Beat-to-Beat Blood Pressure Monitor

This invention is applicable to all segments of the blood pressure monitoring market, including ambulatory, home-based, and high-acuity monitoring.

Lyndon B. Johnson Space Center, Houston, Texas

This device provides non-invasive beat-to-beat blood pressure measurements and can be worn over the upper arm for prolonged durations. Phase and waveform analyses are performed on filtered proximal and distal photoplethysmographic (PPG) waveforms obtained from the brachial artery. The phase analysis is used primarily for the computation of the mean arterial pressure, while the waveform analysis is used primarily to obtain the pulse pressure. Real-time compliance estimate is used to refine both the mean arterial and pulse pressures to provide the beat-to-beat blood pressure measurement.

This wearable physiological monitor can be used to continuously observe the beat-to-beat blood pressure (B3P). It can be used to monitor the effect of prolonged exposures to reduced gravitational environments and the effectiveness of various countermeasures.

A number of researchers have used pulse wave velocity (PWV) of blood in the arteries to infer the beat-to-beat blood pressure. There has been documentation of relative success, but a device that is able to provide the required accuracy and repeatability has not yet been developed. It has been demonstrated that an accurate and repeatable blood pressure measurement can be obtained by measuring the phase change (e.g., phase velocity), amplitude change, and distortion of the PPG waveforms along the brachial artery. The approach is based on comparing the full PPG waveform between two points along the artery rather than measuring the time-of-flight. Minimizing the measurement separation and confining the measurement area to a single, well-defined artery allows the waveform to retain the general shape between the two measurement points. This allows signal processing of waveforms to determine the phase and amplitude changes.

Photoplethysmography, which measures changes in arterial blood volume, is commonly used to obtain heart rate and blood oxygen saturation. The digitized PPG signals are used as inputs into the beat-to-beat blood pressure measurement algorithm. The algorithm consists of the following main components:

- First harmonic isolation bandpass filters take the raw PPG signals and separate out the first harmonics.
- Three harmonic lowpass filters take the PPG signal and filter out all spectral components outside the first three harmonics. The first three harmonics are used for regeneration of the pulse pressure waveforms.
- Phase analysis engine takes the first harmonics of the PPG signals and computes the phase difference between them in real time using a cross-correlation-based algorithm. The phase difference is to the first order correlated to the MAP (mean arterial pressure).
- Compliance estimation engine takes information on the general shape of the waveforms and the phase delay to compute the local compliance of the artery. The higher the arterial pressure, the higher the Young's modulus and thus the lower the compliance.
- MAP computation engine obtains the phase delay and compliance information and provides the mean arterial pressure.
- Waveform analysis engine takes the PPG signal containing the first three harmonics and provides the signal processing needed for compliance (elasticity) estimation and pulse pressure computation.
- Pulse pressure computation engine takes the filtered PPG signal and an estimate of the arterial compliance to regenerate the pulse waveform.
- B3P computation engine takes the MAP and the pulse pressure computations and combines them with a blood pressure model and calibration data to produce the final signal of interest — the beat-to-beat blood pressure.

This work was done by Yong Jin Lee of Linea Research Corporation for Johnson Space Center. ***For more information, download the Technical Support Package (free white paper) at www.techbriefs.com/tsp under the Bio-Medical category****.*

Refer to MSC-24601-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improving Balance Function Using Low Levels of Electrical Stimulation of the Balance Organs

A device based on this technology may be used as a miniature patch worn by people with disabilities to improve posture and locomotion, and to enhance adaptability or skill acquisition.

Lyndon B. Johnson Space Center, Houston, Texas

Crewmembers returning from long-duration space flight face significant challenges due to the microgravity-induced inappropriate adaptations in balance/sensorimotor function. The Neuroscience Laboratory at JSC is developing a method based on stochastic resonance to enhance the brain's ability to detect signals from the balance organs of the inner ear and use them for rapid improvement in balance skill, especially when combined with balance training exercises. This method involves a stimulus delivery system that is wearable/portable providing imperceptible electrical stimulation to the balance organs of the human body.

Stochastic resonance (SR) is a phenomenon whereby the response of a nonlinear system to a weak periodic input signal is optimized by the presence of a particular non-zero level of noise. This phenomenon of SR is based on the concept of maximizing the flow of information through a system by a non-zero level of noise. Application of imperceptible SR noise coupled with sensory input in humans has been shown to improve motor, cardiovascular, visual, hearing, and balance functions. SR increases contrast sensitivity and luminance detection; lowers the absolute threshold for tone detection in normal hearing individuals; improves homeostatic function in the human blood pressure regulatory system; improves noise-enhanced muscle spindle function; and improves detection of weak tactile stimuli using mechanical or electrical stimulation. SR noise has been shown to improve postural control when applied as mechanical noise to the soles of the feet, or when applied as electrical noise at the knee and to the back muscles.

SR using imperceptible stochastic electrical stimulation of the vestibular system (stochastic vestibular stimulation, SVS) applied to normal subjects has shown to improve the degree of association between the weak input periodic signals introduced via venous blood pressure receptors and the heart-rate responses. Also, application of SVS over 24 hours improves the long-term heart-rate dynamics and motor responsiveness as indicated by daytime trunk activity measurements in patients with multi-system atrophy, Parkinson's disease, or both, including patients who were unresponsive to standard therapy for Parkinson's disease. Recent studies conducted at the NASA JSC Neurosciences Laboratories showed that imperceptible SVS, when applied to normal, young, healthy subjects, leads to significantly improved balance performance during postural disturbances on unstable compliant surfaces. These studies have shown the benefit of SR noise characteristic optimization with imperceptible SVS in the frequency range of 0–30 Hz, and amplitudes of stimulation have ranged from 100 to 400 microamperes.

This work was done by Jacob Bloomberg and Millard Reschke of Johnson Space Center; Ajitkumar Mulavara and Scott Wood of USRA; Jorge Serrador of Dept. of Veterans Affairs NJ Healthcare System; Matthew Fiedler, Igor Kofman, and Brian T. Peters of Wyle; and Helen Cohen of Baylor College. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-25013-1

Developing Physiologic Models for Emergency Medical Procedures Under Microgravity

Lyndon B. Johnson Space Center, Houston, Texas

Several technological enhancements have been made to METI's commercial Emergency Care Simulator (ECS) with regard to how microgravity affects human physiology. The ECS uses both a software-only lung simulation, and an integrated mannequin lung that uses a physical lung bag for creating chest excursions, and a digital simulation of lung mechanics and gas exchange. METI's patient simulators incorporate models of human physiology that simulate lung and chest wall mechanics, as well as pulmonary gas exchange.

Microgravity affects how O_2 and CO_2 are exchanged in the lungs. Procedures were also developed to take into affect the Glasgow Coma Scale for determining levels of consciousness by varying the ECS eye-blinking function to partially indicate the level of consciousness of the patient. In addition, the ECS was modified to provide various levels of pulses from weak and thready to hyper-dynamic to assist in assessing patient conditions from the femoral, carotid, brachial, and pedal pulse locations.

This work was done by Nigel Parker and Veronica O'Quinn of Medical Education Tech, Inc. for Johnson Space Center. ***For more information, download the Technical Support Package (free white paper) at www.techbriefs.com/tsp under the Bio-Medical category.*** *MSC-23922-1*

Polyurea-Based Aerogel Monoliths and Composites

These aerogels can be used in portable apparatus for warming, storing, and/or transporting food and medicine, and can be recycled for fillers for conventional plastics.

Lyndon B. Johnson Space Center, Houston, Texas

A flexible, organic polyurea-based aerogel insulation material was developed that will provide superior thermal insulation and inherent radiation protection for government and commercial applications. The rubbery polyurea-based aerogel exhibits little dustiness, good flexibility and toughness, and durability typical of the parent polyurea polymer, yet with the low density and superior insulation properties associated with aerogels. The thermal conductivity values of polyurea-based aerogels at lower temperature under vacuum pressures are very low and better than that of silica aerogels.

Flexible, rubbery polyurea-based aerogels are able to overcome the weak and brittle nature of conventional inorganic and organic aerogels, including polyisocyanurate aerogels, which are generally prepared with the one similar component to polyurethane rubber aerogels. Additionally, with higher content of hydrogen in their structures, the polyurea rubber-based aerogels will also provide inherently better radiation protection than those of inorganic and carbon aerogels. The aerogel materials also demonstrate good hydrophobicity due to their hydrocarbon molecular structure.

There are several strategies to overcoming the drawbacks associated with the weakness and brittleness of silica aerogels. Development of the flexible fiber-reinforced silica aerogel composite blanket has proven to be one promising approach, providing a conveniently fielded form factor that is relatively robust in industrial environments compared to silica aerogel monoliths. However, the flexible, silica aerogel composites still have a brittle, dusty character that may be undesirable, or even intolerable, in certain application environments. Although the crosslinked organic aerogels, such as resorcinol-formaldehyde (RF), polyisocyanurate, and cellulose aerogels, show very high impact strength, they are also very brittle with little elongation (i.e., less rubbery). Also, silica and carbon aerogels are less efficient radiation shielding materials due to their lower content of hydrogen element.

The invention involves mixing at least one isocyanate resin in solvent along with a specific amount of at least one polyamine hardener. The hardener is selected from a group of polyoxyalkyleneamines, amine-based polyols, or a mixture thereof. Mixing is performed in the presence of a catalyst and reinforcing inorganic and/or organic materials, and the system is then subjected to gelation, aging, and supercritical drying. The aerogels will offer exceptional flexibility, excellent thermal and physical properties, and good hydrophobicity.

The rubbery polyurea-based aerogels are very flexible with no dust and hydrophobic organics that demonstrated the following ranges of typical properties: densities of 0.08 to 0.293 g/cm^3, shrinkage factor (raerogel/rtarget) = 1.6 to 2.84, and thermal conductivity values of 15.2 to 20.3 mW/m K.

This work was done by Je Kyun Lee of Aspen Aerogels, Inc. for Johnson Space Center. ***For more information, download the Technical Support Package (free white paper) at www.techbriefs.com/tsp under the Materials & Coatings category.***

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Refer to MSC-24214-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Multiplexed Force and Deflection Sensing Shell Membranes for Robotic Manipulators

This technology can be used to enhance precision in robotic surgery.

Lyndon B. Johnson Space Center, Houston, Texas

Force sensing is an essential requirement for dexterous robot manipulation, e.g., for extravehicular robots making vehicle repairs. Although strain gauges have been widely used, a new sensing approach is desirable for applications that require greater robustness, design flexibility including a high degree of multiplexibility, and immunity to electromagnetic noise.

This invention is a force and deflection sensor — a flexible shell formed with an elastomer having passageways formed by apertures in the shell, with an optical fiber having one or more Bragg gratings positioned in the passageways for the measurement of force and deflection.

One object of the invention is lightweight, rugged appendages for a robot that feature embedded sensors so that the robot can be more "aware" of loads in real time. A particular class of optical sensors, fiber Bragg grating (FBG) sensors, is promising for space robotics and other applications where high sensitivity, multiplexing capability, immunity to electromagnetic noise, small size, and resistance to harsh environments are particularly desirable. In addition, the biosafe and inert nature of optical fibers makes them attractive for medical robotics. FBGs reflect light with a peak wavelength that shifts in proportion to the strain to which they are subjected. Multiple FBG sensors can be placed along a single fiber and optically multiplexed. FBG sensors have previously been surface-attached to or embedded in metal parts and composites to monitor stresses.

An exoskeletal force sensing robot finger was developed by embedding FBG sensors into a polymer-based structure. Multiple FBG sensors were embedded into the structure to allow the manipulator to sense and measure both contact forces and grasping forces. In order to fabricate a three-dimensional structure, a new shape deposition manufacturing (SDM) process was developed. The sensorized SDM-fabricated finger was then characterized using an FBG interrogator. A force localization scheme was also developed.

A sensor is formed from a thin shell of flexible material such as elastomer to form an attachment region, a sensing region, and a tip region. In one embodiment, the sensing region is a substantially cylindrical flexible shell, and has a plurality of apertures forming passageways between the apertures. Optical fiber is routed through the passageways, with sensors located in the passageways prior to the application of the elastomeric material forming the flexible shell. Deflection of the sensor, such as by a force applied to the contact region, causes an incremental strain in one or more passageways where the optical fiber is located. The incremental strain results in a change of optical wavelength of reflection or transmittance at the sensor, thereby allowing the measurement of force or displacement.

The ability to route a single optical fiber through the passageways of the outer shell of the sensor, combined with the freedom to place Bragg grating-based sensors in desired locations of the shell, provides tremendous flexibility in sensing force in three axes, as well as the possibility of providing a large number of sensors for more sophisticated measurement modalities, such as torque and shell deflection in response to multi-point pressure application.

This work was done by Yong-Lae Park, Richard Black, Behzad Moslehi, Mark Cutkosky, and Kelvin Chau of Intelligent Fiber Optic Systems Corp. for Johnson Space Center. ***For more information, download the Technical Support Package (free white paper) at www.techbriefs.com/tsp under the Physical Sciences category****.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Intelligent Fiber Optic Systems Corp.
424 Panama Mall
Stanford, CA 94305

Refer to MSC-24501-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Fuel Cell/Electrochemical Cell Voltage Monitor

Lyndon B. Johnson Space Center, Houston, Texas

A concept has been developed for a new fuel cell individual-cell-voltage monitor that can be directly connected to a multi-cell fuel cell stack for direct substack power provisioning. It can also provide voltage isolation for applications in high-voltage fuel cell stacks. The technology consists of basic modules, each with an 8- to 16-cell input electrical measurement connection port. For each basic module, a power input connection would be provided for direct connection to a sub-stack of fuel cells in series within the larger stack. This power connection would allow for module power to be available in the range of 9-15 volts DC. The relatively low voltage differences that the module would encounter from the input electrical measurement connection port, coupled with the fact that the module's operating power is supplied by the same substack voltage input (and so will be at similar voltage), provides for elimination of high-common-mode voltage issues within each module. Within each module, there would be options for analog-to-digital conversion and data transfer schemes.

Each module would also include a data-output/communication port. Each of these ports would be required to be either non-electrical (e.g., optically isolated) or electrically isolated. This is necessary to account for the fact that the plurality of modules attached to the stack will normally be at a range of voltages approaching the full range of the fuel cell stack operating voltages. A communications/data bus could interface with the several basic modules. Options have been identified for command inputs from the spacecraft vehicle controller, and for output-status/data feeds to the vehicle.

This work was done by Arturo Vasquez of Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-24592-1

Measurement Techniques for Clock Jitter

New approach offers more advanced coded modulation techniques.

Lyndon B. Johnson Space Center, Houston, Texas

NASA is in the process of modernizing its communications infrastructure to accompany the development of a Crew Exploration Vehicle (CEV) to replace the shuttle. With this effort comes the opportunity to infuse more advanced coded modulation techniques, including low-density parity-check (LDPC) codes that offer greater coding gains than the current capability. However, in order to take full advantage of these codes, the ground segment receiver synchronization loops must be able to operate at a lower signal-to-noise ratio (SNR) than supported by equipment currently in use.

At low SNR, the receiver symbol synchronization loop will be increasingly sensitive to transmitter timing jitter. Excessive timing jitter can cause bit slips in the receiver synchronization loop, which will in turn cause frame losses and potentially lead to receiver and/or decoder loss-of-lock. Therefore, it is necessary to investigate what symbol timing jitter requirements on the satellite transmitter are needed to support the next generation of NASA coded modulation techniques.

Measurements of ground segment receiver sensitivity to transmitter bit jitter were conducted using a satellite transponder and two different commercial staggered quadrature phase-shift keying (SQPSK) receivers. The symbol synchronizer loop transfer functions were characterized for each receiver. Symbol timing jitter was introduced at the transmitter. Effects of sinusoidal (tone) jitter on symbol error rate (SER) degradation and symbol slip probability were measured. These measurements were used to define regions of sensitivity to phase, frequency, and cycle-to-cycle jitter characterizations. An assortment of other band-limited jitter waveforms was then applied within each region to identify peak or root-mean-square measures as a basis for comparability.

Receiver clock recovery loops that operate in low SNR ratio environments require that transmit clock jitter be constrained by several measures on different dimensions and operating regions. In this work, effects of transmit phase jitter (PhJ), frequency jitter (FJ), and cycle-to-cycle jitter (CCJ) were studied for sinusoidal and multi-tone jitter profiles on receiver performance. It was demonstrated that the receiver must have a loop bandwidth tight enough to avoid cycle slips, but loose enough to track some movement in the data signal. Movement that a tight loop cannot track is usually manifested first as intersymbol interference (ISI) (SER degradation) and then ultimately as cycle slipping in the receiver.

Results from the tests indicate that the receiver symbol synchronization loop is more sensitive to certain types of symbol jitter and jitter frequencies, depending on the selection of the loop filter and damping ratio. A framework is provided to properly compose a transmit jitter mask depending on receiver design parameters such as damping ratio in order to limit receiver performance degradation at low SNR regions.

This work was done by Chatwin Lansdowne and Adam Schlesinger of Johnson Space Center. ***For more information, download the Technical Support Package (free white paper) at www.techbriefs.com/tsp under the Physical Sciences category****. MSC-24810-1*

Linked-List-Based Multibody Dynamics (MBDyn) Engine

Lyndon B. Johnson Space Center, Houston, Texas

This new release of MBDyn is a software engine that calculates the dynamics states of kinematic, rigid, or flexible multibody systems. An MBDyn multibody system may consist of multiple groups of articulated chains, trees, or closed-loop topologies. Transient topologies are handled through conservation of energy and momentum. The solution for rigid-body systems is exact, and several configurable levels of nonlinear term fidelity are available for flexible dynamics systems.

The algorithms have been optimized for efficiency and can be used for both non-real-time (NRT) and real-time (RT) simulations. Interfaces are currently compatible with NASA's Trick Simulation Environment. This new release represents a significant advance in capability and ease of use. The two most significant new additions are an application programming interface (API) that clarifies and simplifies use of MBDyn, and a link-list infrastructure that allows a single MBDyn instance to propagate an arbitrary number of interacting groups of multibody topologies.

MBDyn calculates state and state derivative vectors for integration using an external integration routine. A Trick-compatible interface is provided for initialization, data logging, integration, and input/output.

This work was done by John Maclean, Thomas Brain, Leslie Quiocho, An Huynh, and Tushar Ghosh of Johnson Space Center. ***For more information, download the Technical Support Package (free white paper) at www.techbriefs.com/tsp under the Software category****. MSC-24925-1*

Plug-in Plan Tool v3.0.3.1

Lyndon B. Johnson Space Center, Houston, Texas

The role of PLUTO (Plug-in Port UTilization Officer) and the growth of the International Space Station (ISS) have exceeded the capabilities of the current tool PiP (Plug-in Plan). Its users (crew and flight controllers) have expressed an interest in a new, easy-to-use tool with a higher level of interactivity and functionality that is not bound by the limitations of Excel.

The PiP Tool assists crewmembers and ground controllers in making real-time decisions concerning the safety and compatibility of hardware plugged into the UOPs (Utility Outlet Panels) onboard the ISS. The PiP Tool also provides a reference to the current configuration of the hardware plugged in to the UOPs, and enables the PLUTO and crew to test Plug-in locations for constraint violations (such as cable connector mismatches or amp limit violations), to see the amps and volts for an end item, to see whether or not the end item uses 1553 data, and the cable length between the outlet and the end item. As new equipment is flown or returned, the database can be updated appropriately as needed. The current tool is a macro-heavy Excel spreadsheet with its own database and reporting functionality.

The new tool captures the capabilities of the original tool, ports them to new software, defines a new dataset, and compensates for ever-growing unique constraints associated with the Plug-in Plan. New constraints were designed into the tool, and updates to existing constraints were added to provide more flexibility and customizability. In addition, there is an option to associate a "Flag" with each device that will let the user know there is a unique constraint associated with it when they use it. This helps improve the safety and efficiency of real-time calls by limiting the amount of "corporate knowledge" overhead that has to be trained and learned through use.

The tool helps save time by automating previous manual processes, such as calculating connector types and deciding which cables are required and in what order.

This project provides a better onboard tool for the crew to safely test ideas for reconfigurations before calling the ground, and send the changes directly. The layout provides clear detail for power channels, module locations, and data ports, and allows for intuitive "drag-and-drop" connections from the database. The software will allow only compatible connections to occur, and will flag violations if they exist. It also allows the user to flag unique constraints that might not be caught by the software's existing rules and calculations.

The PiP Tool includes reporting capabilities that allow the user to export database information and configuration information to Excel to share with others or run detailed comparisons and searches as needed.

This work was done by Kathleen E. Andrea-Liner, Brion J. Au, Blake R. Fisher, Watchara Rodbumrung, Jeffrey C. Hamic, Kary Smith, and David S.Beadle of the United Space Alliance for Johnson Space Center. ***For more information, download the Technical Support Package (free white paper) at www.techbriefs.com/tsp under the Software category****. MSC-24872-1*

Ascent/Descent Software

Lyndon B. Johnson Space Center, Houston, Texas

The Ascent/Descent Software Suite has been used to support a variety of NASA Shuttle Program mission planning and analysis activities, such as range safety, on the Integrated Planning System (IPS) platform. The Ascent/Descent Software Suite, containing Ascent Flight Design (ASC)/Descent Flight Design (DESC) Configuration items (Cis), lifecycle documents, and data files used for shuttle ascent and entry modeling analysis and mission design, resides on IPS/Linux workstations. A list of tools in Navigation (NAV)/Prop Software Suite represents tool versions established during or after the IPS Equipment Rehost-3 project.

This work was done by Charles Brown, Robert Andrew, Scott Roe, Ronald Frye, Michael Harvey, Tuan Vu, Krishnaiyer Balachandran, and Ben Bly of the United Space Alliance for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-24960-1