Virtual Bio-Instrumentation

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Potential VBI Applications

- Basic Research
  - Medical Schools / Universities
  - Private Research Companies (e.g. Pharmaceuticals)
  - Typically Animal based (Human data available in some cases)
  - Freedom to acquire and analyze data according to individual investigators requirements

- Clinical Research
  - Collect data from existing equipment
  - Often includes statistical analysis based on treatment protocols
  - Typically conducted by MDs who may or may not be computer literate
  - Not many willing to devote time to learn or program in LabVIEW
Potential VBI Applications

- Medical Informatics
  - Hospital/Bed Management
  - ICU Data Monitoring / Display

- Hospital / Clinic Diagnostic Tools
  - Diagnostic Equipment
    - e.g. Plethysmograph, Echocardiograph Machine
  - Treatment Equipment
    - e.g. TEMS Unit, Ventilator

- Extended Applications

Governed by FDA
Biomedical Fields for DAQ

- Common Mechanical Stimuli
  - Pressures, Flows, Temperatures

- Biopotentials
  - ECG, EMG, ERG, EEG, ENG, etc
  - μV/mV levels, > 20 kHz Sample Rate

- Imaging Techniques
  - Echocardiogram, blood vessel contraction
  - Edge detection, microscopic imaging

- Clinical Instrumentation
  - Acquisition from existing equipment (mostly serial)
Generic DAQ/Instrumentation Issues

- Amplifier Frequency Response
- FFT of Nerve CAP
Role of Virtual Instrumentation

- User-Friendly GUI Interface for Experiments and Analysis
- Modular Development Scheme
- Flexibility/Adaptability
Generic VI Development Issues

- Simultaneous I/O
- Data storage for post-processing
- Automation and HMI
Basic Research

- Basic Research Field ideal for incorporation of existing NI hardware & LabVIEW / LabWindows.
  - Requires NI personnel be familiar with biomedical applications and sufficiently able to converse in medical lingo.
  - Requires stronger ties with research equipment suppliers [e.g. World Precision Instruments (WPI)].
  - BioBench has been retooled to accommodate a wider variety of experiments and analysis.

- NI, suppliers and users should exercise a substantial list of typical biomedical experiments to understand and document issues.
  - e.g. to understand the appropriate equipment required to record ENG data at 10 µV and 50 kHz, while supplying a 10 sec stimulus pulse every 100 msec.
Basic Research Applications

- Vertebrate Systems
- Mammalian Systems
- Cellular Technology
- Electroneurology
- Cardiopulmonary
- Mathematical Modeling
Electrophysiology

- Recruitment
- Conduction Velocity
- Excitability
- Restitution
- Excitation-Contraction Coupling
- Tetany
Stimulus Artifact Rejection

NERVE STIMULUS ARTIFACT REJECTION ROUTINE

This VI performs nerve compound action potential experiments with the purpose of estimating the stimulus artifact for removal from other data records. The double stimulus method is used in this case as a routine means of estimating the corruption caused by the stimulus. The routine requires a double stimulus, with the second pulse occurring during the absolute refractory period of the nerve in question. The response to the second pulse is then purely artifact and can be subtracted from a standard single pulse test to obtain an estimate of the actual CAP.
Volume Conductor Problem
Cardiac Electrophysiology

- Electrocardiography
- Vectorcardiography
Research Topics

- Heart-Rate Variability
- Parasympathetic Neural Control
- Phase Response
- Entrainment
Cardiovascular Hemodynamics

➢ Cardiac Function

➢ P-V Characterization

[Graph showing various pressure and voltage measurements]
- **Modeling**

  - Right-Left Ventricular Interaction

  - Closed-loop Circulatory Modeling
Cardiovascular Modeling

Online Parameter Sensitivity Analysis

Nonlinear Parameter Estimation
Lung Model Parameter Estimation
Lung Tissue Parameter Estimation

- Pulmonary System Modeling
- Work of Breathing
- Pulmonary Energy Analysis
- Integrated CO₂ / Airway Mechanics Analysis
- Nonlinear Parameter Estimation
Clinical Research

- Clinical Research also has potential for significant infiltration of VBI
  - Requires NI personnel be familiar with biomedical applications and sufficiently able to converse in medical lingo.
  - Requires stronger ties with clinical equipment suppliers.
  - BioBench / LabVIEW incorporate a user-friendly means of collecting and automatically synchronizing data from multiple serial, GPIB, and analog sources.
    - Serial (RS232) output is most common form available from commercial equipment.
  - BioBench now has additional flexibility in allowing data to be analyzed during or after collection
Cardiopulmonary Analysis System

Cardiovascular Pressure-Dimension Analysis

Beat Data
- Beat: 1
- Diastole: 8.7
- Systole: 3.6
- EF/FAC: 0.58
- Stroke Work: 433

Isochronic
- Index: 53.0
- Slope: 23.7
- Inter.: -0.2

PRSWI
- Slope: 76.6
- Inter.: 3.0
- R: 1.00

ESPDR
- Slope: 23.8
- Inter.: -0.3
- R: 0.99

Cycle Analysis
- Type: Chebyshev
- Order: First
- Cutoff Freq.: 300
- No Filter

DAQ (Hz): 200
Total Beats: 18

Data Log

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Pulmonary Function Testing
Ventilatory Patient Management
Medical Informatics

The process of transforming data into information in healthcare

- Electronic Medical Record (EMR)/Computerized Patient Record (CPR)
- Decision support
- Information retrieval
- Imaging / Telemedicine
- Medical education
- Consumer health information systems
- Public health information systems
- Bioinformatics
- Outcome analysis
- Patient monitoring
Patient Monitoring
Telemedicine

- Telerobotic control and data feed
Hospital Information Management
Commercial Medical Devices

- Hospital / Clinical Diagnostic Tools
  - Testing and/or development
  - Requires FDA involvement / approval.
  - Significant time / resource cost for each piece of equipment developed.
  - Recommend this development be left to third party vendors for the near future.
Medical Device Testing
Medical Device Development

- RSI Diagnostic Aid
- FDA Approved

controlled with LabVIEW-based executable
Space Environment
Med Ops Hardware & Operations

- Medical Restraint System
  - Integrated with diagnostic/therapeutic equipment
  - Patient transport during return and recovery

- Cardiac Defibrillator/Monitor
  - Adhesive conductive pads
  - Insulation to protect avionics from EMI

- Advanced Life Support Pack
  - Stowage of emergency meds and equipment
  - Human factors strongly influence success
  - Med shelf-life and waste concerns

- Ventilator
  - Self-contained or overboard dump to prevent $O_2$ buildup in confined volume
**Med Ops Hardware & Operations**

- Stored Intravenous Fluids
  - Must use pressure infusion device

- Medical Computer System
  - Diagnostic Aid
  - Proficiency
  - Medical Records
  - Occupational Exposure Tracking

- Endoscopic Capability
  - Diagnostic/Therapeutic

- Splints and Traction Devices
Cellular Bio-Technology

- Characterization of the response of the human body to the space environment
- Primary outlook is Investigational
- Results are viewed in terms of Scientific Return

Colon Cancer cells cultured in a Bioreactor
Research Hardware & Operations
The effects of $\mu G$ can be difficult to anticipate without operational experience.
Space Medicine

- **Proactive and Reactive Care** of the human organism to optimize physical, physiological and mental well-being
- Primary outlook is **Operational**
- Results are viewed in terms of **Mission Impact**

Cardiovascular Assessment on ISS in Russian Chibis Suit
Space Medicine (Proactive Care)

Exercise is one of the most important proactive medical countermeasures.

- But how do you get good exercise in μG?
Space Medicine (Reactive Care)

Reactive care also requires special attention to operability in μG.

- e.g. How do you respond to cardiac arrest? CPR?
Conclusions

Virtual Bio-Instrumentation

- Academic Applications
  - Instructional
  - Basic Research
  - Clinical Research
- Commercialization
  - Development
  - Test
- Extraterrestrial