Challenges That Might Benefit From Standards Development: Interface Software

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Prospect of Software Standardization

Reducing the time, complexity, risk, and cost of BCI system development
Elements of Software Standardization

Data format

Interfaces between or within sensors, software, and effector
Principal Challenges of Software Standardization

- Fundamental tradeoff between standardization/modularization and system performance
- Huge functional/technical space to cover
- Standardization of hardware and software across the whole BCI space is *unrealistic*
Specific Challenges of Software Standardization

Impossible to engineer general system that is guaranteed to have sufficient tech specs

Technical or physiological dependencies between sensors, software, and effector

Insufficient recognition of the substantial difficulty of BCI software development

“Not invented here” syndrome
Specific Challenges of Software Standardization II

**Commercial:**
Benefit of vertical integration exceeds benefit of horizontal integration

**Academic:**
What are the *perceived* incentives to conforming to standards?
Practical Suggestions

**Commercial:**
Not sure

**Academic:**
Add funding incentives to using standard software
BCI2000:
General-Purpose BCI Software

What it is:
A widely adopted general-purpose software that integrates data acquisition, real-time processing, and stimulus presentation/feedback

Purpose:
Support large-scale research programs in BCI and related fields
BCI2000:
General-Purpose BCI Software

- Acquired by more than 4000 users world-wide
- Used in hundreds of peer-reviewed papers
- Many papers set new directions in BCI research
- BCI2000 is the basis for the first large-scale clinical BCI trial
- Its use extensively featured in scientific and popular media (e.g., NBC, CBS, CNN, Discovery, NPR)
BCI2000:
General-Purpose BCI Software

- Schalk et al., *IEEE Trans Biomed Eng*, 2004

System Model

BCI2000 V1.0
2000-2007

Operator

System Configuration  Visualization

Source
Storage

brain signals
event markers

Signal
Processing

control signals
event markers

User
Application

event markers
System Model

BCI2000 V2.0
2008

Operator

System Configuration
Visualization

Source
Storage

brain signals
event markers

Signal
Processing

control signals
event markers

User
Application

Scripting

Data Format
Export/Import

Matlab
Processing

Real-Time Access
To Control Signals
& Event Markers

Operator

Brain signals
Event markers

Signal
Processing

Event markers

User
Application

Event markers

BCI2000 V2.0
2008
System Model

BCI2000 V3.0
2011

Operator and User Client Applications

Visualization Windows
Log Window
Parameter GUI/IO
Control Button GUI
Console Interface

Operator Library

System State Machine

Source
Storage

Signal Processing

User Application

Data Format
Export/Import

Matlab Processing
Real-Time Access To Control Signals & Event Markers

brain signals
event markers

control signals
event markers

event markers

Matlab

BCI2000 V3.0
2011
Credits

US Army: W911NF-08-1-0216, W911NF-12-1-0158, W911NF-12-1-0109, W911NF-13-1-0479, W911NF-14-1-04
NIH: R01-EB000856, R01-EB006356, P41-EB018783; Fondazione Neurone

NCAN
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