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Development of Tendon-Driven Assistance Manipulator System by Air Pressure Control

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ABSTRACT

At the close of the 20^{th} century, in Japan, the reduction of incidence of the care worker in an aging society is becoming pressing need. Then, we aim at the development of the robot arm for care which is flexible and united with the motion of man.

In this subject, we suggest to develop the “Tendon-Driven 2-Link Manipulator Driven by Pneumatic Cylinder” as the care lift for assisting the rising and sitting of elderly people, disabled people or wheelchair users.

The tendon-driven manipulator system developed in this subject makes use of the pneumatic cylinder as an actuator. A pneumatic actuator is characterized by enabling the flexible action by the compressibility of the air. By means of the flexible action caused by the compressibility of the air, the welfare system making use of a pneumatic actuator can be expected to the “Human-Friendly Assist”.

KEY WORDS

Key words: Tendon Drive, Air Pressure Control, Pneumatic Actuator, Welfare Equipment

NOMENCLATURE

θ_1 : Angle of Link 1
θ_2 : Angle of Link 2
P1 : Supply Pressure to Cylinder 1
P2 : Supply Pressure to Cylinder 2
P3 : Supply Pressure to Cylinder 3
M_d : Mass of Load
L_d : Point of Load from Joint 2

INTRODUCTION

It tries to face a worldwide aged society in Japan now.
And there is a necessity of immediate development of the welfare nursing equipment according to such a social background. Moreover, there is a feature in the air pressure system that is a safe, gentle assistance of the patient by flexible equipment operation. Then, it pays attention in this thesis to the development of the tendon drive manipulator system using the pneumatic cylinder

as the welfare nursing equipment.

In this report, we propose the development of the nursing lift that aims to support the senior people, handicapped person or the wheelchair user's independence changing ships.

OUTLINE OF SYSTEM

Tendon-Driven Manipulator System

Figure 1 shows the outline chart of the tendon drive manipulator system that is developed. The manipulator part is lightened in the weight by locating the pneumatic cylinder apart from the manipulator by transmitting a forth with the tendon which is made by steed wire[1], and making the structure of an acrylic material, and the danger on the accidental collision to the patient has been reduced.

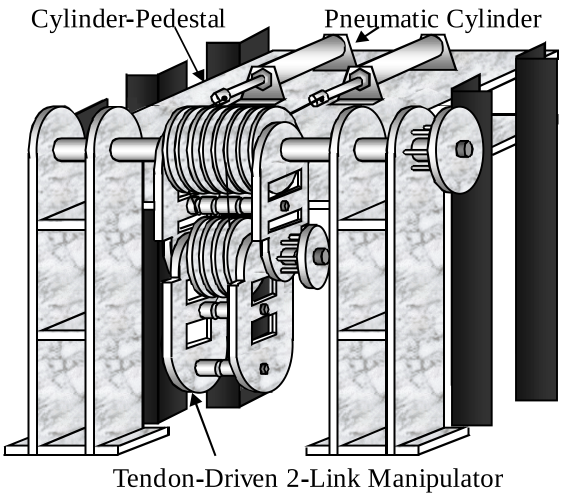

Figure 1 Diagrammatic Illustration of Tendon-Driven 2-Link Manipulator and Cylinder-Pedestal

The manipulator part is composed of two links, six belt pulleys, and four tendons as shown in figure 2. The pneumatic cylinders and each links are connected through the tendon and the belt pulley. This manipulator is a mechanism that drives the vertical plane by giving the tension of the tendon generated by the thrust of the pneumatic cylinder to each link as driving torque.

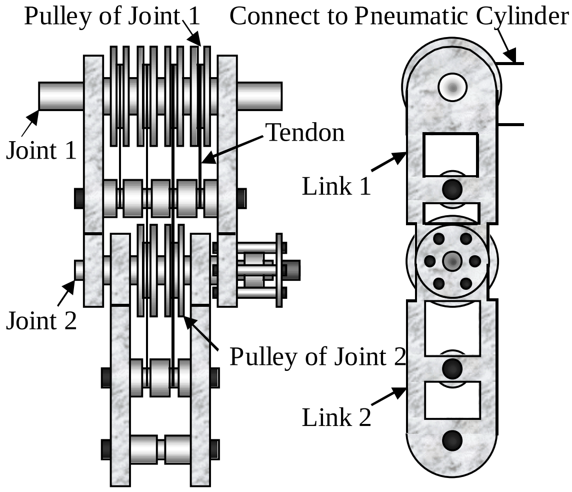

Figure 2 Diagrammatic Illustration of Tendon-Driven 2-Link Manipulator

Tendon-Driven Mechanism

Figure 3 shows the outline chart of the tendon transportation of the tendon drive manipulator system.

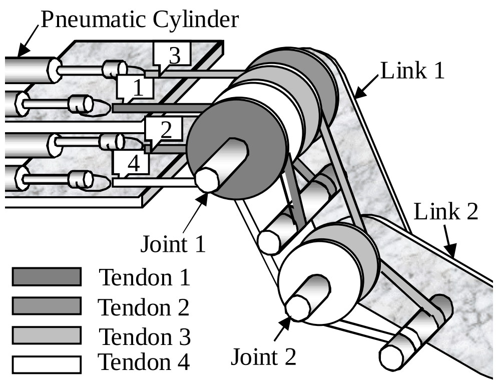

Figure 3 Diagrammatic Illustration of Tendon-Driven Mechanism with 2 D.O.F. and 4 Tendons

Tendon 1 drives Link 1 for above direction, and Tendon 2 drives Link 1 below. And, Tendon 3 drives Link 1 and Link 2 at the same time for above direction, and Tendon 4 is a mechanism that drives Link 1 and Link 2 below at the same time. The pneumatic cylinder which gives the tension to Tendon i shown in figure 3 is defined as Cylinder i.

ELECTROPNEUMATIC SERVO SYSTEM

Figure 4 shows the outline chart of the electropneumatic servo system to control the tendon drive manipulator system.

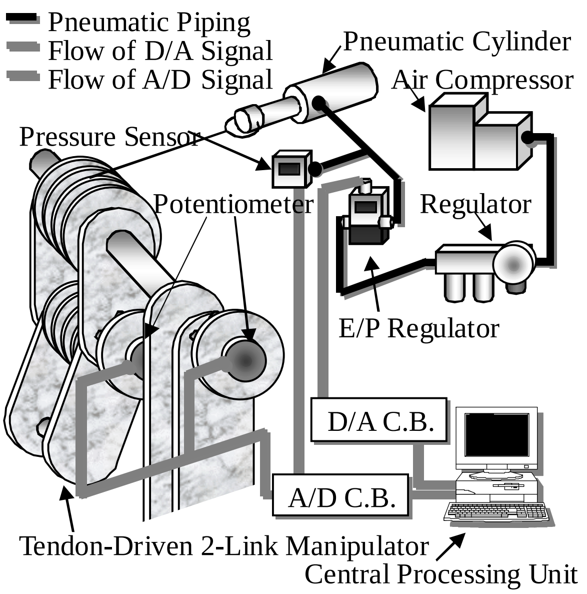

Figure 4 Diagrammatic Illustration of Electro pneumatic Servo System

Four pneumatic cylinders, four electropneumatic regulators, and four pressure sensors are set up in this subject. Each cylinder is a stroke 150 [mm], and is 40 [mm] in the inside diameter, and the compressed air of 0.5 [Mpa] is supplied and used in the maximum. Only the pressure of rod side is controlled, and the pressure is measured with the pressure sensor. The head side of cylinder is always assumed to be the atmospheric pressure liberating. The link angle is measured by the potentiometer.

REAL TIME SYSTEM

In this case, the real time system of the measurement and the control is constructed by using RTLinux[2] that is the real-time Operating System.
RTLinux adopted for the electropneumatic servo system in order to assure the real time response, is a kind of a hard real-time Operating System. The Linux process in the program and the relation of the RTLinux module are simply shown in figure 5.

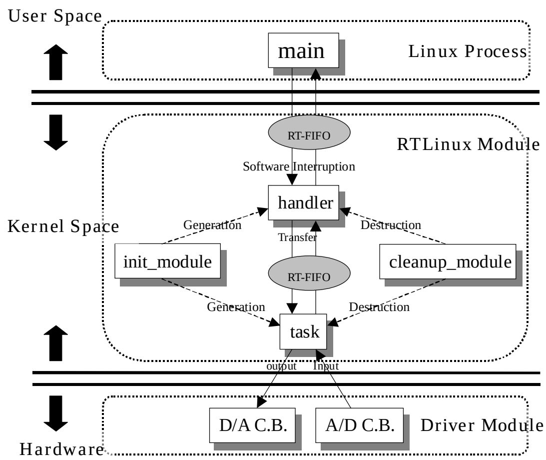

Figure 5 Conceptual Diagram of Real Time System

DEVELOPMENT OF NURSING LIFT

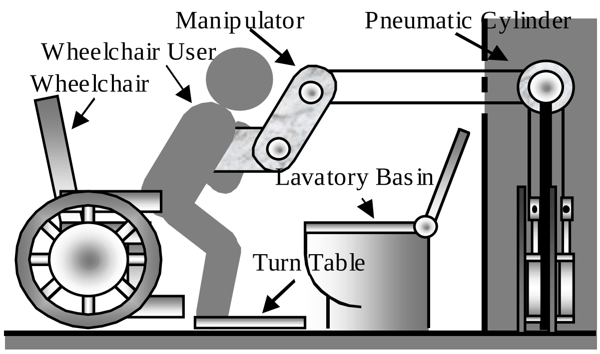

Figure 6 Diagrammatic Illustration of Suggested Care Lift

In this study, the development for the idea of practical use as the nursing lift shown in figure 6 is proposed. The principle of the motion of the lift is to keep the slant of the arm supporting a user to be horizontal in any cases, in order to avoid the slip of user along the arm.
Link angle θ_1 and θ_2 measured in this report are defined as shown in figure 7.

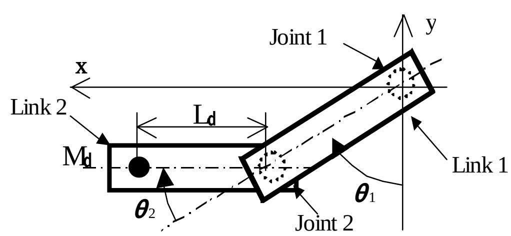

Figure 7 Defining Angle of Link View case with Measuring by Potentiometer

The manipulator must drive satisfying $\theta_1 + \theta_2 = 90°$, $0 \leqq \theta_1 \leqq 90°$, $0 \leqq \theta_2 \leqq 90°$ so that Link 2 may always become the horizontal in this nursing lift. The reason to drive the manipulator is that it is an ideal to operate the same arm in case of the case for the person to nurse in this manner.

When the person nurses, the forearm is made the horizontal and it does. Therefore, link 2 corresponding to person's forearm is always made to become to the horizontal.

STATIC CHARACTERISTIC EXPERIMENT

The state geostationary at the link angle of the manipulator is examined. The result when the load is not built is shown in figure 8 and the result when the load is built is shown in figure 9. P1, P2, and P3 of explanatory notes show the supply pressure to Cylinder 1, Cylinder 2, and Cylinder 3 and L1 and L2 show the link angle of Link 1 and link 2.

The supply pressure to each pneumatic cylinder to each link angle is calculated in this experiment, when the pressure is supplied to each pneumatic cylinder actually, and each link angle is measured.

Each cylinder and each link name relation are as shown in the above-mentioned.

Because the angle is attached in a positive direction from the origin with pressure not supplied to Cylinder 1, Link 1 has returned the starting point the angle of Link 1 by supplying pressure to Cylinder 2.

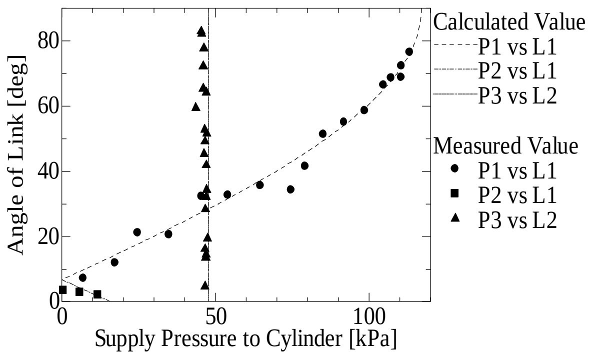

Figure 8 Static Characteristics of Manipulator case with Angle of Link vs. Supply Pressure to Cylinder (No Load)

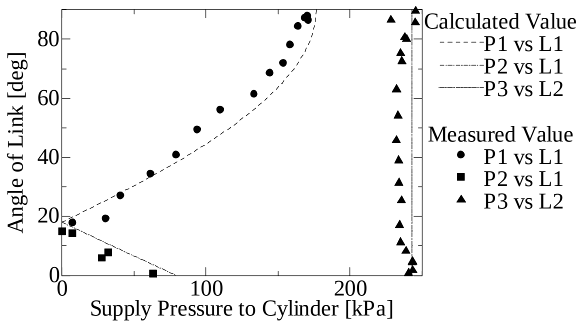

Figure 9 Static Characteristics of Manipulator case with Angle of Link vs. Supply Pressure to Cylinder (Load Point : L_d = 0.22 [m], Load Mass : M_d = 3.0 [kg])

An excellent result without a big error margin when there was no load as showing in Figure 8 was obtained.

It reaches the angle of the target when applying load as shown in Figure 9 by the supply pressure whose link angle of Link 2 is smaller than the theory as the supply pressure to Cylinder 3. It seems as the cause of the error in this experiment is that the weight actually used as a load was not complete ideal mass and so has distributed mass and then it does not load at the constant portion at manipulator.

However, it was confirmed that the theoretical equation of the manipulator was almost effective to deduce the torque against the load by this experiment.

DYNAMIC CHARACTERISTIC EXPERIMENT

Figure 10 shows the result of dynamic characteristic experiment with PID feedback control. This is a control result for adjusting the angle of the link of targets of Link 1 to 60°, and adjusting the angle of the link of targets of Link 2 to 30° to make the arm being horizontal.

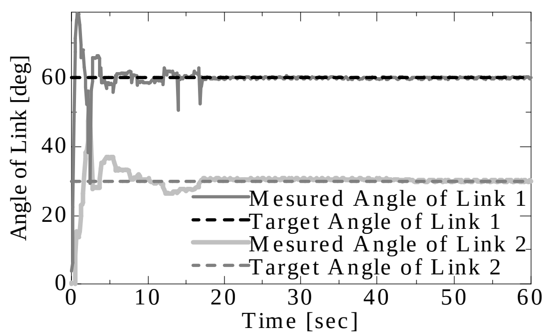

Figure 10 Dynamic Characteristics of Tendon-Driven 2-Link Manipulator case with Angle of Link vs. Time : Dynamic Characteristics (θ_{ta1} : 60 [deg], θ_{ta2} : 30 [deg])

When the angle of the link of targets of Link 1 is set to be 60° and the angle of the link of targets of Link 2 is set to be 30° as shown in Figure10, each link settled to the target link angle and an excellent result was obtained.
However, there is the problem such as setting to a link angle different from the target link angle takes long respond time. And the overshoot was seen, the range of deflection reaches at 30° as Link 1 and 45° as Link 2. The improvement may be expected by adjusting the parameters of the PID feedback control.

CONCLUTION

By using the real time system named RTLinux, the demanded posture of the manipulator could be proven in the achievement of both the static and dynamic controls of the tendon drive manipulator as a nursing lift system that uses the pneumatic cylinder as an actuator.
To put it to practical use as a nursing lift, establishing the stability of system and deriving the dynamic equation of the manipulator that considers the patient's operation is necessary, and these are problems in the next future.

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