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EXPERIMENTAL PROTOTYPING FOR AN ORTHOTIC DEVICE FOR HUMAN INFERIOR MEMBER

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Abstract: *A new rehabilitation mechatronic device equipped with suitable inertial sensors is presented, which enables training of a leg affected by strokes or injuries, in coordination with the movements of the other, normal, leg. This simple 1-DOF device can be included in the category of rehabilitation robotics. The main purpose is acquiring and implementation of an intelligent orthesis used for recovery training of the subject with neuromotor problems. It is destined especially to inferior and superior limbs joints recovery but performing the corresponding exercises will affect also the muscles.*
Keywords: *Medical Rehabilitation, Orthosis, Mechatronics, Experiments.*

1. INTRODUCTION

An *orthosis* is a device that is applied to a part of the body to correct deformity, improve function, or relieve symptoms of a disease. This may be an externally applied device, which supports or assists the musculo-neuro-skeletal system. Orthotics is an allied health profession that is concerned with the design, development, fitting and manufacturing of orthoses, which are devices that support or correct musculoskeletal deformities and/or abnormalities of the human body. The term is derived from the "ortho", meaning to straighten. Sciences such as materials engineering, gait analysis, anatomy and physiology, and psychology contribute to the work done by orthotists, professionals engaged in the field of orthotics.
A new rehabilitation mechatronical device equipped with suitable inertial sensors is presented, which enables training of a leg affected by strokes or injuries, in coordination with the movements of the other, normal, leg. This simple 1-DOF device can be included in the category of rehabilitation robotics.
The main purpose is acquiring and implementation of an intelligent orthesis used for recovery training of the subject with neuromotor problems. It is destined especially to inferior and superior limbs joints recovery but performing the corresponding exercises will affect also the muscles. It will be conceived in a modular way (the mechanic module, the electronic module and the interface module). It is attached to the leg or hand, in the area that need recovery; it is programmed for each subject depending on the program type of every subject. It is made from easy and unassuming materials. As it was demonstrated as well in the evaluation of the actual status, this project's subject is compliant with the European and world trends and priorities for developing robotics systems for medical recovery. Being designed for a large range of people with locomotory and neuromotory problems and with a highly degree of adaptation, the system we want to implement can have an important contribution to knowledge evolvement in rehabilitation robotics field.
So, thru this research work, we want to design, to realize and to implement mechatronical system, which could help people with a specific neuro-motory rehabilitation therapy. We speak about the knee and elbows joint, but the system can be adapted to the hands, ankles, shoulders or haunches joint. Therefore, our intention to realize a robotic mechanical-electronic system, which is a device that helps an organ to have a proper functionality, makes this project to be very important for some category of people.
The main contribution which this project can bring to robotics and recovery orthotics, taking in account the experience of the team members are: identifying new methods for neuromotory recovery; adopting new approaches in the biomechanics of the locomotory system; designing, making and implementation of a intelligent orthosis for jointing problems recovery; evaluating from the user's point of view, the efficiency of the recovery method recommended by the therapist. The system's proposed structure represents a new approach in the afferent area of the subject.

2. EXPERIMENTAL PROTOTYPING

The analysis of virtual prototype, it requires active leg fitted with several types of sensors for measuring the position, angular velocity and acceleration. He studied the use of distinct sensors for measuring kinematic parameters of each part. This solution has the advantage of a lower price, but increases the number of wires connecting more and more complicated data acquisition and evaluation. Since the research had inertial measurement units and MTI MTX capable of simultaneously measuring the 3D orientation angles, angular velocity and acceleration, it was decided that the experiments with the prototype is used orthotics these sensory systems.

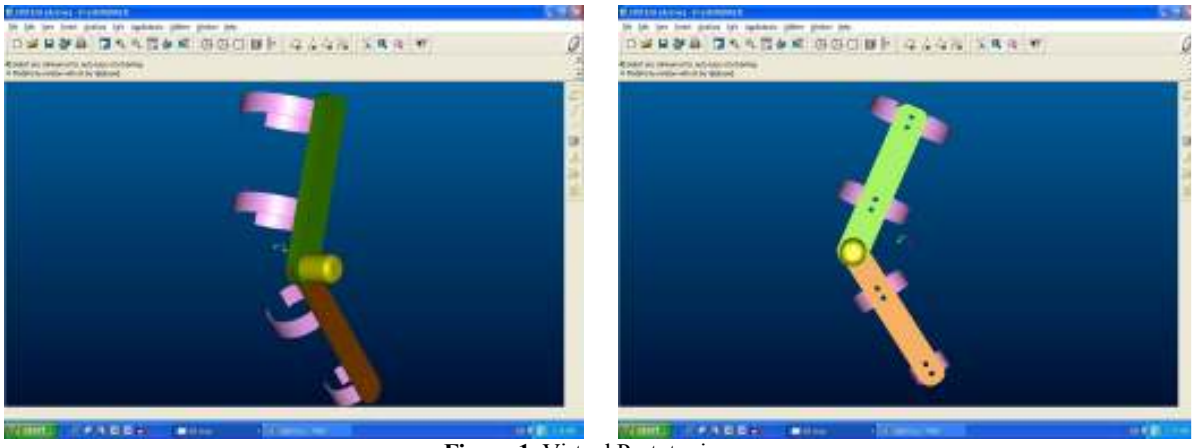

Figure 1. Virtual Prototyping

Regarding orthotics of the trained foot operated actuator current one, have considered two options for tracking movement, both will be tested during the experiments:

- Use an engine equipped with an incremental travel sensor which allows measurement of foot movement involved and ensure a command position of the engine side. The derivation of information from this sensor to determine the angular velocity of movement of coupling Orthotics and engine control, the PWM, to achieve an angular velocity to a copy while on the active leg;
- Fitting leg trained with inertial measurement unit mounted on the leg similar to that asset, which allows simultaneous measurement of position, angular velocity and acceleration and engine side control position and speed.

Figure 2. Orthotic support

2.1. The Components Elements

Therefore, the main components that have been acquired are:

1. ***Base orthotics Stabilopro shaped support open, from Bort, Germany*** (figure 2) [3]. Dry wearing feeling due to naturally breathing and humidity draining material. Polycentric aluminium gear segment hinge for additional medial and lateral stabilization. Functional guidance/stabilization of patella by special patella ring. With 4 circular velcro straps for optimal support. Can be opened completely, lockable with velcro closure. Adjustable extension at 0°, 10°, 15°, 20°, 30°, 40° and 45°. Adjustable flexion at 0°, 45°, 60°, 75° and 90°.
2. ***Micro motors 82-802-0 series from Crouzet U.S.A.*** (figures 3-4) [4]. These products are particularly suitable for use in medical equipment, valves, pumps, access control (barrier, turnstile, lift doors, etc), water treatment, billboards, etc. These are a range of D.C. geared motors with solid metal gears with: mechanical rating of gearbox with output shaft stalled (6 Nm); 10 and 17 Watt motor power; available in either 12, 24 or 48 V D.C.; gearbox ratios options for 4 to 12 rpm.

Tabel 1: The drive motors characteristics

Drive type	**Motor power** [W]	**Output speed** [rot/min]	**Supply voltage** [V]	**Max. perm. torque from gearmotor under cont. cond. for 10 millions turns** [Nm]	**Axial load** [daN]	**Radial load** [daN]	**Max. output** [W]	**Nominal output** [W]	**Weight** [g]
82 802 0X00026Z	17	100	12	1.2	3.5	5	16.3	15.7	670
82 802 0X00130Z	17	20	12	1.2	3.5	5	16.3	15.7	670

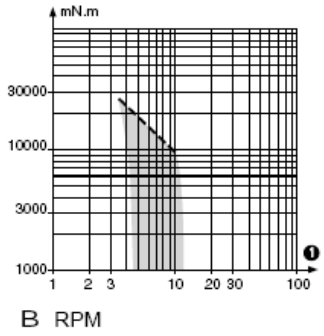

Figure 3. Nominal speed and torque curves

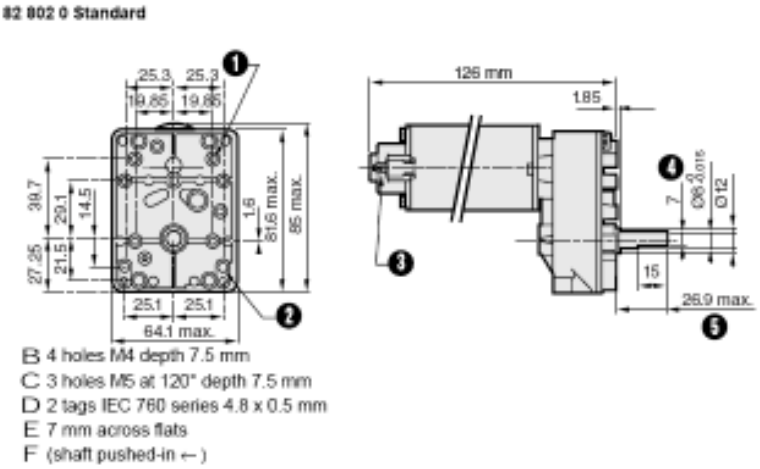

Figure 4. The drive motors

3. ***XBus Kit, from XSens, Holland*** (figures 5-7)

The MTx [5] is an excellent measurement unit for orientation measurement of human body segments. The standard version MTx has a full scale acceleration of 5g, full scales of 18g are available as well.

The MTx uses 3 rate gyroscopes to track rapidly changing orientations in 3D and it measures the directions of gravity and magnetic north to provide a stable reference. The systems real-time algorithm fuses all sensor information to calculate accurate 3D orientation, with a highly dynamic response, which remains stable over time.

Features:

- Accurate full 360 degrees 3D orientation output
- Highly dynamic response combined with long-term stability (no drift)
- 3D acceleration, 3D rate of turn and 3D earth-magnetic field data
- All solid state miniature MEMS inertial sensors inside
- Compact design
- High update rate
- Accepts synchronization pulses
- Individually calibrated for temperature, 3D misalignment and
- Sensor cross-sensitivity

Fields of use: biomechanics; rehabilitation; sports science; virtual reality; ergonomics; animation.

Pre-set user scenarios are available optimizing the Extended Kalman Filter routine for different applications. Based on the chosen scenario the XKF will apply appropriate filter settings recommended for the application. With the MTx Development Kit, the MTx can be easily integrated in any system or (OEM) application. The MTx is available as a stand-alone unit or as an Xbus version. On the Xbus, Xsens' digital data bus, multiple MTx's can easily be used simultaneously, enabling ambulatory and cost-effective measurement of human motion.

Figure 5. MTx Sensor

Figure 6. XBus Kit

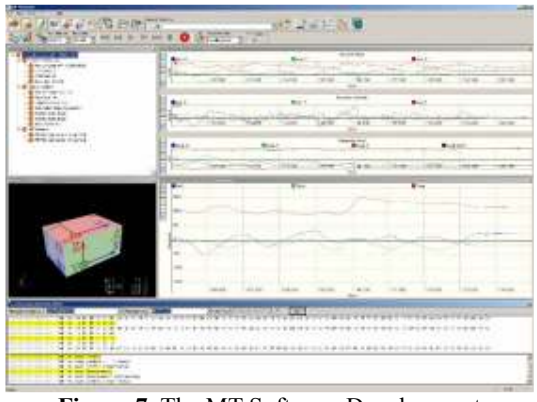

Figure 7. The MT Software Development

The Xbus Master [6] is a lightweight, portable device that controls multiple Motion Trackers (MTx) on the Xbus, Xsens' digital data bus system. The Xbus Master samples digital data from the MTx's and supplies power to the MTx's. The Xbus Master can be connected to a PDA or PC via serial cable or wireless connection, where the data is logged or used in any real-time software application.

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The Xbus Master enables ambulatory measurement of human motion. The MTx's provide drift-free 3D orientation as well as kinematic data: 3D acceleration, 3D rate of turn and 3D earth-magnetic field.
Features:

- Connects multiple Motion Trackers (MTx) on one or two Xbusstrings
- Synchronous sampling of multiple MTx's at adjustable sample frequencies up to 512Hz
- Compatible with PDA and PC via USB cable or wireless Bluetooth 2.0 connection
- Compatible with Xsens MT Software and MT Software Development Kit
- External triggering & notification of trigger moment available for synchronization
- Battery operated or mains power supply
- Low battery indicator
- Internal 64 kByte communication buffer
- Supplies power to MTx's
- Ergonomic design with elastic strap

Fields of use: biomechanics; rehabilitation; sports science; virtual reality; ergonomics; animation.
Together with a set of MTx's, the Xbus Master enables ambulatory measurement of human motion. The MTx's provide drift-free 3D orientation as well as: 3D acceleration, 3D rate of turn (rate gyro) and 3D earth-magnetic field. Xsens' MT Software and SDK are Xbus compatible.

4. ***The AD sensors from Analog Digital, U.S.A***

ADXL213: Low Cost ±1.2g Dual Axis Accelerometer [7] is a low cost, low power, complete dual axis accelerometer with signal conditioned, duty cycle modulated outputs, all on a single monolithic IC. The ADXL213 measures acceleration with a full-scale range of ±1.2 *g* (typical). The ADXL213 can measure both dynamic acceleration (e.g., vibration) and static acceleration (e.g., gravity).
The outputs are digital signals whose duty cycles (ratio of pulse width to period) are proportional to acceleration (30%/*g*). The duty cycle outputs can be directly measured by a microcontroller without an A/D converter or glue logic.
Innovative design techniques are used to ensure high zero g bias stability (typically better than 0.25 mg/°C), as well as tight sensitivity stability (typically better than 50 ppm/°C).
The typical noise floor is 160 μg/√ , allowing signals below 1 mg (0.06° of inclination) to be resolved in tilt sensing applications using narrow bandwidths (<60 Hz).
The user selects the bandwidth of the accelerometer using capacitors C_X and C_{YM} at the X_{FILT} and Y_{FILT} pins. Bandwidths of 0.5 Hz to 250 Hz may be selected to suit the application.
The ADXL213 is available in a 5mm x 5mm x 2mm, 8-pad hermetic LCC package.
Features:

- Dual axis accelerometer on a single IC chip
- 5 mm × 5 mm × 2 mm LCC package
- 1 mg resolution at 60 Hz
- Low power: 700 μA at V_s = 5 V (typical)
- High zero *g* bias stability
- High sensitivity accuracy
- Pulse width modulated digital outputs
- X and Y axes aligned to within 0.1° (typical)
- BW adjustment with a single capacitor
- Single-supply operation
- 3500 *g* shock survival

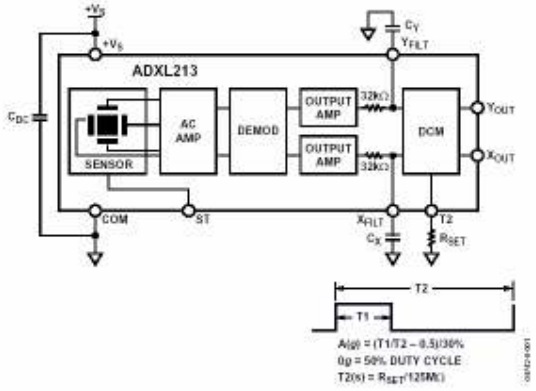

Figure 8. Functional Block for ADXL213 Low Cost ±1.2*g* Dual Axis Accelerometer

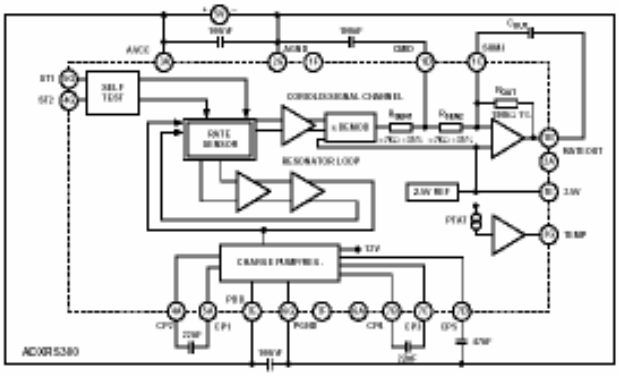

Figure 9. Functional Block for ADXRS300 ±300°/sec Single Chip Yaw Rate Gyro with Signal Conditioning

Applications: automotive tilt alarm; data projectors; navigation; platform stabilization/leveling; alarms and motion detectors; high accuracy, 2-axis tilt sensing.

ADXRS300: ±300°/sec Single Chip Yaw Rate Gyro [8] with Signal Conditioning is a 300 deg/sec angular rate sensor (gyroscope) on a single chip, complete with all of the required electronics. The sensor is built using Analog Devices' proprietary iMEMS® surface micromachining process, the same proven technology that has enabled the company to ship over 100 million inertial sensors. Two polysilicon sensing structures each contain a dither frame which is electrostatically driven to resonance. A rotation about the z axis, normal to the plane of the chip, produces a Coriolis force which displaces the sensing structures perpendicular to the vibratory motion. This Coriolis motion is detected by a series of capacitive pickoff structures on the edges of the sensing structures. The resulting signal is amplified and demodulated to produce the rate signal output. The device is the only commercially available gyro to integrate a digitally controlled, full self-test feature that can be operated while the sensor is active. It includes a temperature sensor for easy-to-implement temperature coefficient calibration, as well as a precision voltage reference. It operates from 5V supply over the industrial temperature range of -40°C to +85°C and is available in a space-saving 32-pin Ball Grid Array surface-mount package measuring a mere 7mm x 7mm x 3mm.

Features:

- Complete rate gyroscope on a single chip
- Z-axis (yaw rate) response
- High vibration rejection over wide frequency
- 2000 g powered shock operation
- Self-test on digital command
- Temperature sensor output
- Precision voltage reference output
- Absolute rate output for precision applications
- 5 V single-supply operation
- Ultrasmall and light (<0.15 cc, <0.5 gram)

Applications: vehicle chassis rollover sensing; inertial measurement units; platform stabilization.

2.2. Assembly of the Medical Rehabilitation System

Figure 10. Phases of the assembly process of Orthotics [1]

3. CONCLUSION

After assembly was found, orthotics support the must be changed. We need a more rigid material as physiological resistance is generated by leg slightly larger than originally estimated. Follow orthotics testing and optimization, a topic first 20 years with a paraplegic leg. Together with physicians profile will be a recovery program and will follow its evolution over time.

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