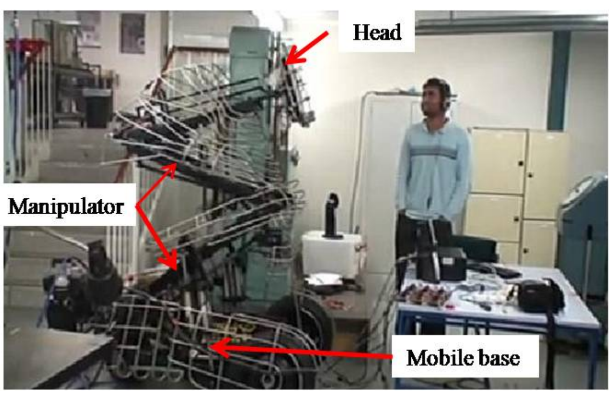

Fig.1 Photograph of the foyer service robot executing "Stand up" command.

Vision tracking algorithm

A simple motion detection algorithm was implemented in prototypical foyer service robot to process the streamline video data acquired from a video camera placed on the top of robot head. The algorithm was implemented using Microsoft shared library Mitov.dll on Microsoft .NET (VB) frame work [1]. It determines the position and direction of motion based on active pixels and time index.

A 20×20 pixel frame is divided into five parts as shown in Fig.2, where (X, Y) represents coordinates of the visual areas. Top-Left, Bottom-Left, Top-Right and Bottom-Right parts are 5 pixels wide and 5 pixels high while Middle part is 10 pixels wide and 20 pixels high.

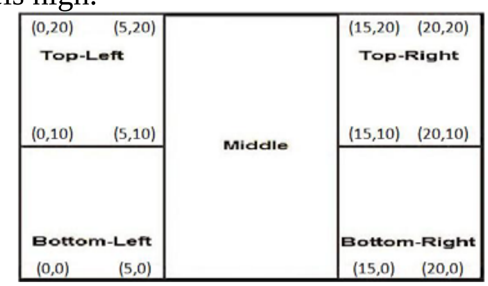

Fig.2 Configuration of the 20×20 pixel frame.

Number of pixels in each part is calculated. Position of motion is resolved by finding which part has the largest number of active pixels. Motion direction and motion position algorithms are different from each other. The motion direction algorithm is based on position algorithm. Besides that, it depends on comparing the difference of pixels on one side (e.g. left), between the two subsequent frames, to the sum of pixel difference on the other two sides between the two subsequent frames (e.g. right and middle).

Table1: Rules for motion direction determination

F1	Rule	F0	Direction
L	(Npl (F1) – Npl (F0)) > ([Npr (F1) – Npr (F0)] + [Npc (F1) – Npc (F0)])	L	T:SS F:UD
L	(Npl (F1) - Npl (F0)) > ([Npr (F1) – Npr (F0)] + [Npc (F1) – Npc (F0)])	C	T:CL F:UD
R	(Npr (F1) – Npr (F0)) > ([Npc (F1) – Npc (F0)] + [Npl (F1) – Npl (F0)])	C	T:CR F:UD

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A Boolean formula was designed to remove uncertainty of motion direction between previous and current position. The direction is recognized if the formula output is true otherwise it is said to be random motion. Below are the nomenclatures of vision tracking algorithm:

Npl: Number of pixels on the left side
Npr: Number of pixels on the Right side
Npc: Number of pixels on the centre side
F1: Current position; F0: Previous position
UD: Unrecognized direction
MN: Motion from position "M" to position "N"
SS: Motion at the same side
T: True; F: False
Positions:
L: Left; R: Right; C: Centre.

Three illustrative cases are exampled in Table 1 regarding rules in determining motion direction based on the captured pixels. The last example in Table 1 shows the motion case from Centre (F0) to Right (F1). For simplicity, this motion is denoted as C→R that is from centre to right. In addition to the three cases shown in Table 1, there are six extra cases, namely C→C, L→R, L→C, R→R, R→L and R→C, all following the same rules for motion direction determination. Utilizing Microsoft.NET frame work, the aforementioned vision tracking algorithm was implemented in the prototypical foyer service robot to execute autonomous motions.

Table 2: Voice command-based actuation

Voice command	Action	Voice Reply	USB pin number
Stand up	Bottom arm→ up upper arm→ up big arm→ up top arm→up	ok	B0→1 B1→1 B2→1 B3→1
Sit down	Bottom arm→ down upper arm→ down big arm→ down top arm→down	ok	B0→0 B1→0 B2→0 B3→0
kneel	Bottom arm→ down upper arm→ up	Yes majesty	B0→0 B1→1
Head up	Head turns up	ok	A0→ 1 A1→ 1

Voice control algorithm

A voice control system was developed to execute human commands on the foyer service robot (e.g. stand up, sit down). Table 2 shows some proper actions of actuators in response to voice commands. Also, voice commands were implemented for different types of head motion such as head down, head left, and head right. Fig.1 illustrates the robot's action following "Stand up" voice command.

Interface circuit controller

The prototypical foyer service robot has six 24V pneumatic actuators and three 12V DC motors. An interface circuit was designed and assembled to act as a bridge between computer commands and actuator actions. Each pneumatic actuator is controlled by one interface circuit channel while each motor requires two channels for direction control and the other for actuation in on-off fashion.
Each interface circuit channel is composed of three sub circuits: current booster, isolation (opto-isolator) to protect the computer from any voltage breakdown on the robot's side, and switching circuit. Schematics of the circuit are shown in Fig.3 [2] [3].
A voltage regulator was built for each channel to manage available power supply lines: 24V from robot, 5V from USB controller. The 24V power supply is used for switches pins while the 5V power supply is further channeled independently to current booster sub-circuit and to phototransistor of opto-isolator to ensure full separation between computer and the robot.

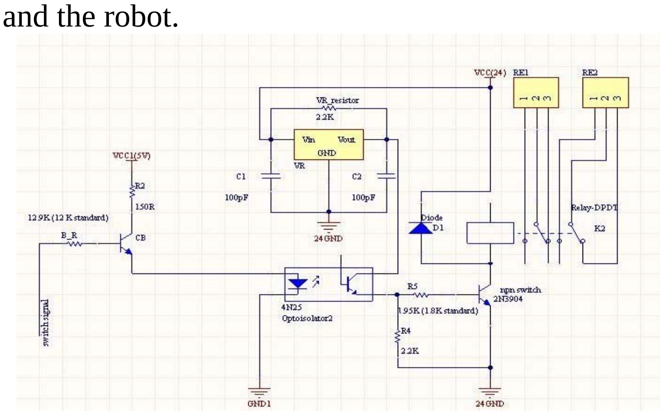

Fig.3 Interface circuit channel design

Six PCB's (12 channels), as shown in Fig.4, were fabricated to connect relay control pins and actuators. Following [4], the traces were set at 2.8 mm wide to carry current load of 5 Ampere operated at temperature rise of 10˚C. Furthermore, USB-PCB control terminal and Robot-PCB power terminal were placed at different ends of the board for easy identification.

Wiring layout of interface circuit board

Table 3 and Table 4 were constructed to simplify wiring layout between the USB controller, interface circuit, and the robot. The 12V motor and 24 V pneumatic actuator control pins are connected to class ‘A’ and ‘B’ of USB pins separately.

Table 3: Wire setup for 12 V DC motors

Pin number	color	function	Circuit board number	Relay number	USB pin number
1	Black	Head Up	1	1	A0
2	Brown	Head Down	1	2	A1
3	Red	Head Left	2	1	A2
4	Orange	Head Right	2	2	A3
5	Yellow	Head twist	3	1	A4
6	Dark green	Head twist	3	2	A5
7	Blue	-			
8	Purple	-			
9	Grey	-			
10	White	Ground			
11	Pink	12 V			
12	Light green	Positive (24 V)			

Table 4: Wire setup for 24 Pneumatic actuators

Pin number	color	function	Circuit board number	Relay number	USB pin number
1	blue	Bottom arm	4	1	B0
2	white	Upper arm	4	2	B1
3	Orange	Big arm	5	1	B2
4	white	Top arm	5	2	B3
5	green	Out arm	6	1	B4
6	white	Extensive arm	6	2	B5
7	Brown	-			
8	white	-			
9	Grey	-			
10	White	-			
11	blue	-			
12	Red	Positive(24 V)			

Color coding of power supplies was employed on the 12-channel interface circuit. These colors are used as following:

Blue: Signal line
Red: 5V USB-current booster circuit supply
Yellow: 24V supply
Black: Ground-2 separate lines for 24V and 5V

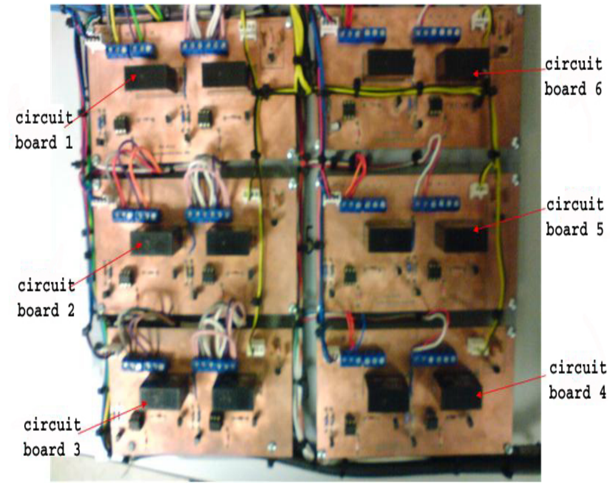

Fig.4 Photograph of the interface circuit controller board.

Summary

This paper presents machine –human interaction through mechatronic integration of vision tracking and voice control algorithms along with the interface circuits. A new vision tracking algorithm was developed based on pixels differences between two subsequent frames. A novel and simple interface circuit design was developed to allow feasibility of the vision and voice command-based actuations for the foyer service robot. To reduce overhead in image processing, development using C++ rather than VB.NET is recommended. To facilitate faster response, inclusion of motor dynamics in the vision tracking algorithm can is suggested to optimize the robot’s actuation performance.

References

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