Evidence Based Exercise Therapy Assisted by Robot and Network for Locomotive Syndrome on the earth and future Mars Base

Akiyoshi KABE *

*Faculty of Human Sciences, Waseda University, Japan
e-mail: akiyoshi.kabe@waseda.jp

Abstract

This paper describes the basic architecture of the evidence based exercise therapy system aided by robot and network for Locomotive Syndrome patients on the earth, the evaluation in a hospital, and feasibility study to adopt on a Mars base.

Locomotion training is strongly promoted by the Japanese orthopedic Association, to prevent diseases of locomotorium. Even strongly recommended, it is actually difficult to keep motivation to have exercise every day for elderly people, mostly alone at home, as instructed by medical doctors. In the evaluation by actual users, most users have positive feeling for robot, friendly animal type, as partner of training.

This positive feeling for robot as a partner, has possibility to support mission specialists by robot on a Mars base, connected by network from the earth. The basic design of robot on a Mars base is tele-presence of family members of mission specialists, to support strongly in severe environment.

1 Locomotive Syndrome

According to the latest investigation carried out by Japanese Cabinet Office, the population is 127,800,000 people in Japan. The number of people over 65 years old is 29,750,000 and is 23.3% of total population. Moreover, the average life span of male is 79.55 years old and average life span of female is 86.30 years old. But the average healthy life expectancy of male is 70.42 years old and average healthy life expectancy of female is 73.62 years old. Consequently, it means that male needs 9.13 years nursing care and female needs 12.68 years nursing care.

Fig.1

Based on this background of Japanese society, it is strongly said to improve QOL(QualityOfLife), and live without nursing care as long as possible. For example, to be able to go toilet without nursing care through life. Therefore, adequate exercise is continuously required for people to realize this life[1][3].

Locomotive Syndrome is described as the high risk condition to be bedridden or nursing care level. It is usually caused by functional decrease of locomotorium such as bone, joints, muscle. The Japanese orthopaedic association proposed Locomotive Syndrome in 2007 in response to the policy of Japanese government which reinforce nursing care systems.

Here is the checklist if someone is in Locomotive Syndrome or not, called “Loco-Check”, named after Locomotive Syndrome check on the earth.

The following seven-point are to be checked.

(1) Can you wear socks, standing by only one foot?
(2) Do you often stumble or slip in your house?
(3) Can you go upstairs without holding balustrade?
(4) Can you cross the pedestrian’s crossing before a green signal turn to red ?
(5) Can you walk for fifteen minutes continuously ?
(6) It is almost impossible to go home with over two kilogram shopping bag.
(7) It is hard to do housework such as using vacuum cleaner or raise bedclothes (a futon in Japan) etc.

In these check points, the person saying at least one “yes” out of 7 check, have a possibility of Locomotive Syndrome. This checklist is described in the guideline distributed by the Japanese Orthopaedic Association.

Additionally the relation between selfsupported degree and Locomotive Syndrome is shown in fig. 1.

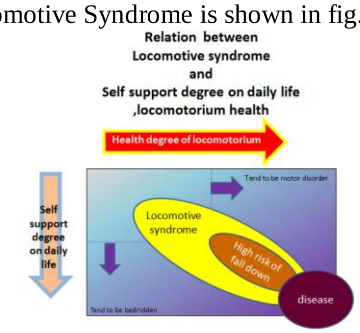


Fig.1 Relationship between Locomotive syndrome and Self support on daily life, locomotorium health (http://www.jcoa.gr.jp)

2 Method And System For Remedy

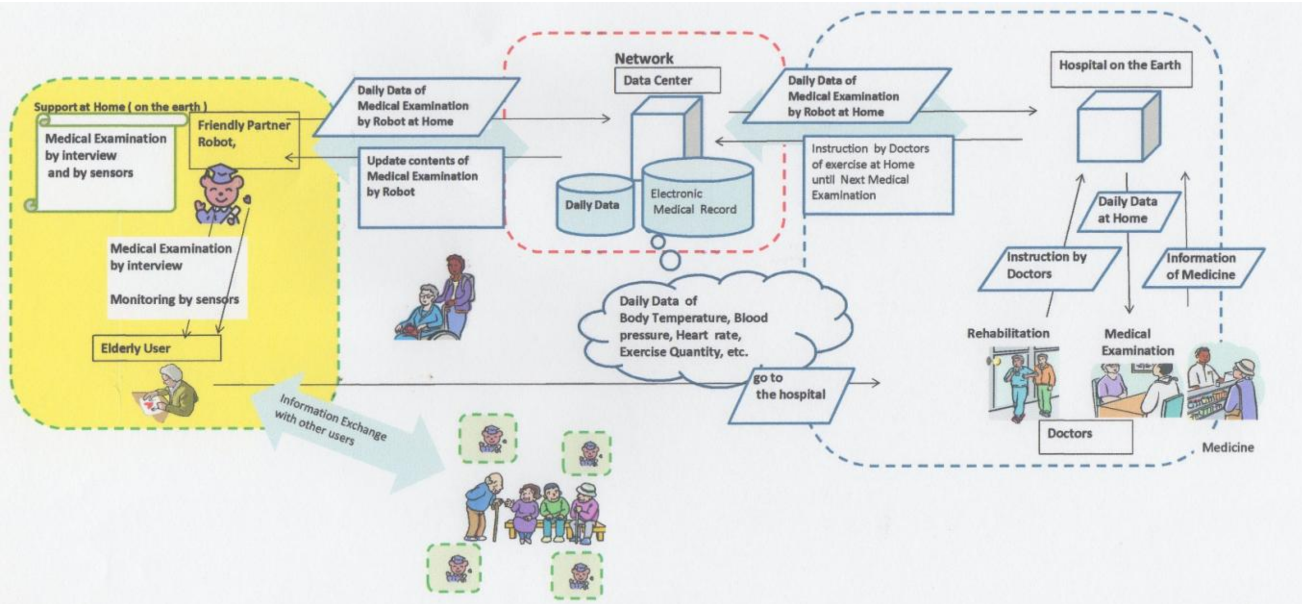


Fig. 2 A Total Architecture of Remote Medical System in the Application on the earth

The actual and only way to prevent Locomotive Syndrome is to keep having moderate exercise every day. For this purpose, the Japanese Orthopaedic Association recommends three types of exercise.

In this paper, robot aided exercise for patients in a hospital, in conjunction with the following three types of exercise, is mainly described. It will be extended to the partner robot to aid patients at home, verify their exercise and inform to medical doctors in hospital through network, as shown in Fig.2. Network based functions will be also discussed to receive evidence data of exercise and send polling to personal robot periodically.

2.1 Locomotion Training

This is the exercise aiming to develop muscles of lower body and a sense of physical balance, which consist of two type of exercises.

(1) Stand on one leg with your eyes open

(2) Squat

It is devised as not to stress legs and loin too much, and also to continue it every day. It is suitable for the people with heavy Locomotive Syndrome or the people trying to prevent to be Locomotive Syndrome.

2.2 The Other Training

To prevent to be Locomotive Syndrome, the training such as "Training program for middle and old age", "taijiquan" are also effective. These training programs contain some element of Locomotion Training such as "Standing on one leg" or "Squat". It is devised as having fun with friends.

2.3 The other sports

The other sports are also effective to prevent to be Locomotive Syndrome. But it must be careful not to be too hard.

2.4 The Training for Lumbago or Gonalgia

Exercise for back pain or exercise for gonalgia is also effective.

3 Locomotion Training In Details

3.1 Rules for training

The detail information of Locomotion Training, defined and recommended by the Japanese Orthopaedic Association is as follows;

The aim of locomotion training is to be able to walk without support and not to tumble. It consist of "Stand on one leg with your eyes open" and "squat" with five rules.

<Rule> During Locomotion Training, it is necessary to follow these rules for safety.

1. If you feel uneasy about your health or strength, consult a doctor first.
2. Do it at your own pace, don't do it too hard.
3. Be careful not to fall down
4. Do not do it right after a meal.
5. If you feel pain, stop the exercise and consult doctor.

3.2 Stand on one leg with your eyes open

A1. Keep open your eyes, stand on one leg and hold it up for a minute.

A2. Both standing on right leg and standing on left leg are one set. Three set per day.

A3. Be careful not to fall down

3.3 Squat

Squat is the training which reinforce muscles such as gluteus maximus muscle, quadriceps muscle, hamstring. Those muscles are used for stabilize backbone, knee and ankle. There are many kinds of squat, but in Locomotion Training it has to be minimum stress on knee and loins.

B1. Repeat squat training five or six times with a slow pace.

B2. B1. is one set. Keep do this three set per day.

3.4 Problem To be Solved

Locomotion Training is effective exercise to prevent to be Locomotion Syndrome, and easy exercise so that people can exercise whenever or wherever they want to do. But because of the easiness, it is quite boring for patients and people trying not to be Locomotion Syndrome. This is the reason why Locomotion Training is accepted as purpose point of view , but doesn't spread out in society. The major attempt in this research is to make Locomotion Training more fun and more acceptable with the aid of partner robot and vision sensors to verify the achievement of exercises.

4 Partner Robot To Assist Locomotion Training

4.1 Partner Robot for applications on the earth

A Partner robot is introduced to assist people in Locomotion Training, called "Tocco" as shown in Fig. 3, for the application on the earth.

Fig.3 A Partner Robot for Locomotion Training, Friendly Animal Type in the application on the earth

This robot system consists of robot body, valve-unit for air driven actuators, control unit, and interface parts.
The robot body is covered by plush of panda to make users feel more familiar.

Air-Driven actuator system has 5 parts and 9 degree of freedom to move the neck, shoulders and legs. The moving range of Neck is 28 degree for forward and backward, 40 degree for left and right to revolve. The moving range of Shoulder is 40 degree for forward and backward, 30 degree for left and right. The movement range of Leg is 20 degree for backward and forward as shown in Figure 4.

This Robot body is controlled by Pneumatic valve located in the box under the robot body. This Pneumatic valves are directly controlled by Real Time High Speed Network, CC-Link, one of the world standard in industries, and widely used in many applications worldwide.
The Pneumatic valves are controlled by use of Oil-free, small-size compressor located nearby robot body.

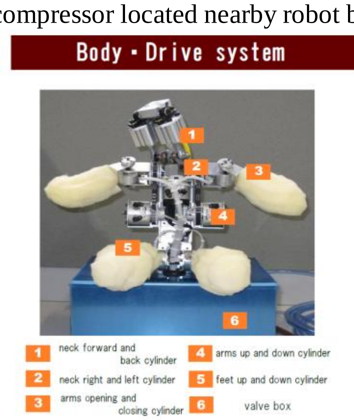


Fig.4 The Robot Body with Air-driven Cylinder, and Valve-Unit to control air cylinders, valves are connected though network, CC-Link, to controller

The control unit consists of PLC (Programmable Logic Controller, FX1N-24MT sequencer) with the CC-Link Interface of PLC (FX2N-16CCL-M) and other modules, such as Analog/Digital module, I/O Module as shown in Fig. 5.

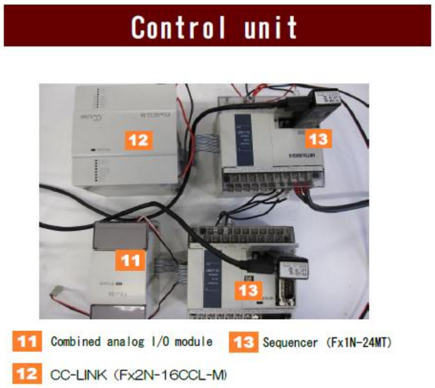


Fig.5 Configuration of PLC based Control Unit

4.2 Computer Vision System to Assist Locomotion Training (on the Earth and extended to on Mars)

The computer vision is also introduced in this robot system to verify the user motion of exercises if users perform correctly.

Some inexpensive devices are already available in the market, which have enough capability and reasonable price for the personal use.

KINECT has been selected for robot system because of the capability and high cost performance. The application programs of KINECT make it possible to detect a skeleton of human body as shown in Fig. 7. Kinect is the controller of Xbox360, and manufactured by Microsoft (Figure 6).

A voice recognition system is also introduced in this robot system, which engine is Julius, as two-pass large vocabulary continuous speech recognition (LVCSR) decoder software.

Julius adopts acoustic models in HTK ascii format, pronunciation dictionary in almost HTK format, and word 3-gram language models in ARPA standard format (forward 2-gram and reverse 3-gram trained from same corpus).

Fig. 6 The Vision System of Robot System,

Kinect manufactured by Microsoft

The great feature of Kinect is to be controlled without any specific additional devices for recognition of human body. This KINECT is placed in about 2m distance from users and detect the human body and also its detail as skeleton, including detail direction and position of each arm and each leg.

The robot system can detect and verify the exercise of users, by use of KINECT's capability to detect the detail direction and position of each leg of a user.

In 'Stand on one leg with your eyes open' exercise, it is necessary to raise one's leg 10 cm upper from the ground, and keep that position for a minute. KINECT with application program detect the position of one's leg, and verify the position from the ground and measure the duration for a minute.

The whole sequence of "the measurement of position of leg, for duration of a minute, and other sequence including voice recognition, voice generation to motivate a user", can be started by very simple gesture of a user or by voice recognition of keyword, such as 'Start'.

These functions are very easy for users, especially for elderly people, without requiring any special knowledge of robot and computers.

4.3 Application Program For Locomotion Training (on the Earth and extended to on Mars)

By use of vision system: Kinect and voice recognition system, this robot system can provide advices about Locomotion Training as follows. Currently, the application for "Stand on one leg with your eyes open" and "Squat" exercise has been implemented , and can be extended to other exercises as well.

First of all, if a user want to start Locomotion Training program of this robot system, all the user needs to do is just to wave hand to this robot “Tocco”, as KINECT is located beside, and in the direction to the user. After capturing the image of the waving hand user from embedded camera, Kinect detects the waving of user’s hand. According to this signal, the application of robot system starts.

During the Locomotion Training, if user’s leg descends to lower position comparing to the required position as 10cm upper or more from the ground, the robot “Tocco” generate the voice to say “Please raise your leg more!”(Fig. 7).

This dialogue between users and robot possibly contribute to make users feel friendly with robot, and improve their motivation to continue exercises.

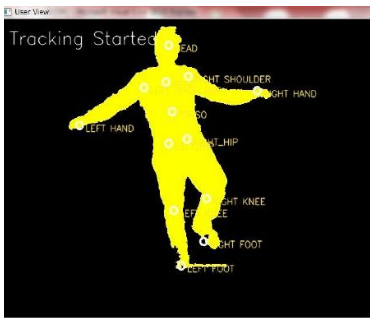


Fig. 7 An captured image and position information of user’s exercise by Kinect

4.4 Reaction from Users in the Actual Evaluation and Questionnaire for the application on the earth

The evaluation of robot system with actual users in hospital was held in Kochi-Hata-kenmin Hospital in Kochi prefecture. 40 male and female persons of actual patients of this hospital, from 45 years old to 85 years old, joined in this evaluation.
The related questionnaire, 50 Questions in total and 1 free comment, was also answered by these users, to know how this robot system work to help user to have more fun in Locomotion Training(Figure 8).

Some of Question items are shown as below.

Q. Please tell us your impression of the robot.

Q33.Do you have more friendly feeling to “Tocco” than other normal machines, because of cuteness?

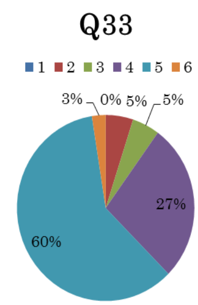
Q34.Do you think “Tocco” is instrumental in exercise of Locomotion training?

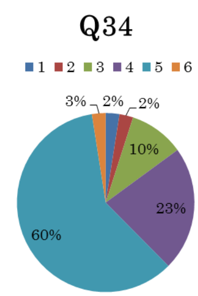
Q35.Do you want to be supported when you exercise Locomotion training?

Q36.Do you feel a connection with doctors and supporters through the robot “Tocco”?

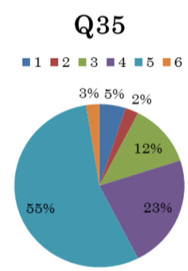
Answer
1. Not applicable
2. Little bit applicable
3. Not either
4. Nearly applicable
5. Applicable
6. No answer

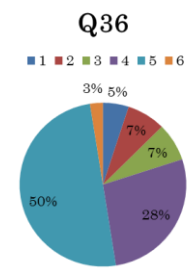
Followings are distribution maps of answer for each Question items.





Answer of Q33 shows us that 87% of users have more friendly feeling toward robot “Tocco” than other normal machines.
Answer of Q34 shows that 83% of users think robot “Tocco” is instrumental in exercise of Locomotion training.





Answer of Q35 shows that 78% of users want to be supported by robot “Tocco”, when they exercise Locomotion training.
Answer of Q36 shows that 78% of users feel a connection with doctors and supporters through robot “Tocco”.

The partner robot system was evaluated by actual users in the following process, shown in Figure 8, to start the system by user’s motion. During the exercise, this partner robot respond to the performance of user’s exercise, to encourage their motivation by Robot-Human voice Dialogue.

After this communication between Partner robot and Users, most of users talk to robot, like friend, - with Smile, “So Cute !”, “Yes, I will !” -, and feel that this Robot is their partner.
This is very significant result of the evaluation by actual users on the earth, which shows Robot can be a partner for mission specialists to keep their health on Mars.

Fig.8 (1) Standing on two legs in preparation
(2) Standing on one leg
(3) ~(4) Wave hands to start training program
(5) Keep one leg up for a minute

4.5 A Proposed Partner Robot on Mars and related System

A proposed partner robot on Mars is Humanoid type with tele-presence functions, remotely accessed by family members, of mission specialists staying in Mars base.
It is said that “Workloads, performance pressures, or lack of privacy are all factors known to increase stress and reduce mental stability in human space explorers” in the current research [5]. The tele-presence functions are important to support human in Mars base.
The family members encourage mission specialists with multimedia communication, to keep their health by their own exercise based on the instructions of Doctors (Fig.9).
This partner robot has smart phone equivalent “Face” device to communicate, as much as possible, like their family. The size is about 40cm height similar to a child.

Fig.9 A Partner Robot for Locomotion Training, Humanoid Type in the application on Mars

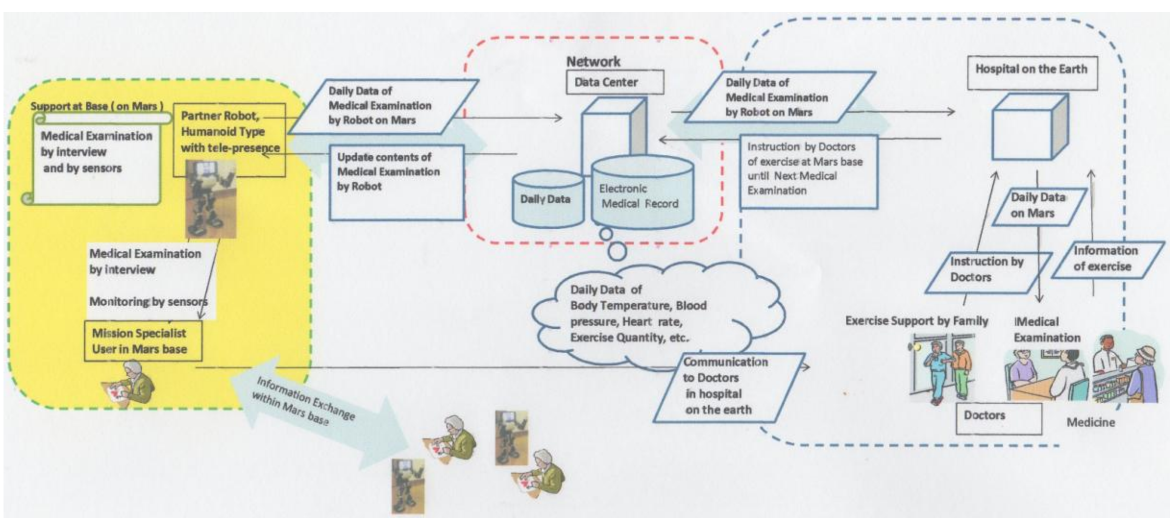


Fig.10 A Total Architecture of Remote Medical System in the application on Mars base

5 Discussion

The evaluation of functions and feedback from actual users in the hospital on the earth show that this robot system has possibility to be accepted by actual users as friendly partner of Locomotion Training to improve their motivation, and effective to verify the performance of exercises.

The evaluation was done in hospital at first, and can be done at home as well in further evaluation with questionnaire. After these evaluations, the functions of this robot system must be improved according to the feedback from actual patients.

Human-robot cooperation in Mars exploration research has been carried out in many space institutes, NASA, ISU, etc.[4][5]. The robot technology is discussed for 'In Situ Resource Utilization for Mining', 'Robotic Assisted Suit Systems for Surface Mobility – Suits', 'Robotic Construction and Set-up Equipment, Robotics and Vision Systems for Surface Mobility – Vehicles', and can be discussed for 'Health Care for Long-Duration Space Missions for Human Support' [4].

The architecture of system to support patients on the earth remotely, is mostly similar to the architecture of system to support mission specialists on Mars. We will keep working on this research and provide better system including remote control, monitoring through network as mentioned in Figure 1, and to extend to the application to support human on Mars as shown in Figure 10.

Acknowledgment

The research described in this paper, related to the applications on the earth, was carried out at Faculty of Human Sciences, Waseda University, by graduate and undergraduate students, and cooperation with Hata-Kenmin hospital in Kochi prefecture.

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