3D MODELLING AND DESIGNING OF DEXTO:EKA:

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Abstract- The presented paper is concerned with designing of a low-cost, easy to use, intuitive interface for the control of a slave anthropomorphic teleo- operated robot. Tele-operator “masters”, that operate in real-time with the robot, have ranged from simple motion capture devices, to more complex force reflective exoskeletal masters. Our general design approach has been to begin with the definition of desired objective behaviours, rather than the use of available components with their predefined technical specifications. With the technical specifications of the components necessary to achieve the desired behaviours defined, the components are either acquired, or in most cases, developed and built. The control system, which includes the operation of feedback approaches, acting in collaboration with physical machinery, is then defined and implemented.

Keywords*- humanoid, tele-operated, exoskeleton, robot, anthropomorphic*

I. INTRODUCTION

In this paper we present “DEXTO:EKA: - the humanoid robot”, which is a human-scale tele-operated self-balancing anthropomorphic robot. "Anthropomorphic" means having a shape like a human and "Tele-operated" means operated from a remote location. The humanoid is able to perform simultaneous mimicking motion of a person. The overall system is aimed at being able to yield complex meaningful interaction in a seamless and continuous manner. This humanoid will have torso with a head, two arms, face, eyes, mouth, ears and lots of sensors. Its upper body will resemble human while its lower body will be wheeled. Fig. 1 shows the block diagram of humanoid control system, in which the servos, sensors and all the peripherals are interfaced with the microcontroller unit. Audio and video are sent via Wi-Fi and all other data is sent to the other end via Xbee. Fig. 2 shows the block diagram of Man Machine nterface (MMI), which is used by the tele-operator to remotely control the robot. It consists of an Exoskeleton, joystick, display unit and an auditory system. The mode selection switch enables the tele-operator to select one of the three modes of operation. The three modes of operation are manual, semi-autonomous and autonomous. In manual mode, full control will be in the hands of the tele-operator and robot won’t be able to perform any action on its own. In semi-autonomous mode, the control will be still in the hands of the tele-operator but the robot will reject the commands if they are dangerous for survival of the robot. In autonomous mode, the robot will be autonomous and will do live entertainment

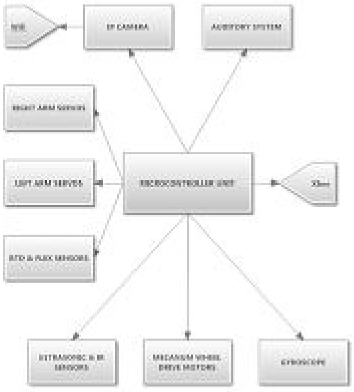

Fig. 1: Block diagram of humanoid control system

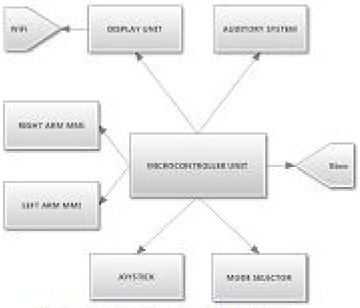

Fig. 2: Blockdiagram of the Man Machine Interface

II. STRUCTURE

After conducting various tests on the mecanum drive developed, it was concluded that the weight of the complete robot can’t be more than 20kg. Several computer based sketches were made to get a design which weighs less than 20kg and has a center of mass at the midpoint of the robot. Out of the 17 designs, the design in Fig. 3 was selected as it best suited our requirements. Most of the structure is made up of aluminium alloy to keep the robot lightweight nd compact. Aluminium has higher strength to weight ratio, compared to other metals. For both 1 kilogram of aluminium and steel material, aluminium is stronger. It’s hard but easily shaped (bent) properties are ideal for this project. echanical structure and motor brackets can be formed using aluminium. Main controller, batteries, servo controllers/drivers are located in chassis. The torso is a lightweight hollow structure, which has wires passing through the backbone. The backbone is a hollow Galvanised Iron pipe. The camera is placed at the top of the robot and is hidden in hair.\

Fig. 3: 3D computer generated sketch of the robot

III. LOCOMOTION

A. Drive One of the common omni-directional wheel designs is Mecanum Wheel or Ilon wheel. Mecanum wheel is based on the principle of a central wheel with a number of rollers placed at an angle around the periphery of the wheel. The angled peripheral roller translates a portion of the force in the rotational direction of the wheel to force normal to the wheel directional. Depending on each individual wheel direction and speed, the resulting combination of all these forces produces a total force vector in any desired direction thus allowing the platform to move freely in direction of resultant force vector, without changing the direction of the wheel. Fig. 4 shows Mecanum wheel design by Ilon with the peripheral roller with 45° degree slope held in place from the outside.

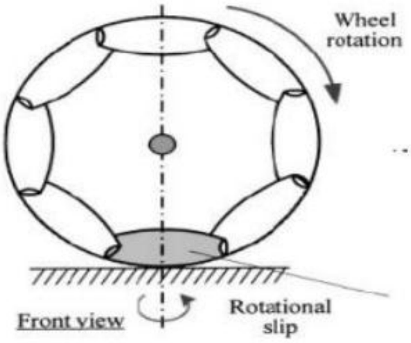

Fig. 4: Front view of Mecanum wheel

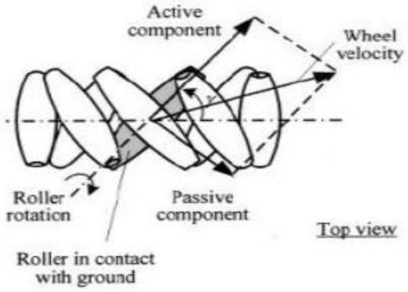

Fig. 5: Top view of Mecanum wheel

This design ensures that the rollers are always in contact with the work surface, thus allowing better performance on uneven surfaces. Using four of Mecanum wheels provides omni-directional movement for a vehicle without needing a conventional steering system. Positioning four Mecanum wheels, one at each corner of the chassis (two mirrored pairs), allows net forces to be formed in the x, y and rotational direction.

B. Navigation Depending on each individual wheel direction and velocity, the resulting combination of all these forces produce a total force vector in any desired direction thus allowing the platform to move freely in the direction of the resulting force vector, without changing of the wheels themselves. Fig. 6 shows the force vectors created by Mecanum wheels for each wheel. Summing these vectors we get a resultant vector in forward direction, thus giving us a forward motion

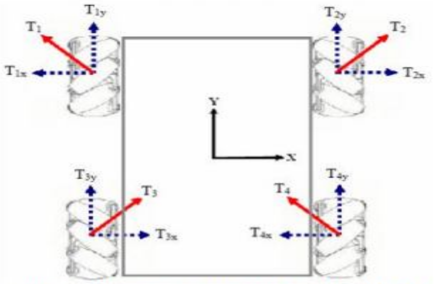

Fig. 6 : Force vectors created by Mecanum wheel.

Fig. 7 shows the robot motion according to the direction and angular speed of the wheels. Thus the robot is able to translate on any direction, forward/backward but also sideways left/right and turning on the spot, thanks to its special wheels. This is especially helpful when having to manoeuvre in tight environments.

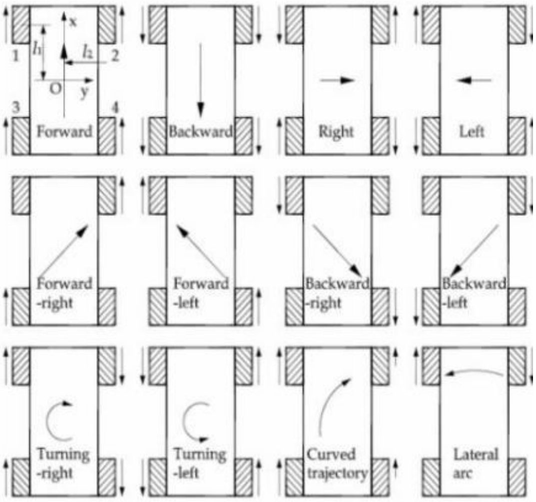

Fig. 7: Robot motion according to the direction and angular speed of the wheels

The navigation of a multi-sensor based mobile robot requires a good representation of the environment. An autonomous mobile robot should be able to construct a map of it senvironment based on the sensory information. Ultrasonic sensors have been widely used in mobile robots applications as they can produce good range information. Sharp IR sensors and Ultrasonic sensors are used for measuring distance of an object from the robot.

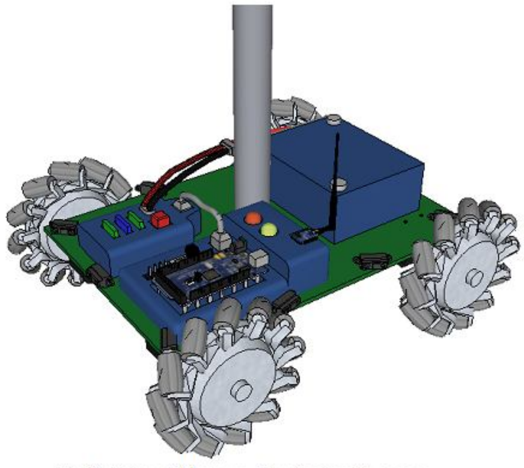

Fig. 8 : Design of Mecanum drive chassis with sensors

Ultrasonic sonar sensors actively transmit acoustic waves and receive them later. This is done by ultrasonic transducers, which transform an electrical signal into an ultrasonic wave and vice versa. Often it is possible to use the same transducer for both transmitting and receiving. On its path from the transmitter to the receiver, the wave becomes modified by the situation under investigation. The ultrasound signal carries the information about the variables to be measured. The task for the ultrasonic sensors is not merely to detect ultrasound. As intelligent sensors they have to extract the information carried by the ultrasonic signals efficiently and with high accuracy. To achieve this performance, the signals are processed, demodulated and evaluated by dedicated hardware.

C. Self-balancing

The robot is capable of both balancing dynamically and has entirely holonomic ground movement. This is achieved using a gyroscope module, which is a low power 3-axis angular rate sensor. A rectangular arrangement of mecanum wheels gives it the load-lifting, performance, and manipulation benefits of a dynamically-balancing platform without the maneuvering difficulties. The arrangement is capable of holonomic motion, describe a controller that maintains dynamic balance during holonomic motion. Omnidirectional navigation is also clearly advantageous. The orientation of the humanoid can be found out with the help of the sensor data. The gyroscope is calibrated before using. The sensor is placed at the top of the robot, so that it is highly sensitive to change in orientation. If a situation rises,which causes the robot to incline in the forward direction, the gyroscope would send out the changed orientation data to the microcontroller which will interpret the data and respond accordingly, in this case it would make the robot move forward so that the head and the lower body of the robot are in the same plane perpendicular to the surface it is moving on. This would greatly increase the probability of the robot to remain stable in rough terrain and while moving on an inclined or rough surface.

IV. ROBOTIC ARM

A. Design The main advantage of teleoperation is that human beings are adaptive and so are better able to deal with unstructuredwhich causes the robot to incline in the forward direction, the gyroscope would send out the changed orientation data to the microcontroller which will interpret the data and respond accordingly, in this case it would make the robot move forward so that the head and the lower body of the robot are in the same plane perpendicular to the surface it is moving on. This would greatly increase the probability of the robot to remain stable in rough terrain and while moving on an inclined or rough surface.

IV. ROBOTIC ARM

A. Design The main advantage of teleoperation is that human beings are adaptive and so are better able to deal with unstructured nvironments. Specifically, this is an anthropomorphic robotic arm with 6-DOF (degree of freedom) as shown in Fig 1. The 6-DOF covers the major and most common arm movements to cover a large area, and it also makes the arm easy to maneuver to lift and move objects in any direction.It is very similar to a human arm with respect to the number and position of the joints. Of the six degrees of freedom, four are for positioning (including the gripper) and two for orientation. If the joints are compared to their human equivalent, then the robotic arm can be said to have the following joints: abduction (shoulder rotation), shoulder back and forth, elbow, wrist up and down, pivot (wrist rotation), and gripper.

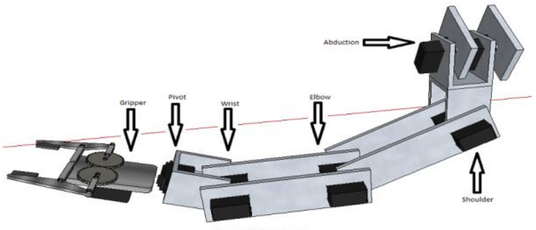

Fig. 9: 6-DOF robotic arm

The actuators for all of these joints are servo otors. The gripper is a two-finger construction; each finger with two parallel links. Force sensors are mounted between the joints of the manipulator. These sensors measure the amount of strain placed on each of these joints: the higher the strain, the greater is the amount of force that the joint is exerting. The main advantages of this system are that it measures actual forces and that the measurement does not interfere with the operation of the joints themselves. It is appropriate, for the gripper joint, to use a force sensor to measure the amount of force the slave is exerting on an object in its grip.

TABLE 1
Joint ranges and joint torques

S.NO.	JOINT	RANGE (degrees)	TORQUE (Kg-cm)
1.	Abduction	140	52.3
2.	Shoulder	110	47.7
3.	Elbow	125	32.6
4.	Wrist	180	13.1
5.	Pivot	180	8.4
6.	Gripper	NA	3.2

To measure the force, a sensor is attached to the inside of one of the gripper prongs. When the gripper closes around the object, the sensor is compressed between the object and the gripper prong. From this the force can be measured.These sensors are mounted on a flexible circuit board and have a small circular dot of force-sensitive ink. The resistance of this ink increases as the force applied increases. By using a simple operational amplifier based circuit this force can be converted into an analog voltage that can be fed into one of the ADC inputs of the transducer interface.

B. Man-Machine Interface Special emphasis has been given to the ease of operation and some form of force sensation. The control rig is fitted to the user's arm. Use of a 'wearable' jig in a bilateral master slave control setup has been introduced to simplify the MMI (Man-Machine Interface).The prototype of the master unit, shown in Fig. 10 and Fig. 11, is aluminium frame which the user straps
onto his arm.

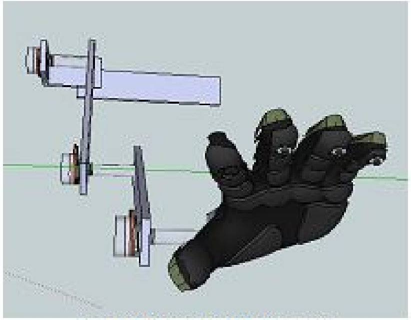

Fig. 10: 3D sketch of the MMI (Front view)

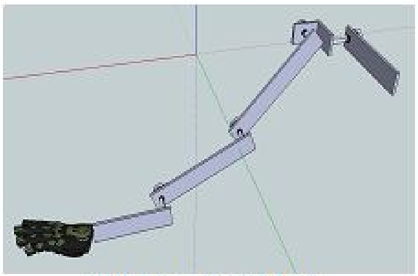

Fig. 11: 3D sketch of the MMI (Side view)

The proposed sensing mechanism is cost effective, accurate and can be easily implemented. In MMI, control methodology, which has been used in our work, the slave robot (teleoperator) exactly replicates the movements of the operator. Four potentiometers are placed on the slave robot, one each at the wrist, elbow, abduction and shoulder joints. The movements rotate the potentiometers' (relative to robot links) movements rotate the servo motors, by generating a variable analog voltage. The voltage signals from the potentiometers are fed to the transducer unit where their values are sampled and measured by an analog to-digital (ADC) converter. The voltage is thus a measure of the angular position of the robot joint. This arrangement is used to measure the positional error. A joint is commanded to move to a certain angle, and the voltage from the corresponding potentiometer is read.

V. VISUAL & AUDITORY SYSTEM

An Internet Protocol (IP) camera is used as the visual system. It is a type of digital camera which can send and receive data via computer network and the internet. They can be moved around anywhere on an IP network (including wireless). e
have day and night vision with 11 IR LEDs (night visibility up to 10 metres). It allows remote viewing video and record from any internet connection and remote pan and tilt control, giving us 2-DOF. It has a

higher image resolution of 640x480 and is Wi-Fi compliant with IEEE 802.11 b/g. Thus the teleoperator can view the live stream on a computer which is connected to internet. Fig. 12 shows the face with the IP camera, speaker and microphone mounted.Two- way build in audio via single network allows the teleoperator to communicate with what he is seeing. Thus we get the auditory system by installing a speaker and microphone to the IP camera and the teleoperator can communicate using headphones at tached to the same computer mentioned above.

Fig. 12: 3D sketch of the face

VI. CONCLUSION This paper presented how we designed the humanoid robot Dexto: Eka:. Future work includes evaluating developed Dexto: Eka: through experiments. An improvement of Dexto: Eka:, which reflects user's feedback during experimental tests, is also our future work. Our desire is to put the Dexto: Eka: to practical use and creating a real market for enhanced versions of Dexto: Eka: such as Dexto: Dvitiya:, Dexto: Tritiya: etc. This also presented how we designed the 3D model of humanoid robotic platform for Dexto: Eka:, which has a ability to cope with rough terrain in the open air, to prevent tipping over, and mimic the movements of the tele-operator.

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REFERENCES

[1] Thomas Braunl,2003 Embedded Robotics: Mobile Robot Design and Applications with Embedded Systems, First Edition. Springer-Verlag, Berlin.

[2] Anglees, J. (2005). An innovative Drive for Wheeled Mobile Robots, IEEE/ASME Tran. on Mechatronics, Vol. 10, No.1.

[3] J. W. Kang, H. S. Hong, B. S. Kim, and M. J. Chung, "Assistive Mobile Robot Systems helping the Disabled Workers in a Factory Environment," International Journal of Assistive Robotics and Mechatronics, Vol. 9, No. 2, pp. 42 – 52, June 2008.

[4] K. Kaneko, S. Kajita, F. Kanehiro, K. Yokoi, K. Fujiwara, H. Hirukawa, T. Kawasaki, M. Hirata, and T. Isozumi, , "Design of Advanced Leg Module for Humanoid Robotics

Project of METI," Proc. IEEE Int. Conference on Robotics and Automation, (to be appeared), 2002.

[5] J.A Cooney, W.L. Xu, "Motion Control and Intelligent of an Mobile Robot", Massey University.

[6] K. Nagatani, S Tachibana, I Nagai and Y Tanaka, " Navigation of Omni-directional Vehicle wheel with Mecanum Wheels", Okayama University.

[7] Stephen L. Dickerson, Brett D. Lapin, "Control of An Omni-directional Robotic Vehicle with Mecanum Wheels", Georgia Institute of Technology.

[8] P. Viboonchaicheep, A. Shimada, Y. Kosaka, "Position

Rectification Control for Mecanum Wheeled Omni-directional Vehicles", Hashimodotai Polytechnic University.

[9] I. W. Park, Y. Y. Kim, S. W. Park, and J. H. Oh, "Development of Humanoid Robot Platform KHR-2(KAIST Humanoid Robot - 2)", Int. Conf. on Humanoid 2004.

[10]J. Yamaguchi, and A. Takanishi, "Development of a Biped Walking Robot Having Antagonistic Driven Joints Using Nonlinear Spring Mechanism", in Proc. of IEEE Int. Conf. in Robotics and Automation, pp.14–21, 1997.

[11]Jung-Yup Kim, Ill-Woo Park, Jungho Lee, Min-Su Kim, Baek-Kyu Cho and Jun-Ho Oh, "System Design And Dynamic Walking Of Humanoid Robot KHR-2", IEEE International Conference on Robotics & Automation, 2005.

[12]J. J. Craig, Introduction to Robotics: Mechanics and Control, 2nd e. (Addison-Wesley Publishing Company 1989), p.129.

[13]M. Gienger, K. Loffler and F. Pfeiffer, "Walking Control of a Biped Robot based on Inertial Measurement", in Proc. Of Int. Workshop. on Humanoid and Human Friendly Robotics, pp.22–30, 2002.

[14] S. Kuindersma, E. Hannigan, D. Ruiken, and R. Grupen. Dexterous Mobility with the uBot-5 Mobile Manipulator. In 14th International Conference on Advanced Robotics (ICAR'09), 2009.

[15] T. Lauwers, G. Kantor, and R. Hollis. A dynamically stable singlewheeled mobile robot with inverse mouse-ball drive. In IEEE International Conference on Robotics and Automation (ICRA), 2006,pages 2884–2889, May 2006.

[16] Lauwers, T. and Kantor, G. and Hollis, R. One is enough! In Proceedings of the 12th International Symposium on Robotics Research, October 2005.

[17] K. M. Lynch and M. T. Mason. Stable pushing: Mechanics, controllability, and planning. Int. Journal of Robotics Research, 15(6):533–556, 1996.

[18] Franch J. Agrawal S. Pathak, K. Velocity and position control of a wheeled inverted pendulum by partial feedback linearization. IEEE Transactions on Robotics, 21, 2005.

[19] A. Salerno. Design, Dyamics, and Control of a Fast Two-Wheeled Quasiholonomic Robot. PhD thesis, 2006.

[20] E. Salih, J. Designing omni-directional mobile robot with mecanum wheel. American Journal of Applied Sciences, pages 1831–1835, 2006

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