Personalized Signal Processing for Gait Analysis and Medical Diagnostic Enhancement

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The INERTIA Team

Significance of Gait Analysis in Medical Diagnosis

Pre-HVLP
Brain imaging
Cognitive skills assessments
Gait performance

HVLP
High Volume Lumbar Puncture
Temporarily drains cerebrospinal fluid

Post-HVLP
Cognitive skills assessments
Gait performance

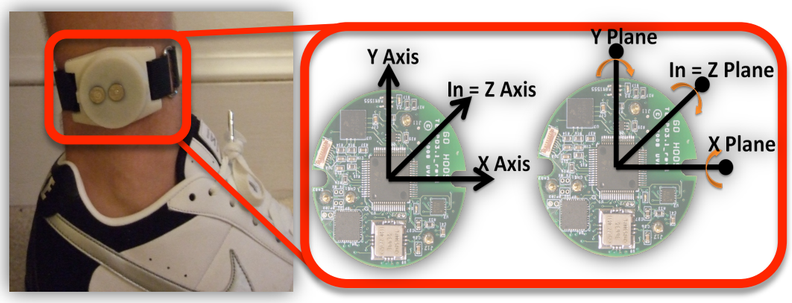
cf.

Normal Pressure Hydrocephalus (NPH)
- Similar symptoms as dementia and neurological movement disorders
- Difficult differential diagnosis

Gait performance comparison pre- to post-HVLP
- Limited resolution from clinical observation
- Need for higher precision gait analysis for each individual patient

Common need in many medical applications
- Early Multiple Sclerosis and Parkinson's Disease diagnosis
- Orthopedic device assessment

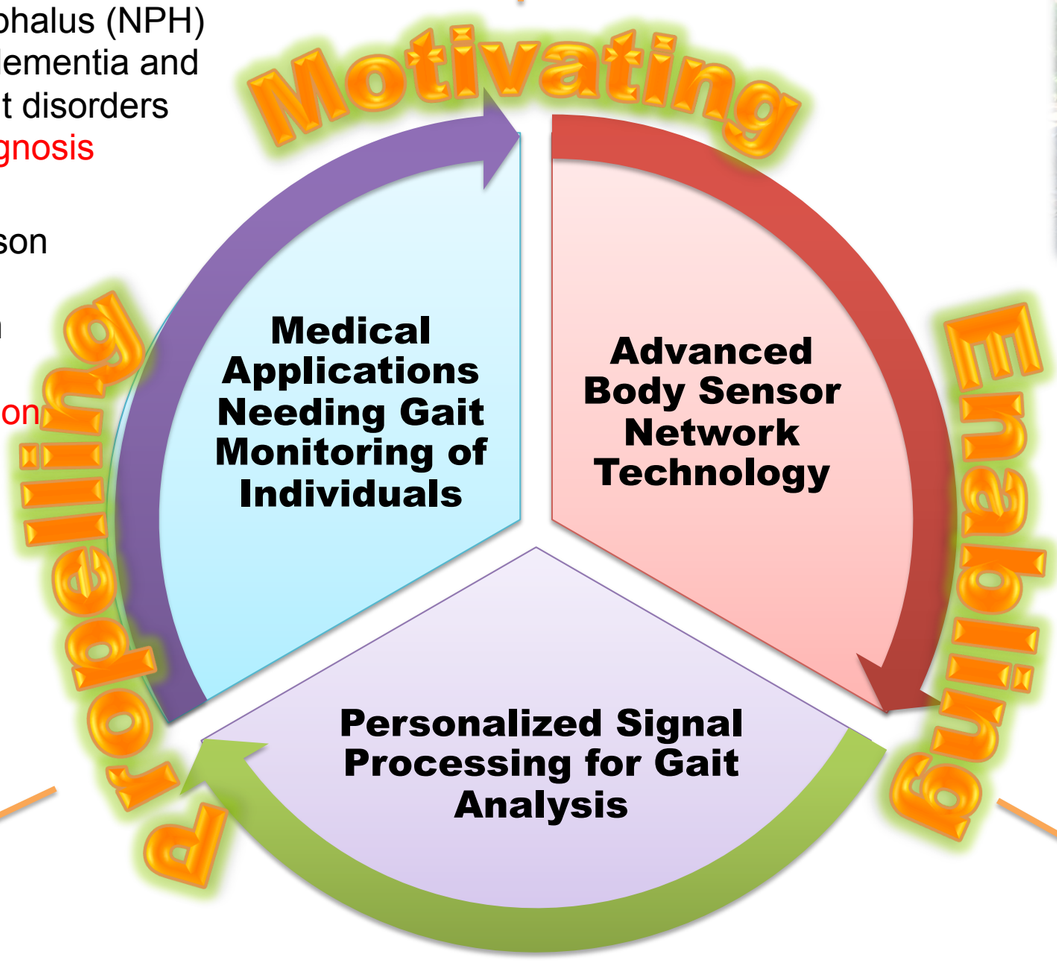
Inertial Body Sensor Network (BSN) Technology



TEMPO Motion-Capture BSN Node

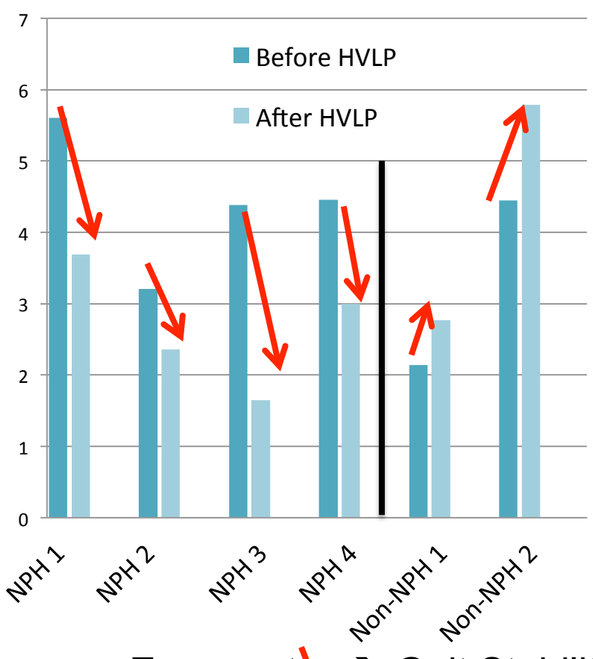
System Design

- 6 degrees-of-freedom motion capture in a wrist watch form factor
- Programmable sampling rate to capture subtle motion
- Bluetooth and local flash memory compatible based on real-time needs and battery life requirements



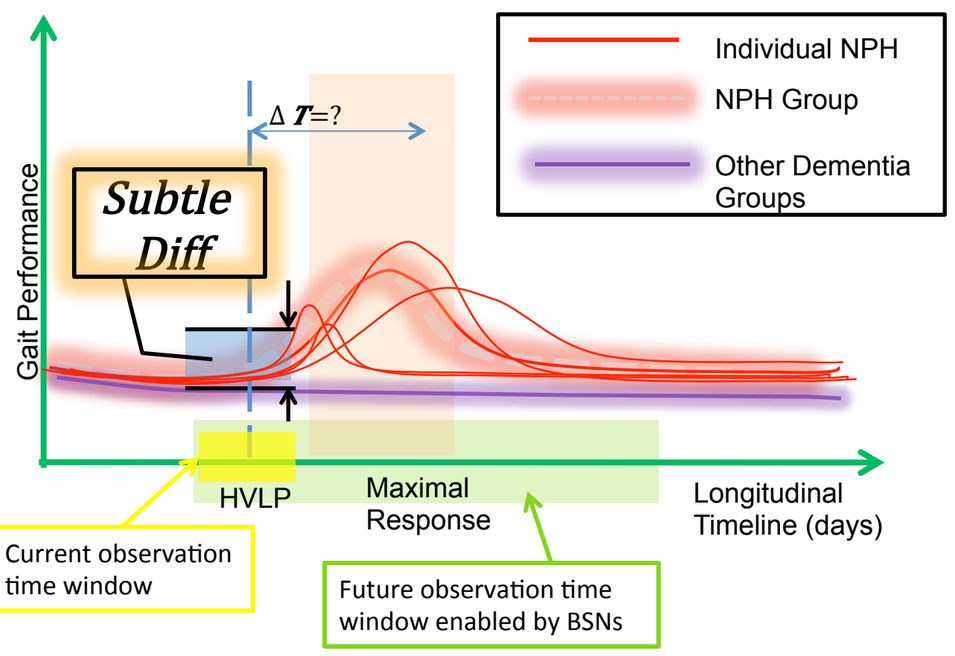
Deployable
Non-invasive
Continuous
Longitudinal
High-fidelity
Out-of-lab
Gait Monitoring

Successful Diagnostic Separability



Lyapunov Exponent ↘ ➔ Gait Stability ↗

Qualitative Patient Response



For many diseases and disorders associated with mobility impairment, early diagnosis is the key for successful intervention and maximized wellness, and accurate mobility assessment is central to monitoring progression and evaluating the impact of physical and pharmaceutical therapies. Inertial body sensor networks (BSNs) have the potential to aid such assessments with continuous, non-invasive collection of high-precision motion data in any location over an extended period of time, but uncontrolled out-of-clinic BSN deployments introduce nuisance variables that make absolute assessments challenging.

However, the purpose of mobility assessments as described above does not truly depend on absolute assessments compared to a statistic norm but rather on relative assessments compared to an individual's baseline, which eliminates nuisance variables and makes out-of-clinic assessments using a BSN a more tractable problem. This project is exploring such personalized gait analysis to enable continuous, longitudinal gait assessments using a BSN for two example conditions with mobility impairment symptoms: normal pressure hydrocephalus (NPH) and multiple sclerosis (MS).

Specific anticipated contributions include:
1) identifying signal features that can be feasibly extracted from out-of-clinic inertial BSN data and effectively utilized for detecting individualized gait changes,
2) developing new signal processing algorithms for the individualized identification and relative quantification of gait changes, and
3) exploring techniques for implementing forms of personalized signal processing on resource-constrained BSN platforms to enable more intelligent data reduction and dynamic energy optimization strategies that can extend the battery life of such systems.

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