Navigation algorithm of Mobile Robot for helping brain disease patient's gait rehabilitation

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Abstract: In existing factory, robot has less necessity that consider person. However, person should be considered at design and use of service robot. To service robot can be used in everyday life along with this, more functions are required. Specially, medical service robot needs function that is intelligence function. Especially, to help patient brain disease patient (cerebral hemorrhage, cerebral infarction, imbecility), gait assistance Mobile robot consider ergonomic element necessarily. In order to develop the medical support service robot, the ergonomic design should be considered. This robot ergonomic design parameters are treated in ("Development of Medical Support Service Robot Using Ergonomic Design", 2003, ICASS) Fig2 show this Robot. In this study, navigation algorithm of walk assistance robot is analyzed in ergonomic view. Navigation algorithm of Mobile robot can divide by two patterns. Traditional derivative method has shortcoming in dynamic environment. Reactive method is result that react excellently in dynamic environment. However, number of behavior function is limited. So hybrid navigation algorithm was proposed by the alternative way. We consider enough user specificity at navigation algorithm application of gait assistance robot.

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Keywords: mobile modeling, navigation.

1. INTRODUCTION

We approach and assume robot user as by brain disease patient who has hemiplehia(hemiplehia is one side local paralysis). For patient's rehabilitation .that first step is rising from bed and sitting, that second is sitting on wheel chair move down bed, that third standing up, fourth step is walking.

At this process, step that robot is used is fourth. For effective result, long-term and constant rehabilitation training should be gone. This time, robot has possibility as good rehabilitational implement.Existent gait rehabilitational mechanism appliance walker had danger of collision accident at patient's walk of hwmiplehia.

Fig. 1 Existing Worker

Compare to existent walker, safety in several danger that produce rehabilitation training, a nurse or protector from time to time t remote control function to do monitor patient, that result effect is that doctor and nurses' labor power decrease,for performance ability of more wide and long-term rehabilitation plan for effective and stable rehabilitation, when rehabilitation of other level by patient state is required[1], then, robot supplies more excellent implement of rehabilitation.

When robot is used department of neurosurgeon ward or rehabilitation center, we assume that outside environment of robot is limited to ward.

Fig. 2 REMEROB (Rehabilitation medical Robot)

For this, robot must be able to autonomous navigation with considering to patient's state. Also, when patient shows hemiplegic gait, robot, in range that do not give overwork to patient, must do rehabilitation. Studied two point to consider as is different from function of gait rehabilitation medicla service robot and existing Mobile robot.

First is kinematics and dynamic modelling of whole system that robot and human. We assume that external load occur by hemiplegic gait of patient. To this system, input value generate

given action command from human, then robot generate path to Goal and move self. Relation at robot and human interaction is resemblance with robot wheel chair [2][3].
If user specifies goal, robot creates path by reference input to move. Reference input of robot motion is given by path generation algorithm, that is navigation algorithm. Studied path generation algorithm that consider human secondary for such reason. This paper consider application availability of dynamic environment, soft path, motion that overwork does not go, stable navigation etc...and study existing algorithm and alternative.

2. SYSTEM MODELING

2.1 Robot System

In this paper, a dynamic model of a wheeled mobile robot is utilized to describe the system dynamics including wheel slip ad external loads as disturbances to the system.[3][4]
Robot receives cyclic external loads by patient's hemiplegic gait.Cyclic disturbance is given to robot by it.[3] [4]
Can know that it are with existent Mobile robot difference kinematics and dynamic model.
Kinematics and dynamic modeling of robot are as following.

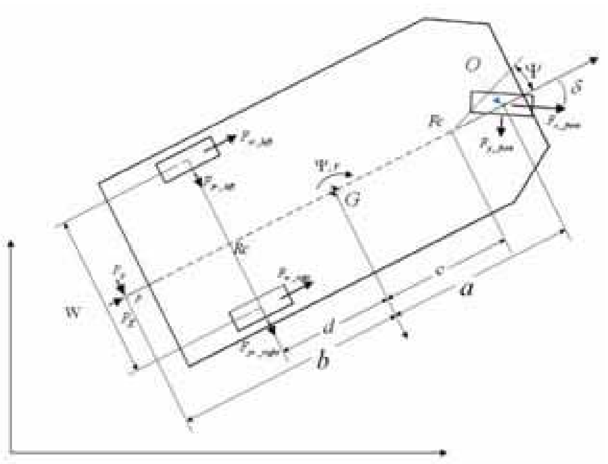

Fig. 3 REMEROB SYSTEM

2.2 Kinematics equations

This equations are derived from the constraints on the velocity components. Kinematics equations shown this.

$$u = \frac{1}{2}(u_l + u_r), \quad (1)$$

$$v = \frac{b}{w}(u_l - u_r) + v^s, \quad (2)$$

$$r = \frac{1}{w}(u_l - u_r), \quad (3)$$

$$u_l = Rw_l - u_l^s, \quad (4)$$

$$u_r = Rw_r - u_r^s, \quad (5)$$

w_l and w_r : Given the wheel velocities
u : the longitudinal velocities at the center of velocity
v : the lateral velocities at the center of velocity
r : the yaw rate
u_l : the longitudinal speeds of the left wheel centers
u_r : the longitudinal speeds of the right wheel centers
v^s : lateral slip speed of the wheel axle
u_l^s : the longitudinal slip of the center of the left wheels
u_r^s : the longitudinal slip of the center of the right wheels
R : the radius of the driving wheels

$$\dot{X}(t) = U = u\cos\Psi - (v + er)\sin\Psi, \quad (9)$$

$$\dot{Y}(t) = V = u\sin\Psi + (v + er)\cos\Psi, \quad (10)$$

$$\dot{\Psi}(t) = r, \quad (11)$$

U and V are the velocity components in the world coordinates.

2.3 Dynamics equations

m : mass of the robot
I_z : moment of inertia of the robot platform about the z-axi
a and d : distances from the center of mass
to the platform about the axle and tool location
F_{xr_right},F_{yr_right},F_{xr_left}, and F_{yr_left} : the tire force on the driving
P_x and P_y : external forces acting on the robot at the tool lo
I_e: is the effective moment of inertia combining
the wheel and motor assembly
n: gear ratio
T_l and T_r : the control inputs, motor torque

$$\dot{u} = \frac{1}{m}(F_{xr\_left} + F_{xr\_right} + P_x) + vr, \quad (12)$$

$$\dot{v} = \frac{1}{m}(F_{yr\_left} + F_{yr\_right} + P_y) - ur, \quad (13)$$

$$\dot{r} = \frac{1}{I_z}\left[\frac{w}{2}(F_{xr\_left} - F_{xr\_right}) - d(F_{yr\_left} + F_{yr\_right}) - bP_y\right], \quad (14)$$

$$\dot{w}_l = \frac{1}{I_e}[n\tau_l - F_{xr\_left}R], \quad (15)$$

$$\dot{w}_r = \frac{1}{I_e}[n\tau_r - F_{xr\_right}R], \quad (16)$$

Now, eliminating the tire force terms and re-arranging the full dynamic equations(12)-(16) with the kinematics equations(1)-(5) and (9)-(11) leads to the following equations:

$$\begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{\Psi} \\ \dot{u} \\ \dot{r} \end{bmatrix} = \begin{bmatrix} u\cos\Psi-(e+d)r\sin\Psi \\ u\sin\Psi+(e+d)r\cos\Psi \\ r \\ \frac{mdR^2}{\Theta_u}r^2 \\ -\frac{2dmR^2}{\Theta_r}ur \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ \frac{2nR}{\Theta_u} & 0 \\ 0 & \frac{2nRw}{\Theta_r} \end{bmatrix} \begin{bmatrix} \tau_u \\ \tau_r \end{bmatrix} + \begin{bmatrix} \delta_x \\ \delta_y \\ 0 \\ \delta_u \\ \delta_r \end{bmatrix} \quad (17)$$

where

$$\Theta_u = mR^2 + 2I_e,\ \Theta_r = I_e w^2 + 2R^2(I_z + md^2), \quad (18)$$

$$\delta_u = \frac{1}{\Theta_u}\{R^2P_x + mR^2rv^s - I_e(\dot{u}_l^s + \dot{u}_r^s)\}, \quad (19)$$

$$\delta_r = \frac{1}{\Theta_r}\{2(d-b)R^2P_y - 2R^2dmur - I_e w(u_l^s - u_r^s) - 2mdR^2v^s(t)\}, \quad (20)$$

$$\delta_x = -v^s\sin\Psi, \quad (21)$$

$$\delta_y = v^s\cos\Psi, \quad (22)$$

$$\tau_u = \frac{1}{2}(\tau_l + \tau_r), \quad (23)$$

$$\tau_v = \frac{1}{2}(\tau_l - \tau_r). \quad (24)$$

The vector [δ_x δ_y 0 δ_u δ_r] represents the uncertainties due to the wheel slip and the external forces.
This Modeling equation is said by YULIN ZHANG,JAE H. CHUNG , STEVEN A. VELINSKY[3].

3. HUMAN

3.1 Gait analysis for from robot to human

Gait rehabilitations effect is relation with the speed of walk.[5] Dae-Jin Jang analysis gait into Ascending motion, Swing moti on, Descending motion [6]. According to ISO 9996 (1996 Year s) and ISO 13090 (1995 Years),he observe low frequency human vibration within0 [Hz] ~ within 30 [Hz]. Equation about low frequency vibration exposure of human body is as following on ISO 9996.

$$(a_{h,w})_{wq(T)} = \{\frac{1}{T}\sum_{i=1}^{n}[(a_{h,w})_{eq(ti)}]^2 t_i\}^{1/2} \quad (25)$$

$$a_{h,w} = \{\sum_{j=1}^{n}[(k_j a_{h,j})]^2\}^{1/2} \quad (26)$$

$$a_{hws} = (a_{hwx}{}^2 + a_{hwy}{}^2 + a_{hwz}{}^2)^{1/2} \quad (27)$$

This shows that activeness of human body, preservation of health, safety elevation relation to low frequency human body vibration. Through this thing, show that robot navigation is connection with patient's rehabilitation.

3.2 Human as Robot disturbance parameter

Yi Jin-bock analyzed gait focused on dextropedal(right leg motion).[7] His method to divide gait cycle by Right stance-phase and Right-swing phase study acceleration and characteristic of gait cycle step by step. Figure 4 is Yi Jin-bock's graph that analyze walk. This picture shows when acceleration happens. Through this, we inference external loads cyclic receiving to Robot by patient's hemiplegic gait.. And so, Cyclic disturbance is able to inference.
However, parameter about human body acts individually.
Therefore, need research about patient's parameter.

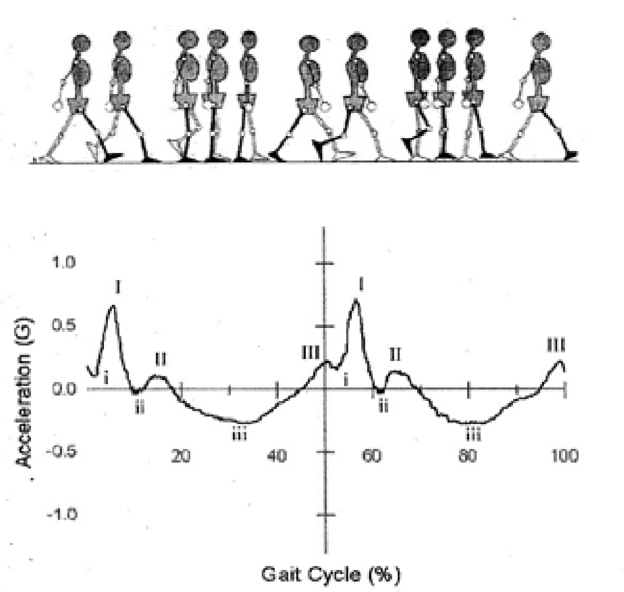

Fig. 4 Gait analysis

4. RELATION ROBOT AND HUMAN

We have touched on the robot system subject briefly above.
User is consider as dynamic disturbance in this system. However, robot exists for user. Therefore, must consider human's character. Fig. 5 show that Input signal of this whole system act motor. And for autonomous navigation, input signal is generated. Finally, Input motor signal is thing for robot to track reference path. When see more greatly, navigation path of robot offers reference input to system.
Finally, navigation path relate to input signal of robot.
So, we study path generation algorithm in user's view.
Application availability of dynamic environment, soft path generation, suitable move for user, stable navigation, motion that overwork does not go user etc...
We consider this factor, study existing algorithm, problem and alternative.

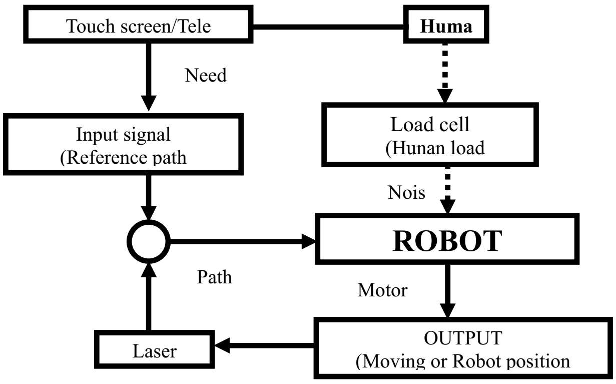

Fig. 5 Remerob system process

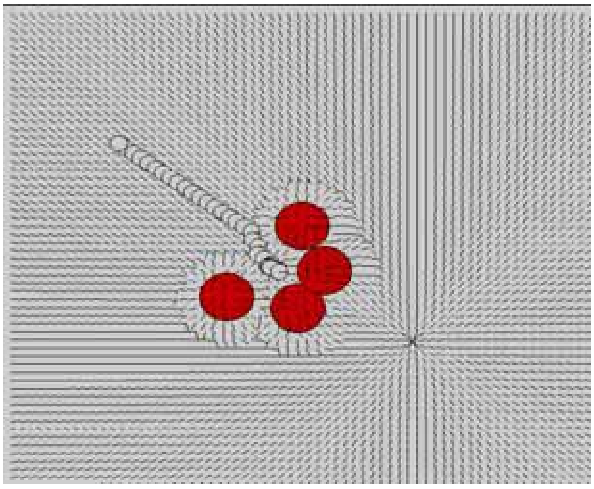

Fig. 5 local Minimum

5. NAVIGATION ALGORITHM

As conventional, path generation method classifies by two tendency. Classify by deliberative method and reactive way. This classification is general. This algorithm must have active function in outside environment is realizable and, stable and, roughness in real life.
Robot control refers to the way in which the sensing and action of a robot are coordinated. There are infinitely many possible robot programs, but they all fall along a well-defined spectrum of control. Along this spectrum, there are four basic practical approaches being used today: [8][9][10] ,Table1 show control method and way

Table 1 navigation algorithm

Control architecture	way
Deliberative Control	Think hard, then act.
Reactive Control	Don't think, (re)act
Hybrid Control	Think and act independently, in parallel.
Behavior-Based Control	Think the way you act.

5.1 Deliberative algorithm

A* of the example of Deliberative method is spread algorithm. A* has limit that the calculation amount is much when this method applies in actuality dynamic environment.
Now, algorithm is introduced of until D* that can react in dynamic environment. Also, there is Dubins's Car model by much mentioned algorithm. Kokou Djath, Ali Siadat[11] is introducing result that apply Dubins's Car model to this system.

5.2 Reactive control and Behavior-Based Control

To make behavior of worm functional representation is reactive control that method to get sensing value and react to motor. Behavior-based control reacts well in dynamic environment through mixing this behavior..
However, this method has disadvantage that behavior number to appear in real situation limit .Sometimes, robot fail to path generation when situation need more intelligent decide.
The representative example is local minimum case of Fig .6.

5.3 others algorithm

Additional, there is interesting path generation algorithm that method to use modeling to be fluid field[12]. As another potential method, a potential viscous fluid field method ,that making generate optimal path planning uses fluid field method , proposed by C.Louste and A.Liegeois
But this method has much arithmetic. To get fluid path, Integral calculus arithmetic must calculate real time. This method need more verification the hypothesis ,for being possible. Therefore ,this method unsatisfied apply to medical service mobile robot.

5.4 Application algorithm : Hybrid Control

A.R. Dieguez, R.Sanz and J.Lopez compares and studied deliberative way and reactive way[13].
Finally, problem must be solved, It is that overcome Local minimum and that search for most optimal path.
In this paper, another point is,considering human, path generation algorithm.
So, generated path must be application availability of dynamic environment, soft path generation, suitable move for user, stable navigation, motion that overwork does not go to user. This subject was touched on above.

5.5 Solution

Behavior-Based control have difficult problem when robot meet trap situation. It is proposed that giving noise factor to make it overcome this to escape trap. However, this method gives vibration to robot. There is that this vibration is bad influence to patient, to introduce in 3.1 of above.
Robot need stable navigation, so these noise factor bad influence things. Therefore, these method should be excepted to medical robot.

It is hybrid control that is proposed by other solution..
A.R. Dieguez, R.Sanz and J.Lopez[13] introduces the hybrid application. Yong-Kyun Na[14] is supplying other solution that behavior Modules that use neural network. However, it need re-checking whether this module can apply equally in dynamic environment.

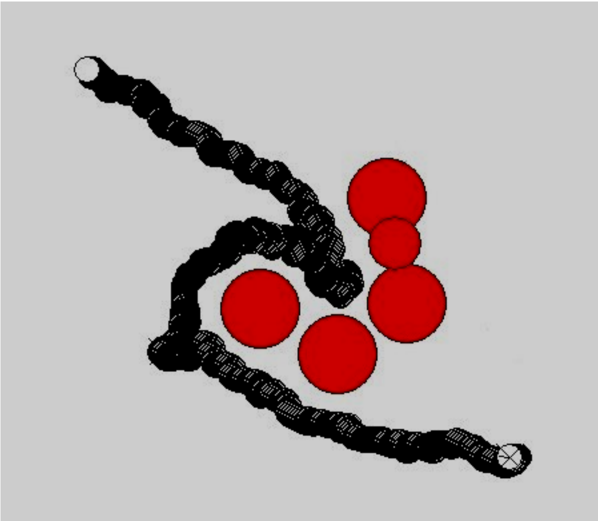

Fig. 6 Noise effect

6. CONCLUSION - THE PROPOSE TRAP BEHAVIOR

When robot meet trap situation, noise effect to escape bad influence to patient. This time, must escape local minimum other method. If a bug meet local minimum environment, that it is easy for bug to lost path unless has other sense to find position and path. So, let's give the function of more intelligent to robot. Now, that is, regard space that fall to local minimum as some pitfall. That is, regard environment that make to fall to local minimum as single obstacle that must avoid. If robot regard trap environment as wide obstacle, then robot has more intelligence.
This is hybrid navigation algorithm.

Trap algorithm consists of order show following.
Firstly use criterion of local minimum mode and estimate trap situation. Estimating whether robot meet in trap state through time versus position information.
This time, form conclusions from experiences position information of robot by technique that is probability. Then the trap point must do marking. And the making point regards as place that have trap environment.
Secondarily, to confirm trap, adding weight at position that pass after robot escape to local minimum and search trap.
Then thirdly, create virtual huge obstacle.
This time, obstacle size proportional value of distribution, that distribute variance calculate from front probability technique.
Fourthly, create virtual obstacle and pass environment that have local minimum.
This process is trap behavior's processing.

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