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Development of Anthropomorphic Robot Hand

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Abstract

The anthropomorphic robot hand with the linear actuators consisting of a motor and a lead screw has the stronger grasping power than the hand actuated by motors and insufficient gear reduction. This paper presents the SKKU Hand II parallel mechanism to use the linear actuators effectively for the robot hand. It enables us to get the forward/inverse kinematic solutions, while the previous mechanism for the linear actuator failed. The driving circuits for the SKKU Hand II are embedded in the hand, and each driving circuit communicates with others using CAN protocol. In addition, a tactile sensing system is developed with miniaturized electronic hardwares such as charge amplifier, signal processing unit etc., and it is integrated into the robot hand. In addition, the workspace of the robot finger module is enlarged by EM joint locking mechanism depending on the locking states. In order to verify the effectiveness of the mechanisms adopted in the robot hand, we theoretically and numerically analyze the performances of the robot finger module such as bending speed, fingertip force, and workspace.

Keywords: Robot Hand, Anthropomorphic, Parallel Mechanism, Kinematics, CAN Protocol

1. Introduction

Recently, robots have begun to perform various tasks on replacing the human in the daily life such as cleaning, entertainments etc. In order to accomplish the effective performance of intricate and precise tasks, robot hand must have special capabilities, such as decision making in given condition, autonomy in unknown situation and stable manipulation of object. It must also possess tactile information to be able to carry out complicated manipulative tasks in a natural environment. Consequently, the tactile sensor is required to support natural interaction between the robot and the environment.

Many researches on the tactile sensing and the anthropomorphic multi-fingered robot hand have been reported up to now. Dario *et al.* developed "Artificial tactile sensing system" for a robot finger (Dario & Buttazzo, 1987). The system is able to detect the contact force, the vibration and the variation of temperature like mechanoreceptor of the human by arranging PVDF films that possess piezoelectricity and pyroelectricity. Howe *et al.* developed a dynamic tactile sensor that can detect slippage by means of the change of stresses due to deformation of the contact with the object (Howe & Cutkosky, 1993). Maeno *et al.* presented a tactile sensor, called "artificial finger skin" based on PVDF (Fusjimoto et al., 1999; Yamano et al., 2003). The sensor capable of detecting the incipient slip was designed to possess the characteristics similar to that of the human finger. Hosoda *et al.* reported a soft fingertip with two layers made of different kinds of silicon rubbers (Hosoda et al., 2003). The Utah/MIT hand developed by Jacobsen *et al.* is driven by actuators that are located in a place remote from the robot hand frame and connected by tendon cables (Jacobsen et al., 1984; Jacobsen et al. 1988). Hirzinger *et al.* developed DLR-Hand II, which build the actuators into the hand. Each finger of robot hand is equipped with motors, 6-DOF fingertip force torque sensor and integrated electronics (Butterfass et al., 2001; Gao et al., 2003). Kawasaki *et al.* presented anthropomorphic robot hand called the Gifu hand III, which has a thumb and four fingers (Kawasaki et al., 2002; Kawasaki et al., 2002). The thumb has 4 joints with 4-DOF and each of the fingers has 4 joints with 3-DOF. Moreover, the distributed tactile sensor which is made of conductive ink is arranged about 859 sensing points on the palm and the fingers. Shimojo *et al.* utilized the pressure conductive rubber as a pressure sensitive material (Shimojo et al., 2004). They attached the sensor onto a four finger robot hand and a demonstrated it's grasping operations with a column, sphere, etc. Although a number of researches have been done up to now, however, their motion of robot hands is unlike that of the human because the mechanism of robot hands is different from that of human in many aspects. A study on the grasping motion of the human hand noted that the metacarpal link of the thumb plays the key role in power grasping (Calais-Germain, 1993). Despite these differences, however, many researchers have been investigated about the robot hand of gripper type, which is difficult to perform dexterous grasping and manipulation of object like the human hand. Furthermore, most developed robot hands are larger than human hands. In addition, more researches are still necessary to put the tactile sensor into the practical use, because there remain many problems such as the limitations in the hardware as well as the algorithms for signal processing, the lack of the reliability, accuracy, response speed, dynamic, static characteristic, economical efficiency (Nicholls & Lee, 1989; Lee & Nicholls, 1995).

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Fig. 1. SKKU Hand II with Tactile Sensor

In this paper, we propose an anthropomorphic robot hand called SKKU Hand II, which has a miniaturized tactile sensor applicable to the robot hand. Thumb is at an angle opposite to its other fingers, and the thumb and fingers are orthogonal, such that it can performs dexterous grasping and manipulation like the human hand. The hand is similar to the human hand in geometry and size because inessential degree-of-freedom is abbreviated during grasping. All parts of the SKKU Hand II were composed of independent modules from each finger to the electric board for control. Moreover, SKKU Hand II's fingertip tactile sensor is composed of two functional units: a PVDF-based slip sensor designed to detect slippage such as incipient slips between sensing elements and contact surfaces, and a thin flexible force sensor that can read the contact force of and geometrical information on the object using a pressure-variable resistor ink. Both of them are integrated into a tactile sensor. All the sensing system can be embedded into the fingertip by miniaturizing the sensor and signal processing units. The proposed system is able to communicate with PC or external devices to provide information for controlling the robot hand. Also, the actuators, driving circuits of SKKU Hand II and its entire sensing system are embedded in the hand, and each driving circuit communicates with others using CAN protocol.

2. Kinematic Design of SKKU Hand II

To develop the SKKU Hand II, the design process started with the simulation to get optimal ratios of link lengths of finger (Kyriakopoulos et al., 1997; Wilkinson et al., 2003). We estimated an index of power grasping and fingertip grasping using kinetics model. Through the kinematic analysis and simulation, we decided that the ratio of length of link is 2-3-5 by Fibonacci sequence. Human hand is able to grasp objects by finger and thumb crossing each other to length way. The position of thumb and other finger is opposite to each other and thumb parallels other finger when gripper-type robot hand is grasping. However, in case of anthropomorphic robot hand, it grasps an object using the angle to direction of length of each finger for the power grasp and fingertip grasp. Especially, it has more powerful grasp by using the angle to direction of length of each finger in pinch grasp.

	Joint	Gear	Torque	Size [L× M][mm]	Weight [kg]
Finger	J1	275:1	0.115	115×22.5	0.116
	J2	258:1	0.106		
Thumb	J3	275:1	0.285	139×28	0.242
	J4	275:1	0.285		
	J5	258:1	0.106		
	J6	64:1	0.0297		
Total	-		-	-	0.9

Table 1. Specification of SKKU Hand II

3. Mechanical Design of SKKU HAND II

The SKKU Hand II is designed to be anthropomorphic in terms of geometry, size, and kinesis so that it performs power grasping and fingertip grasping as well as manipulations like the human hand. Especially, all of the parts consist of modules for easy development, maintenance and repair.

3.1 Finger module

As shown in figure 2, the SKKU Hand II has three fingers, and it is about 1.1 times bigger than a human hand. Each finger module has total 3-DOF, including coupled joint of the last two joints, and degree of freedom of finger of robot hand is smaller than that of human finger and the difference is due to the reduction of unnecessary degree of freedom for the ability of grasp and maximization of efficiency with size of robot hand very close to that of human hand. The actuator of finger module has two electric motors. And every motor is installed possibly close to palm module in order to consider weight balance and kinesis. And the last two joints, distal phalange and medial phalange joint, are mechanically coupled like a human finger by the pulley and timing belt. Also, it has some special space for being easy to install a variety sensors and the sensor processing circuit, in which for movement is more similar to human hand.

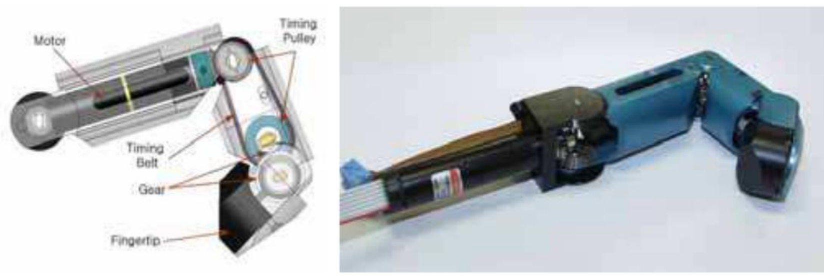

Fig 2. Finger Module

3.2 Thumb module

The thumb module has four DOF, and it is about 1.1 times bigger than a human thumb. The thumb has played a very important part in the anthropomorphic robot hand as well as human hand. The thumb can fulfil a complex work by means of saddle joint that is closest to the wrist. In general, the saddle joint of human has 3-DOF, and it is possible to manipulate any motion in the three-dimensional space because the motion of pitch, roll and yaw is performed simultaneously. The motion of pitch and roll is usually used to grasp the object, and the motion of yaw is used to circumvolve the object (precision grasp) motion like opening the cap of bottle. As depicted in Fig. 3, SKKU Hand II is realized with mechanism which imitates the role of saddle joint of human, but motion of yaw is neglected. The transmission of power is used with the bevel gear with 1:1 ratio, but distal phalange joint is composed of the double universal joint so that the position of motor stays close to palm module and for the independence of actuators.

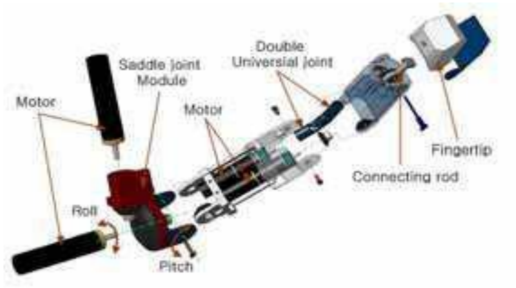

Fig 3. Thumb Module

3.3 Fingertip module

The shape of human fingertip is not just round but polyhedral. The surface of the fingertip can be discriminated into five parts depending on the grasping modalities such as pinch grasp, fingertip grasp and power grasp. The fingertip grasp uses a bottom of fingernail, the pitch grasp that hold a small and long object strongly and safely uses a side of fingertip. In the power grasp which is for wrapping an arbitrary object, the object is restricted using bottom of finger, thumb, and palm, and then object is fixed by bottom of fingertip at last. Consequently, the fingertip of SKKU Hand II is designed as a unique shape which can realize composite task like fingertip of human.

3.4 Motor control board

Our anthropomorphic robot hand has the ten motor control boards. As shown in Fig. 4, each board size is 39.5 x 23.5(mm) and every board is able to control just one corresponding motor. All of this board is composed independently from each other, but they are connected by CAN protocol. Also main microprocessor of motor control board used PIC16F458 and the Motor control board includes the current sensor and counter chip to check the state of motor in real time. Each current sensor which can be utilized information of force feedback control with tactile sensor of fingertip is used to measure the torque of finger joint.

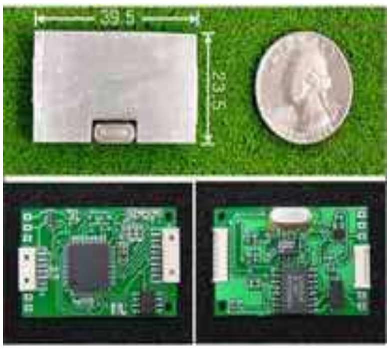

Fig 4. Motor Control Board

3.5 Integrated fingertip tactile sensor of SKKU Hand II

The finger tip tactile sensor consists of two different sensing elements, which is a thin flexible force sensor for detecting the contact force and location and the PVDF sensor for incipient slip. The structure of the fingertip tactile sensor is shown in Fig. 5. Thin flexible force sensor which possesses 24 sensing elements is attached under the fingertip to detect static contact force. Also, the PVDF sensor which has two PVDF strips is located on the thin flexible force sensor to detect dynamic response such as slippage using the mechanical deformation of the silicone (Choi et al., 2005).

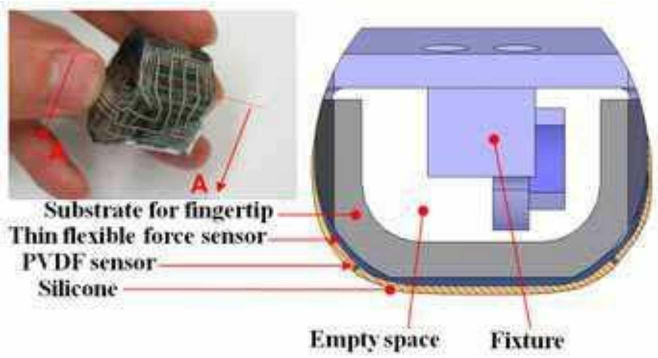

Fig. 5. Structure of Fingertip Tactile Sensor

4. Control of the SKKU hand II

The SKKU Hand II is able to control and communicate with motor control boards through CAN communication method. As shown in Fig. 6, motors are controlled by each independent motor control board respectively. If main control receives a message for control of finger from other application, this message is sent to each motor control board by the main controller. Then motor controllers control the motors of each finger using PID control. Force feedback control can be interpreted in the main controller using output signal of thin

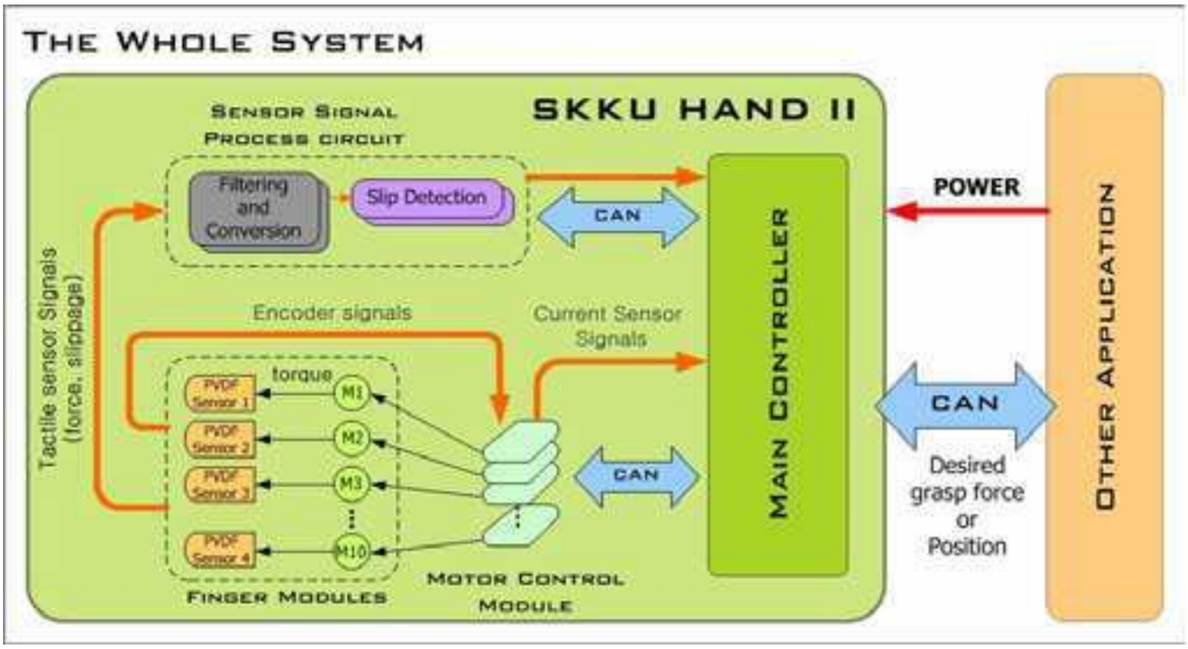

Fig 6. System schematic of SKKU Hand II

5. Experimental Results

In the first experiments, the sensor was touched and rubbed after installing on the fingertip. As shown in Fig. 7, it is noted that there exists the sharp change of signals, which implies that stick-slip occurred between the sensor and the contact surface. Also, the weight of 100g was rolled on the PVDF sensor. As shown in Fig. 8, the effect of stick-slip was not found and the smoother patterns of the signal compared to Fig. 7, was observed. When the weight of 100g rolled on the sensing element the output indicated about 1.2V constantly. Consequently, it is concluded that the characteristic of response can be discriminated depending on the surface characteristics of the object and the contact method, although calibrations are still needed.

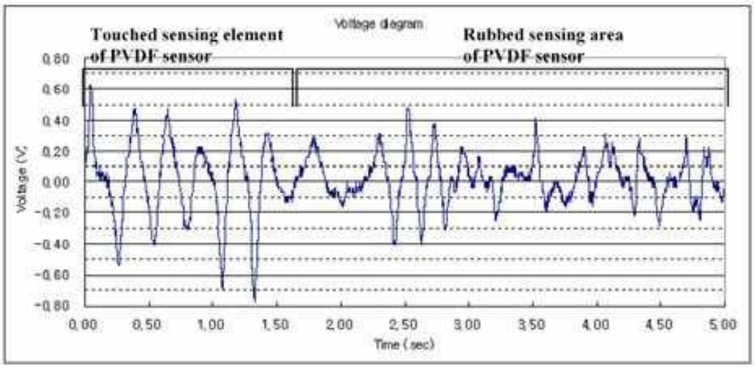

Fig. 7. Signal Output from Touching and Rubbing.

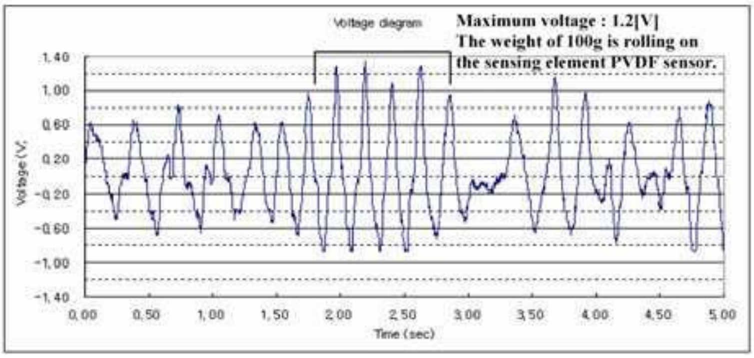

Fig. 8. Signal Output from Rolling of 100g Weight

In the second, the force sensor was tested. Static loads with the weight of 100g and 200g were applied, and the responses were obtained. As shown in Fig. 9, the output voltages of 2V and 4.25V were obtained for each weight. It is noted that the output has linear relation with the weight.

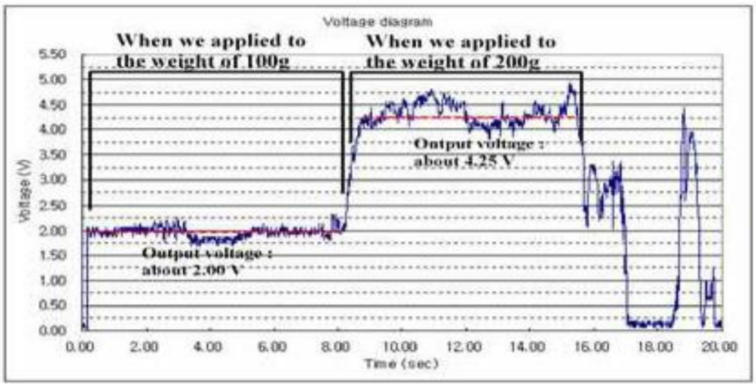

Fig. 9 The response of PVDF sensor, when we applied to the weight of 100g and 200g

6. Conclusion

In this paper, an anthropomorphic robot hand with tactile sensing system called SKKU Hand II was developed. Different from the previous gripper-type robot hands, the thumb of SKKU Hand II is designed as one part of the palm and provides the mobility of the palm. The robot hand is actuated by built-in DC motors, and fingertip tactile sensors are attached to its fingertips. A tactile sensor which can detects contact normal forces as well as slip is made of two organic materials, such as polyvinylidene fluoride (PVDF) that is known as piezoelectric polymer, and pressure variable resistor ink. Also, the tactile sensor is physically flexible and it can be deformed three-dimensionally to any shape so that it can be placed on anywhere on the curved surface. In order to detect incipient slip, a PVDF strip is arranged along the direction normal to the surface of the finger of the robot hand. Also, a thin flexible sensor to sense the static force as well as the contact location is fabricated into an arrayed type using pressure variable resistor ink. The driving circuits and sensing systems for the SKKU Hand II were miniaturized as small as to be integrated into the robot hand. The SKKU Hand II which integrated fingertip tactile sensors is validated through preliminary experiments. According to experiments on this research, it is possible to confirm that the each fingertip tactile sensor can detect the static force, location of contact and slippage.

7. References

1. Ashruf, C. M. A. (2002). Thin Flexible Pressure Sensor, *Sensors Review*, Vol.22, No.4, 2002.02, pp. 322-327, ISSN: 0260-2288
2. Butterfass, J.; Grebensteion, M.; Hirzinger, G. & Liu, H. (2001). DLR-Hand II : Next Generation of a Dexterous Robot hand, *Proceedings of IEEE International Conference on Robotics and Automation*, pp. 109-114 , ISBN: 0-7803-6576-3, Seoul, Korea, 2001.05, IEEE, Seoul.
3. Calais-Germain, B. (1993). *Anatomy of movement*, Eastland Press, ISBN: 0-9396-1622-X, Seattle, WA, USA
4. Choi, B. J.; Kang, S. C. & Choi, H. R. (2005). Development of Tactile Sensor for Detecting Contact Force and Slip, *Proceedings of IEEE/RSJ International conference on Intelligent Robots and Systems*, pp. 1977-1982, ISBN: 0-7803-8912-3, Edmonton, Alberta, Canada, 2005.08, IEEE/RSJ, Edmonton, Alberta
5. Dargahi, J. (2000). A piezoelectric tactile sensor with three sensing elements for robotic, endoscopic and prosthetic applications., *Sensors and Actuators A: Physical*, Vol.80, 2000.11, pp. 23-30, ISSN: 0924-4247
6. Dario, P. & Buttazzo, G. (1987). An Anthropomorphic Robot Finger for Investing Artificial Tactile Perception, *International Journal of Robotics Research*, Vol.6, No.3, 1987, pp. 25-48, ISSN: 0278-3649
7. Fraden, J. (1997). *Handbook of Modern Sensors: Physics, Designs, and Applications*, American Institute of Physics Press, ISBN: 0-3870-0750-4, USA
8. Fusjimoto, I.; Yamada, Y. & Maeno, T. (1999). Development of Artificial Finger Skin to Detect Incipient Slip for Realization of Static Friction Sensation, *Proceedings of IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems (MFI2003)*, pp. 15-20, ISBN: 0-7803-7987-X, Tokyo, Japan, 2003.08, IEEE, Tokyo
9. Gao, X. H.; Jin, M. H.; Jiang, L.; Xie, Z. W.; He, P.; Yang, L.; Grebenstein, M. & Hirxinger, G. (2003). The HIT/DLR Dexterous Hand: Work in Progress, *Proceedings of IEEE International Conference on Robotics and Automation*, pp. 3164-3168, ISBN: 0-7803-7736-2, Taipei, Taiwan, 2003.09, IEEE, Taipei
10. Hosoda, K.; Tada, Y.; Yamasaki, Y. & Asada, M. (2003). Sensing the Texture of Surfaces by Anthropomorphic Soft Fingertips with Multi-modal Sensors, *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems*, pp. 31-35, ISBN: 0-7803-7860-1, Las Vegas, Nevada, USA, 2003.10, IEEE/RSJ, Las Vegas, Nevada
11. Howe, R. D. & Cutkosky, M. R. (1993). Dynamic Tactile Sensing: Perception of Fine Surface Features with Stress Rate Sensing, *IEEE Transaction on Robotics and Automation*, Vol.9, No.2, 1993, pp. 140-151, ISSN: 1042-296X
12. Jacobsen, S. C.; Wood, J. E.; Knutti, D. F. & Biggers, K. B. (1984). The Utah/MIT dexterous hand: Work in progress, *International Journal of Robotics Research*, Vol.3, No.4, 1984, pp. 21-50, ISSN: 0278-3649
13. Jacobsen, S. C.; McCammon, I. D.; Blggers, K. B.; & Phillips, R. P. (1988). Design of Tactile Sensing Systems for Dexterous Manipulator, *IEEE Control Systems Magazine*, vol. 8, issue. 1 ,1988, pp. 3-13, ISSN: 0888-0611
14. Kawai, H. (1969). The Piezoelectricity of Poly(vinylidene fluoride), *Japanese Journal of Applied Physics*, Vol. 8, 1969.05, pp. 975-976, ISSN: 1882-0778
15. Kawasaki, H.; Komatsu, T. & Uchiyama, K. (2002). Dexterous Anthropomorphic Robot Hand with Distributed Tactile Sensor: Gifu hand II, *IEEE/ASME Transactions on Mechatronics*, Vol.7, No.3, 2002, pp. 296-303, ISSN: 1083-4435

16. Kawasaki, H.; Komatsu, T. & Uchiyama, K. (2002). Anthropomorphic Robot Hand: Gifu Hand III, *Proceedings of International Conference on Control, Automation, and Systems*, pp. 1288-1293, Muju, Korea, 2002.06, ICASE, Muju
17. Kolesar, E. S.; Dyson, C. S.; Reston, R. R.; Fitch, R. C.; Ford, D. G. & Nelms, S. D. (1996), Tactile Integrated Circuit Sensor Realized with a Piezoelecric Polymer, *Proceedings of Innovative Systems in Silicon, Eighth Annual IEEE International Conference*, pp. 372-381, ISBN: 0-7803-3639-9, Austin, TX, USA, 1996.04, IEEE, Austin, TX
18. Kyriakopoulos, K. J.; Riper, J. V.; Zink, A. & Stephanou, H. E. (1997). Kinemaic Analysis and Posiotion/Force Control of the Anthrobot Hand, *IEEE/ASME Transactions on Systems, Man and Cybernetics*, Vol.27, 1997, pp. 95-104, ISSN: 1083-4427
19. Lee, M. H. & Nicholls, H. R. (1995). Tactile sensing for mechatronics-A state of the art survey, *Mechatronics*, Vol.9, 1999, pp. 1-31, ISSN: 0957-4158
20. Nicholls, H. R. & Lee, M. H. (1989). A survey of robot tactile sensing technology, *International Journal of Robotics Research*, Vol.8, No.3, 1989.07, pp. 3-30, ISSN: 0278-3649
21. Russell, R. A. (1990). *Robotic Tactile Sensing*, Prentice Hall Inc., ISBN: 0-13-781592-1 , USA Shimojo, M.; Namiki, A.; Ishikawa, M.; Makino, R.; & Mabuchi, K. (2004). A Tactile Sensor Sheet using Pressure Conductive Rubber with Electrical-Wires Stitched Method, *IEEE Sensors Journal*, Vol.4, No.5, 2004, pp. 589-596, ISSN: 1424-8220
22. Wilkinson, D.; Weghe, M. V. & Matsuoka, Y. (2003). An Extensor Mechanism for an Anatomical Robotics Hand, *Proceedings of IEEE International Conference on Robotics and Automation*, pp. 238-243, ISBN: 0-7803-7736-2, Taipei, Taiwan, 2003.09, IEEE, Taipei
23. Yamano, I.; Takemura, K. & Maeno, T. (2003). Development of a Robot Finger for Five-fingered Hand using Ultrasonic Motors, *Proceedings of IEEE/RSJ International Conference on Robots and Systems*, pp. 2648-2653, ISBN: 0-7803-7860-1, Las Vegas, Nevada, USA, 2003.09, IEEE/RSJ, Las Vegas, Nevada
24. Yu, K. H.; Kwon, T. G.; Yoon, M. J. & Lee, S. C. (2002). Development of a Tactile Sensor Array with Flexible Structure using Piezoelectric Film, *KSME International Journal*, Vol.16, No.10, 2002, pp. 1222-1228, ISSN: 1738-494X