A Study on Infra-Technology of RCP Mobility System

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Abstract: Most recently, CP(Cellular Phone) has been one of the most important technologies in the IT(Information Tech-nology) field, and it is situated in a position of great importance industrially and economically. To produce the best CP in the world, a new technological concept and its advanced implementation technique is required, due to the extreme level of competition in the world market. The RT(Robot Technology) has been developed as the next generation of a future technology. Current robots require advanced technology, such as soft computing, human-friendly interface, interaction technique, speech recognition, object recognition etc. unlike the industrial robots of the past. Therefore, this paper explains conceptual research for development of the RCP(Robotic Cellular Phone), a new technological concept, in which a synergy effect is generated by the merging of IT & RT.

RCP infra consists of $RCP^{Mobility}$, $RCP^{Interaction}$, $RCP^{Integration}$ technologies. For $RCP^{Mobility}$, human-friendly motion automation and personal service with walking and arming ability are developed. $RCP^{Interaction}$ ability is achieved by modeling an emotion-generating engine and $RCP^{Integration}$ that recognizes environmental and self conditions is developed. By joining intelligent algorithms and CP communication network with the three base modules, a RCP system is constructed.

Especially, the RCP mobility system is focused in this paper. $RCP^{Mobility}$ is to apply a mobility technology, which is popular robot technology, to CP and combine human-friendly motion and navigation function to CP. It develops a new technological application system of auto-charging and real-world entertainment function etc. This technology can make a CP companion pet robot. It is an automation of human-friendly motions such as opening and closing of CPs, rotation of antenna, manipulation and wheel-walking. It's target is the implementation of wheel and manipulator functions that can give service to humans with human-friendly motion. So, this paper presents the definition, the basic theory and experiment results of the RCP mobility system. We confirm a good performance of the RCP mobility system through the experiment results.

Keywords: Robotic Cellular Phone(RCP), Robot Technology(RT), Information Technology(IT), RCP mobility system

1. INTRODUCTION

Most recently, the CP(Cellular Phone) has been one of the most important technologies in the IT(Information Technology) field, and it is situated in a position of great importance industrially and economically. To produce the best CP in the world, a new technological concept and its advanced implementation technique is required, due to the extreme level of competition in the world market [1].

RT has been developed as the next generation of a future technology. Especially, entertainment robots, types of personal robots for amusement and education, are studied world wide currently. These robots do not work in fixed tasks but rather in flexible and various environments. So the toy robot should be an intelligent system with which emotional communication is possible as in humans. Therefore, this paper explains conceptual research for development of the RCP(Robotic Cellular Phone), a new technological concept, in which a synergy effect is generated by the merging of IT & RT.

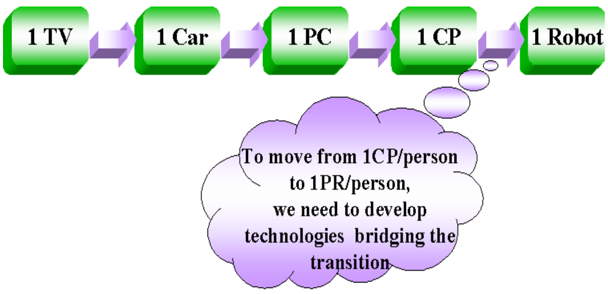

Fig. 1 A Industrial and Economic Role of RCP

The RCP, CP(Cellular Phone) having personal robot services, will be an intermediate hi-tech personal machine between one CP a person and one robot a person generations as shown in the figure 1.

The RCP is an intelligent robot constructed with new technology, which can have both novel and convenient functions through grafting of IT & RT. The grafting technology is implemented by advanced design engineering. RCP consists of three sub-technologies, automatic mechanical motion, emotional expression and intelligent feeling, recognition of self-state and environments. This is shown in the figure 2.

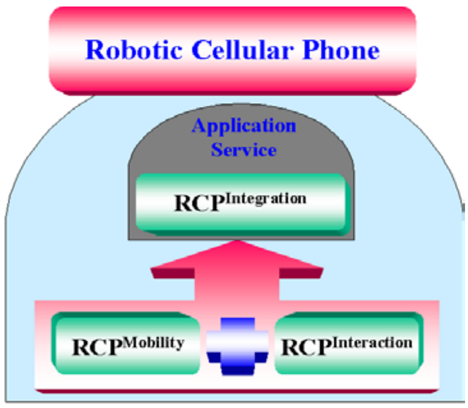

Fig. 2 Sub-Technologies of RCP

Figure 3 shows the $RCP^{Mobility}$(Robotic Cellular Phone for Mobility). $RCP^{Mobility}$ refers to RCP's function that makes individual service possible by robotic mobility.

RCP^{Mobility} is designed to realize automatic mechanical actions. In this paper, automatic movement experiments use built-in micro DC geared motors. RCP^{Mobility} is the automation of human-friendly motions such as opening and closing of the CP, rotation of antenna, manipulation and wheel-walking. RCP^{Mobility}'s final target is the implementation of walking and manipulation functions that can give service to humans with human-friendly motion [2-5].

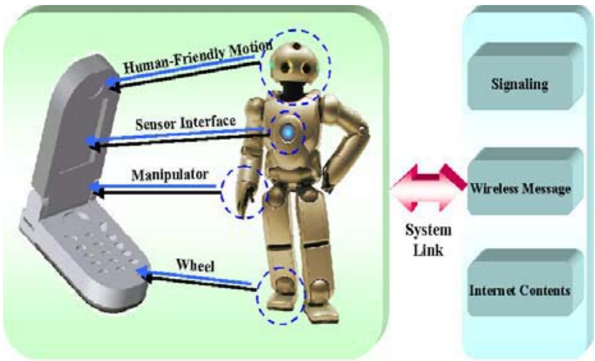

Figure 3. The Technical Contents of RCP^{Mobility}

The infra-technology of RCP mobility system, including a technical configuration of wheel-based navigation module, is explained in the section 2. The experiment results and considerations, including the experimental setup, are given in the section 3. Finally, it is concluded in the section 4 to confirm a good performance of the RCP through the experiments of the mobility module system.

2. The Infra-Technology of RCP^{Mobility}

2.1 Technical Configuration of RCP^{Mobility}

RCP^{Mobility} refers to the RCP's function that it makes individual service possible by robotic mobility. RCP^{Mobility} is the automation of human-friendly motions such as opening and closing of the CP, rotation of antenna, manipulation and wheel-walking. It needs intelligent control technology to give smart service to humans, and to implement modularization of function and growth, change etc.

It is therefore an object of the RCP^{Mobility} to provide a robotic cellular phone having a personal robot function in a cellular phone. It is therefore another object of the RCP^{Mobility} to provide a robotic cellular phone having personal service and entertainment functions of a robot. According to an embodiment of the RCP^{Mobility}, a robotic cellular phone includes as follows:

- A plurality of wheels formed on a part of rechargeable battery
- A wheel driving motor for supplying power to the plurality of wheels
- An antenna driving motor for supplying power to an antenna and for moving the antenna to an optimum location
- A folder driving motor for supplying power for opening, closing, and rotating a folder in response to a receiving signal or a termination signal by pushing an ending button
- A micro-processor for outputting control signals for controlling operations of the wheel driving motor, the antenna driving motor, and the folder driving motor.

2.2 Wheel-Based Navigation Module of RCP^{Mobility}

Figure 4 is the block diagram of a control system for wheel-based navigation. As seen in figure 4, it consists of a speed closed loop controller and a position controller, which use PID feedback control method. The speed and position output is feedbacked to the input stage of the controller. The controlled signal, which is computed by PID control algorithm, is converted to PWM signal and then is inputed to DC motors.

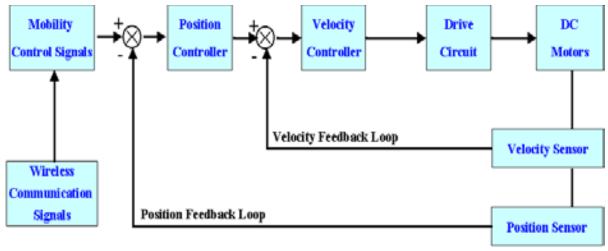

Fig. 4 Wheel-Based Navigation Control System

The RCP must be able to recognize own position, or user must be able to control for wheel-based navigation functional module. Therefore, we need kinematics analysis about RCP's motion [6-9]. We used two wheel structures of mobile robot for wheel-based navigation technology. As seen in figure 5, two wheel drive robots are the mobile robot structure of simplest form [10-11]. RCP's kinematics equation models can get from figure 5.

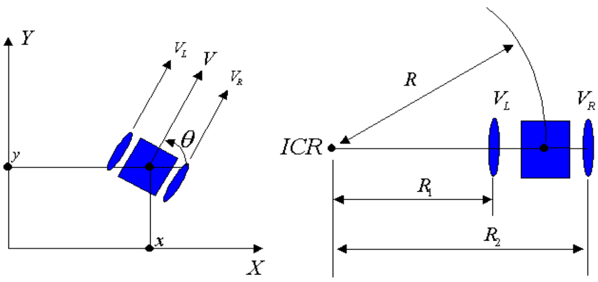

Fig. 5 Two Wheel Drive Robots

The angular velocity of left wheel and right wheel is ω_L and ω_R, and the speed at point of contact with wheels and floor can get with equation (1) according to non-slipping condition. Therefore, RCP's line velocity and angular velocity can get with equation (2) and equation (3).

$$V_R = \gamma\,\omega_R \;,\quad V_L = \gamma\,\omega_L \tag{1}$$

$$\omega = \frac{V_R - V_L}{L} = \gamma\,\frac{\omega_R - \omega_L}{L} \tag{2}$$

$$v = \frac{V_R + V_L}{2} = \gamma\,\frac{\omega_R + \omega_L}{2} \tag{3}$$

Therefore, relation of $[x \quad y \quad \theta]^T$ and $[v \quad \omega]^T$ can expressed by kinematics model such as equation (4) [12-13].

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v \\ \omega \end{bmatrix} \tag{4}$$

As seen in equation (4), controllable elements are two in RCP, but position and angle that should be controlled by RCP have 3 degree of freedom. Therefore, when control to move from RCP's current position to target position, it is happened on limited condition. If we use non-slipping condition(speed component of vertical direction bottom and contact point of wheel is zero), then we can get following non-holonomic condition limit [14-15].

$$H \cdot \dot{p} = [\sin\theta \quad - \quad \cos\theta] \begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} = \dot{x}\sin\theta - \dot{y}\cos\theta = 0 \qquad (5)$$

Here, H is identity vector that form verticality on bottom side of wheel. Condition of limitation becomes with equation (5), and it is expressed with $\tan\theta = \dot{y}/\dot{x}$. This means that RCP's moment transfer direction should be same with angle of RCP.

From equation (5), speed V_L and V_R of two wheels are proportional with distance of R_1, R_2 until wheels from ICR that is expressed to figure 6.

$$\begin{aligned} V_L : R_1 &= V_R : R_2 \\ V_L \Big/ \left(R - \frac{L}{2}\right) &= V_R \Big/ \left(R + \frac{L}{2}\right) \\ R &= \frac{L}{2} \frac{V_R + V_L}{V_R - V_L} \end{aligned} \qquad (6)$$

In case of the RCP goes straight on, it is $R = \infty$, and $V_R = V_L$. Also, in case RCP rotates at place, it is $R = 0$, and $V_R = -V_L$.

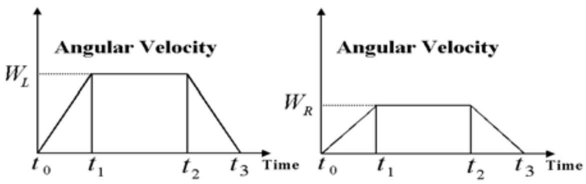

Fig. 6 Velocity Profile of the RCP Wheels

Drive of actuality motor is acceleration and deceleration section with figure 6. If motor are same acceleration and deceleration time of two wheels with figure 6, then the RCP moves drawing an arc. In this case, we can get as following from equation (2), equation (3) and equation (6) about distance of movement(equ. (7)), radius of rotation(equ. (8)) and angle of rotation(equ. (9)).

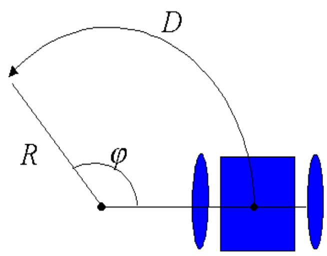

Fig. 7 Distance of Movement and Angle of Rotation

$$D = \int_{t_0}^{t_3} \frac{V_L + V_R}{2} dt = \frac{1}{2}\gamma \frac{\omega_L + \omega_R}{2}(t_1 - t_0 + t_2 - t_1) \qquad (7)$$

$$R = \frac{L}{2}\frac{V_R + V_L}{V_R - V_L} = \frac{L}{2}\frac{\omega_R + \omega_L}{\omega_R - \omega_L} \qquad (8)$$

$$\varphi = \frac{D}{R} = \frac{\gamma}{2L}(\omega_R - \omega_L)(t_3 - t_0 + t_2 - t_1) \qquad (9)$$

The mobility function part is for moving the antenna to an optimum location to increase a sending or receiving signal sensitivity and for opening and closing a folder by using a plurality of wheels formed on a part of rechargeable battery. Figure 8 is the automation control system for human-friendly motions.

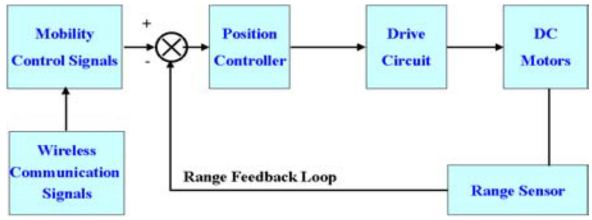

Fig. 8 Human-Friendly Motion Control System

3. RESULTS AND CONSIDERATIONS

3.1 Experimental Result of Wheel-Based Navigation Module

To wheel-based navigation module is run effectively, selection of suitable motor should be go ahead. RCP receives limitation dimension and weight because should be designed conveniently to carrying along. Therefore, selection standard of motor is difficult and important factor. Selection standard of motor is such as the torque, power dissipation, maximum speed, size, it all conditions effective must.

The Power dissipation is related with battery used in RCP. When look at Li-ion or Li-polymer battery of middle capacity that is used to cellular phone as standard, about 300mA is used to circuit among average supply current of whole 800mA. And, we supposed that remainder 500mA is used in motor.

In case of motor that is used in the RCP, the fast speed is not important factor. Therefore, maximum speed of motor is not important. But, the torque needs enough to do navigation and opening, closing, and rotating of the RCP's folder. The torque is related with the coefficient of friction that exists between the RCP's wheel and the room floor. The RCP's weight is 0.1kg, and when the coefficient of friction that exist between floor and the RCP's wheel is 0.4 and diameter of wheel shaft is 0.01 ㎝, the minimum torque can be expressed by equation (10).

$$\begin{aligned} \tau_G &= \frac{1}{2} \times F \times R = \frac{1}{2} \times \mu \times m \times g \times R_0 \\ \tau_G &= \frac{1}{2} \times 0.4 \times 0.1kg \times 9.8 m/s^2 \times 0.0001m = 0.0196mNm \end{aligned} \qquad (10)$$

A Size of motors can regard that there is no problem if it is within 3 ㎝ including gear head, motor, and encoder. So, we chose suitable micro motor on request specification of gear head and motor in this paper. Table 1 is design standard of motor.

Table 1 Design Item of Motor Including Gear

Standard	The Terms desired
Power dissipation	3.7V, 500mA less than
Torque	0.0196mNm over
Length	3cm less than

All mechanical motions of RCP are implemented by micro DC geared motors, which have 64:1 gear ratio. Then motor driving circuit used H-bridge method. The designed result of the RCP^{Mobility} is shown in figure 9.

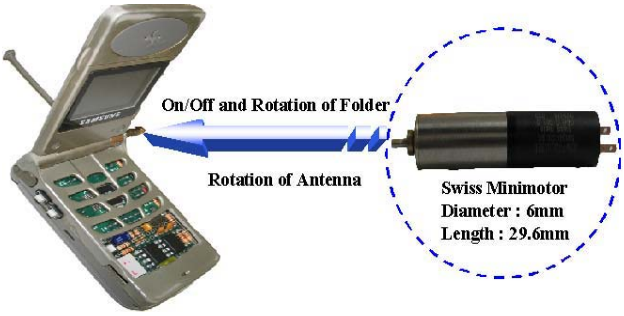

Fig. 9 Experiment of RCP^{Mobility}

Figure 10 shows an experimental result of speed control for wheel driving motor through the RCP's prototype. As shown velocity profile, we can confirm that is correctly tracking the command speed, 3000RPM, using the PI control algorithm. Sampling time of PI controller is 10ms and acceleration time and deceleration time are 0.3S. Therefore, we can confirm that acceleration and deceleration are moving very smoothly processed.

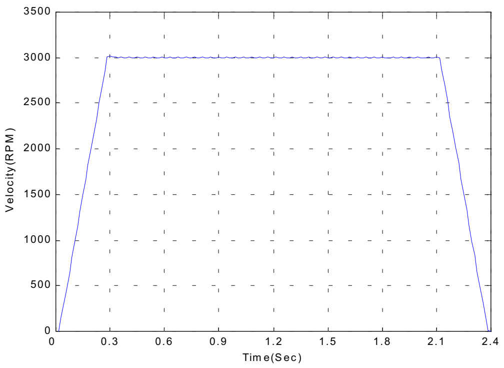

Fig. 10 Result of Speed Control for Wheel-Based Navigation

3.2 The Developed RCP Prototype

Figure 11 shows an electrical hardware prototype of RCP that is developed in this paper.

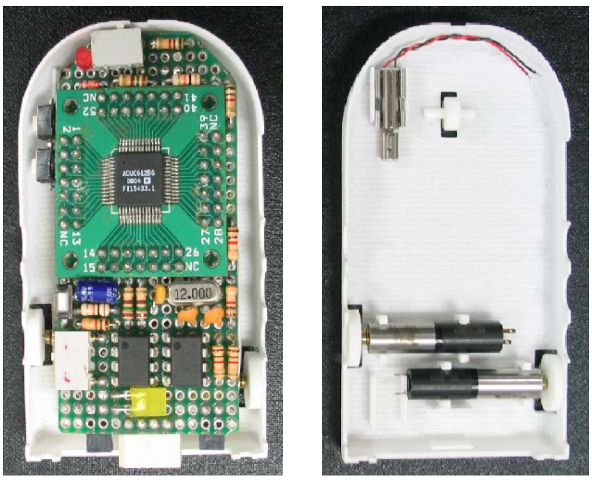

Fig. 11 The Developed RCP Prototype

The motor driver IC runs the micro DC geared motor, vibrator, and touch and light sensor is used in this prototype. The RCP's operation power supply uses a 3.7V Li-ion Battery of cellular phone and the CPU uses an ADuC812, which is provided by an Analog Devices Inc., 8-bit micro controller.

Figure 12 shows the designed results of mechanical system for the RCP prototype.

Fig. 12 The Mechanical System Design of RCP Prototype

4. CONCLUSION

RCP(Robotic Cellular Phone), a new technological concept which could make a synergy effect through merging of RT & IT, was proposed.

This paper presented the definition, the basic theory and experimental results of RCP^{Mobility} and the sub-technologies of the RCP. RCP^{Mobility} was implemented for the automation of human-friendly motions such as opening and closing of the CP, rotation of antenna, wheel-walking. RCP^{Mobility}'s final target is the realization of wheel and manipulator functions. We could give service to humans with human-friendly motion through it.

We confirmed a good performance of the RCP through the experiments of the mobility system. We convinced that the technology of the RCP should progress.

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