# Study on a welfare robotic-type exoskeleton system for aged people's transportation

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***Abstract* - In recent years, the rate of aged people is continuously increasing in Japan: in ten years, around 30% of the Japanese population will be aged more than 65 years old. These people often need some help from caretakers, and this causes a problem for the caretakers: it takes a very big burden for caretakers, for example, to lift people from their bed, when they need to go to toilets. So, a system to help caretakers would be needed: This is a master-slave unit exoskeleton, which helps the caretaker while loading the patient. It is moved by a Hydraulic Bilateral Servo system, whose master cylinders are moved by servo-motors. Presently, the conceptions of the body and hardware are finished. We are developing the servo-loop system and the driving software for the system, and more specially the pulse generation software for the motor of the master part of the exoskeleton. We will be able to discuss about the driving of the entire robotic-type exoskeleton system with a computer, through a PCMCIA interface system.**

## I. INTRODUCTION

In recent years, the rate of aged people is continuously increasing in Japan: in ten years, around 30% of the Japanese population will be aged more than 65 years old. The problem extends also to other developed countries, in Europe for example. The aged people often need some help from caretakers in everyday's life; because it is sometimes difficult for them to walk, so the caretakers must lift them, take care of them, this causes problems to the caretakers: it takes a very big burden for them, for example, to lift people from their bed, when they need to go to toilets. For patients and severely injured people, the problem is the same, so, a system to help caretakers would be needed. Some systems already exist on the market or in development, but these systems have several defects and must be ameliorated. Needed system must match the 2 important following points:

- To be able to lift from a bed, a wheelchair or a futon (on the ground).(mechanical conception)
- To be able to greatly reduce the force needed by the caretaker to lift the patient.(Mechanical and software matters)

## II. HARDWARE POINT OF VIEW

### *A. The Exoskeleton system :*

This system is a master-slave system: Slave system consists of an exoskeleton in which takes place the caretaker (Fig.1) who drives the slave system, helped by the hydraulic assistance system. The master system (Fig.2) uses motors to move, through a screw system, the master cylinders. The motor's servopacks are also situated in the master unit. The two units are linked with an Hydraulic Bilateral System (Fig.3). This Hydraulic Bilateral system consists of hydraulic cylinders, linked by a fluid that makes them move at the same time. (Fig.4). In this system, we use silicon oil to link the master and the slave part. The motor's nominal speed is about 3000[Rpm], but in fact, the using speed will be about 1500[Rpm]. To get the experimental information, we use 2 types of sensors in the system: position sensors attached to cylinders, and pressure sensors, measuring pressure in all the system's chamber (both sensors are attached to Slave unit, for two reasons: first is because the HBSA could induce some precision errors, and second is that the most important variations are observed in the Slave system, which supports the charge of the patient and the orders of the caretaker).

Fig. 1 : Position of the caretaker in the slave system. Note that oil tubes and caretaker's arm's protective parts are missing in this picture.

Fig. 2 : Master unit. Note : the oil pipes between the master and the slave unit are missing, and this pictures only shows cylinders of only one side of the unit.

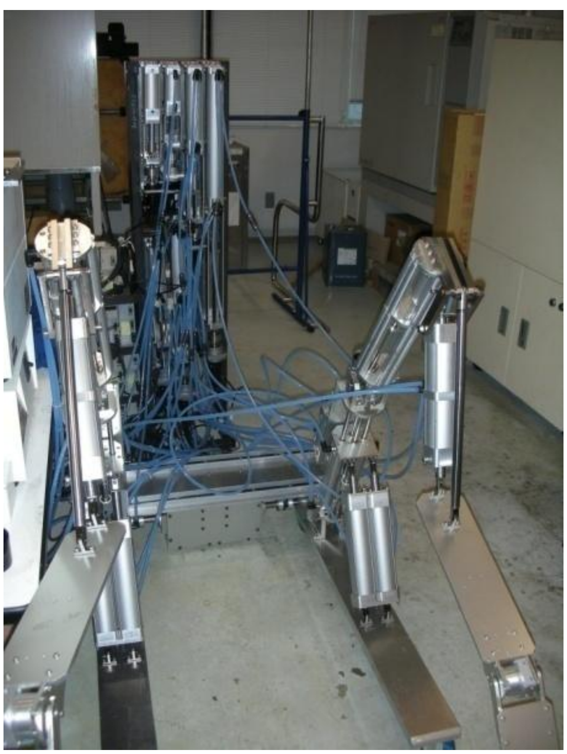


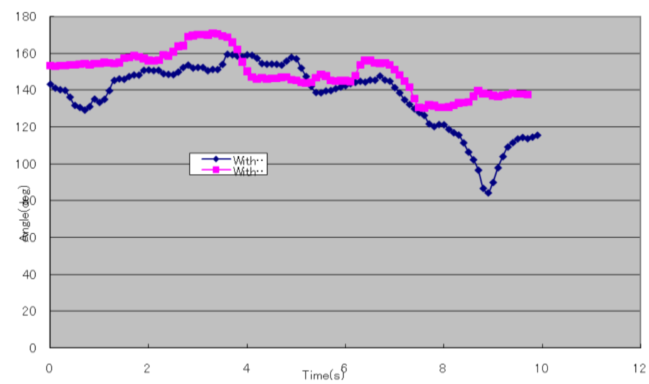
Fig. 3 : the two units are linked by the bilateral servo system. Note that short pipes are used for the moment.

*B. The Slave unit in details :*

The slave unit has been designed in order to not to be a nuisance for the caretaker's movements. Moreover, the patient should be lifted from a bed or from a futon, and from a wheelchair. So this slave unit must have many degrees of freedom. The slave unit specifications are given in Table I. We have done some experiments with Motion Capture, with the exoskeleton or without, in order to check if the slave unit's degree of freedom were enough (Fig. 4).

TABLE I
SLAVE UNIT SPECIFICATIONS

<table>
<tr><th>Part</th><th colspan="2">Mobile part</th><th>Actuator</th><th>Stroke</th><th>output power</th></tr>
<tr><td>Li-1</td><td rowspan="2">Legs</td><td>flexion</td><td rowspan="4">One articulation HBSA</td><td>30 [deg]</td><td>5105 [N]</td></tr>
<tr><td>Li-2</td><td>Up/Down</td><td>200 [mm]</td><td>1838 [N]</td></tr>
<tr><td>Li-3</td><td rowspan="2">back</td><td>flexion</td><td rowspan="2">40 [deg]</td><td>5105 [N]</td></tr>
<tr><td>Li-4</td><td>right/left</td><td>2553 [N]</td></tr>
<tr><td rowspan="2">Li-5</td><td>shoulder</td><td rowspan="3">picking</td><td rowspan="2">two articulations HBSA</td><td rowspan="2">43 [deg]</td><td rowspan="2">1838 [N]</td></tr>
<tr><td>Elbow</td></tr>
<tr><td>Ro-6</td><td>wrist</td><td>rotating HBSA</td><td>60 [deg]</td><td>9 [N-m]</td></tr>
</table>




Fig, 5 : measure of the shoulder angle while grabbing someone. The blue curve shows the angle while using the slave unit, the pink one shows the angle if you don't use the system. The two curves are relatively similar, and the slave system doesn't seem to be a nuisance to the caretaker.

*C. The Hydraulic Bilateral System Actuator :*

Between the master and the slave unit, the Hydraulic Bilateral System Actuator (Fig. 5) links the Master unit's master cylinders and the slave unit slave cylinders with tubes filled machine oil. The maximal pressure is about 2[MPa]. After many tests carried out with silicon oils of different viscosities in order to determine the optimal viscosity, high grade machine oil with the same viscosity (around 56 [cSt] ) has been chosen. This system has two great advantages compared with a directly motor-moved system:

- The slave unit's inside pressure can be easily measured, which couldn't really be realized with motors.

- Thanks to the oil's viscosity and compressibility, this HBSA obtains very smooth movements, and this is a very important capacity for that type of carrying system.

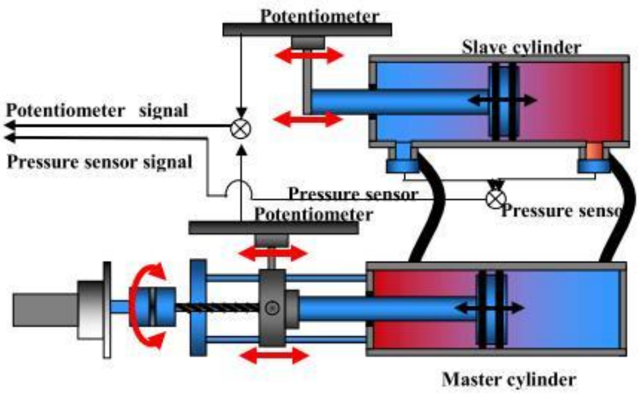



Fig. 5 : the HBSA schematic. The motor moves the master cyclinder by moving, then the master cylinder, by displacing oil, moves the slave cylinder.

## III. System Control

### *A. Communication with the hardware :*

The Motor's rotating speed is controlled directly by the frequency of the pulse signal sent to the servopack. (See Patterns in Fig. 6) Despite of this, this servo-pack is very flexible and offers many different patterns we can use to control this rotation speed. In order to reach the Motor's nominal speed (3000[Rpm]), we need a signal about 100[KHz]. So, just by modifying the pulse' frequency, we can control the speed of the Motor. This way, we intend to drive the complete hardware system, by using potentiometer's and pressure sensor's informations. This driving will probably need a very complicated servo-loop system, whose core should be based on a Matlab-developed software. In fact, it is very important for the caretaker's and the patient's safety that the system must react correctly without any unstable results, whatever the conditions are.

| Cn-02 Bit D | Bit 5 | Bit 4 | Bit 3 | Input Pulse Multiplier | Reference Pulse Form | Motor Forward Run Reference | Motor Reverse Run Reference |
|---|---|---|---|---|---|---|---|
| 0 (Positive logic setting) | 0 | 0 | 0 | | Sign + pulse train | PULS (1CN-1) SIGN (1CN-3) "H" | PULS (1CN-1) SIGN (1CN-3) "L" |
| | 0 | 1 | 0 | ×1 | Two-phase pulse train with 90° phase difference | 90° PULS (1CN-1) SIGN (1CN-3) | 90° PULS (1CN-1) SIGN (1CN-3) |
| | 0 | 1 | 1 | ×2 | | 90° PULS (1CN-1) SIGN (1CN-3) | 90° PULS (1CN-1) SIGN (1CN-3) |
| | 1 | 0 | 0 | ×4 | | | |
| | 0 | 0 | 1 | | CW pulse + CCW pulse | PULS (1CN-1) "L" SIGN (1CN-3) | PULS (1CN-1) SIGN (1CN-3) "L" |

Fig. 6 : control signal Pattern. The pulses depend on the settings we use for the servopack.

### *B. Control software and servo-loop :*

To control this system, potentiometers and pressure sensors are attached to both master and slave units. In order to use the information sent by these sensors to drive the system, a servo-control would be needed, This servo-control' loop' schematics is given in Fig.5,in which the parts in red designate the software parts, subject that will be developed further. This loop' schematic is aimed to help to understand how the system acts and moves.

- First of all, the caretaker acts on the slave unit, creation a modification of parameters.(Pressure in cylinders and cylinder' position)
- That modification is detected by the sensors, and the system calculates the forces needed to "help" the caretaker to move the way he'd like to.

While the servo control operates and gives orders, the master system's motor rotate to create needed pressures (calculated at step 2) and, that way, match the needed force to help the caretaker to lift the patient.

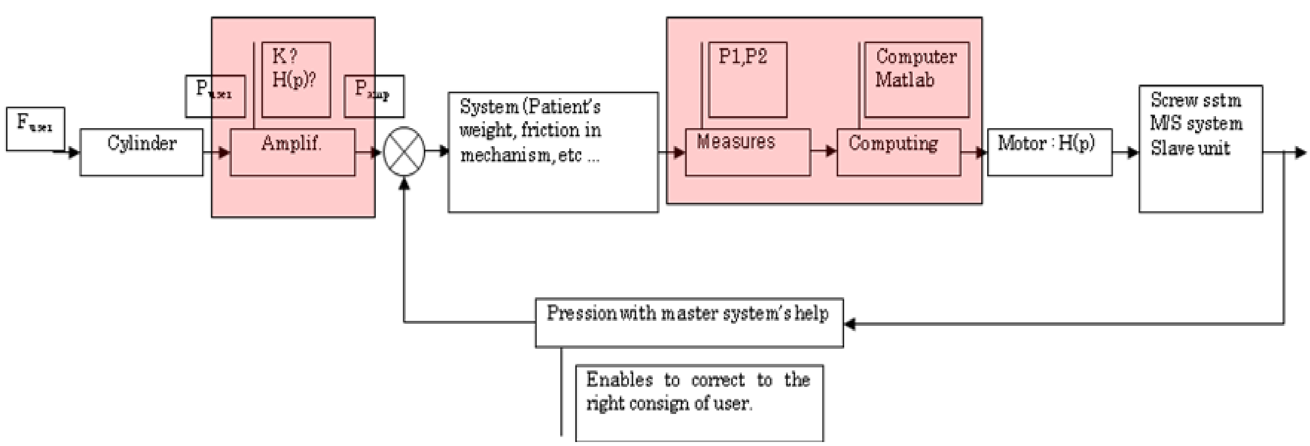



Fig. 7 : Servo control schematics.

*C. Open loop Tests :*

We decided to run Open loop tests on the system before starting developing the servo control Software. The reason behind this is simple: before developing the software, it is very important to know how this system reacts to pressure changes of variations of force. We used a square function generator, plugged directly to the system servopack, and by sending a pulse pattern, we made the motor rotate, which made the master and slave system move. While moving, we monitored the pressure inside the cylinder' three chambers and the two elbow angles. We made several experiences, sometimes without interfering; sometimes we added suddenly a load on the arm, in order to understand how the system would react. These curves are presented on Fig. 8

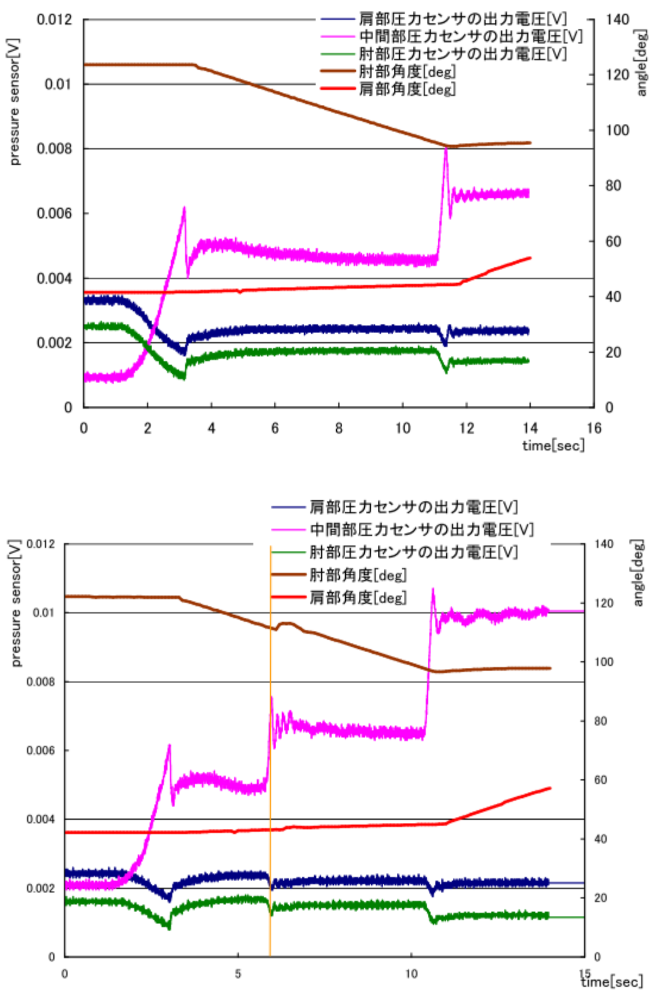



Fig. 8 : Cylinder's inside pressure (3 chambers) and articulation angle graph. The first graph shows the movement with no interference: the blue and green curves show the external chamber' pressure, the pink one shows the central chamber' pressure. The red and brown curves refer to the angles of the articulations. We can see a intense variation of the pressure when the movement stops. The second graph shows the same movement but this time, at the 6th second, we added a weight of 2 [kgf], we can see a little variation of angle and an intense variation of the central chamber' pressure.

*D. About the software :*

This software will be decomposed in three main parts:

- The first part will gather the information from sensors.
- The second part will calculate the needed force from the parameters and calculate the necessary pulses that will be sent further to the servopacks.
- The third software will generate and send the pulses to the servopack

The third software will be created in C++ language, for commodity and compatibility with the PCMCIA communication hardware. For the moment, only the sending pulse software has been coded, the main code is given Fig.9. This software has been tested (Fig. 10), in order to see if we could generate a square type signal directly from the computer with the interface PCMCIA card (Fig. 11)

```
int main(int argc, char* argv[])
{
    CFbiMTR742020 mtr;
    CDIOPort port;
    unsigned int uOut = 0x0000FFFF;

    CHECK_ERROR( mtr.Init() );

    const DWORD BASE_TIME = 2;
    DWORD dwStartTime;

    timeBeginPeriod( 1 );

    cout << "波形を生成します。" << endl;
    _getch();
    dwStartTime = GETTIME();

    TIMECAPS ptc;
    timeGetDevCaps( &ptc, sizeof(TIMECAPS));

    while ( 1 )
    {
        DWORD dwNowTime = GETTIME();
        DWORD dwDiff = dwNowTime - dwStartTime;
        if ( BASE_TIME <= dwDiff )
        {
            port.BIT.P1 = !port.BIT.P1;
            dwStartTime = dwNowTime;
            CHECK_ERROR( mtr.DOut( port ) );
        }
    }
    timeEndPeriod( 1 );

    return 0;
}
```

Fig. 9 : sending pulse program : this is the most basic file, the file that creates the square signal that will be sent to the PCMCIA interface and will make the motor rotate.

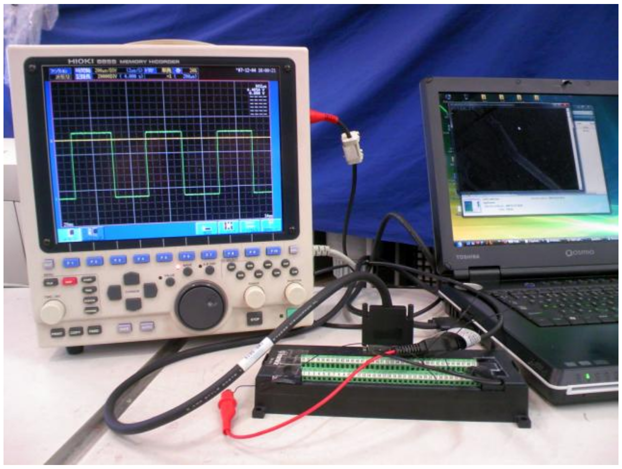


Fig. 10: Generation of pulses directly with a C++ based software, sent by the PCMCIA cardbus. Note: you can see the dock which is plugged to the interface. The motor and sensors will be linked to this dock.

Fig. 11: The PCMCIA CardBus we use for Input/Output matters.

## IV. Conclusion and Future developments

By helping to lift the patient, this system aims at reducing the burden for the caretaker. It isn't a nuisance for the movement of the caretaker, and enables him to lift a person from a bed or a futon. For the moment, the mechanical part's design is finished, and the research is, at that time, focused on the communication interface between the computer and the system. Moreover, we are studying the servo-control system and amelioration of some part of the mechanical part, in order to make the driving software more efficient, and to protect both caretaker's and patient's life.

Since we are still doing research at that time on the interface and software control, and on the sensor's implementation, we will probably present an ameliorated software part at the conference

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