The Ottawa Hospital RESEARCH INSTITUTE | L'Hôpital d'Ottawa INSTITUT DE RECHERCHE

uOttawa

LabStreamingLayer in Virtual Reality and Intracranial Neurophysiology

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Senior Research Associate,
Ottawa Hospital Research Institute

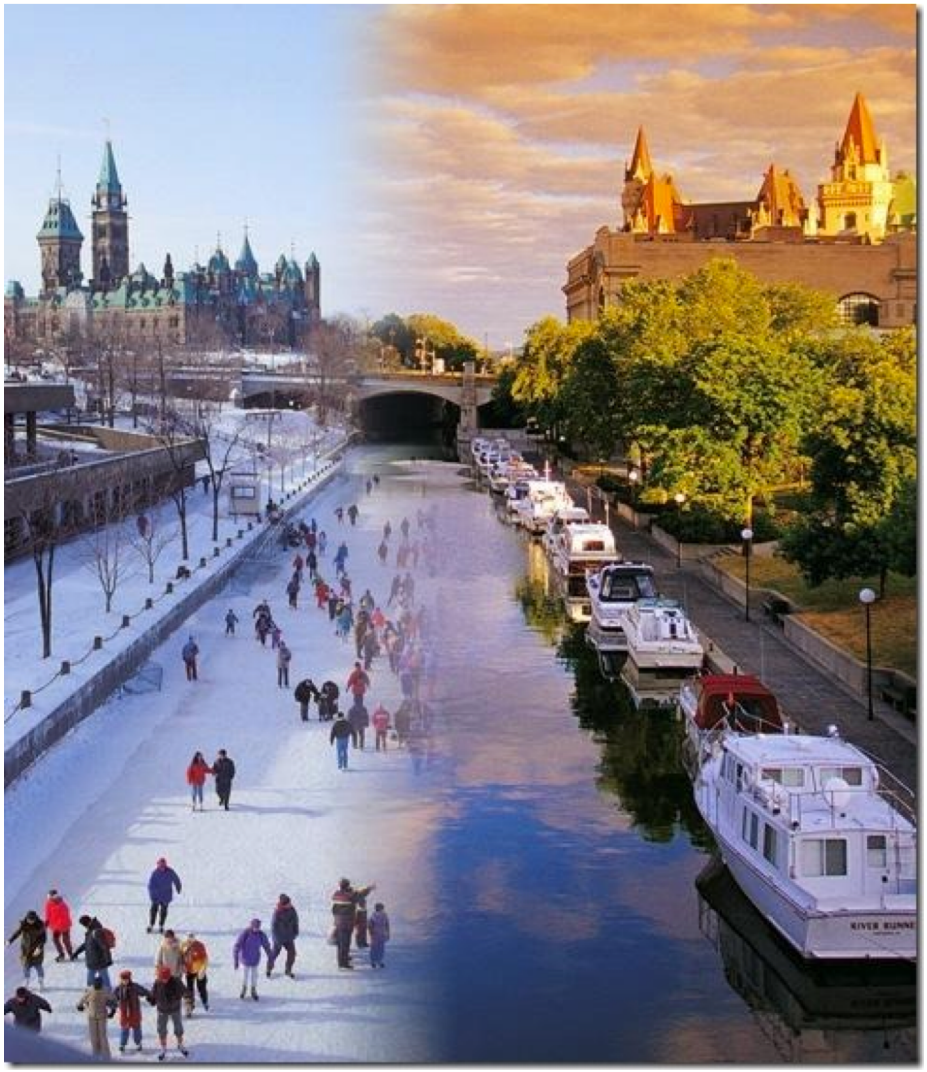
intheon

Outline

- My LSL Use Cases
- Streaming Motion Controllers
- Streaming Game Engine Events (in VR)
- Streaming intracranial neurophys data
- Remote control LabRecorder

My LSL Use Cases

Role	PI	Location	Field
PhD	Jon Wolpaw	Albany, NY USA	EEG-BCI; Rat reflex
Postdoc	Junichi Ushiba	Keio, Yokohama, Japan	EEG, TMS, fMRI, BCI for rehab
Sr. Research Associate	Adam Sachs	Ottawa, Ontario, Canada (pictured)	BCI for PD therapy; invasive BCI



Winter/Summer in Ottawa, Ontario, Canada

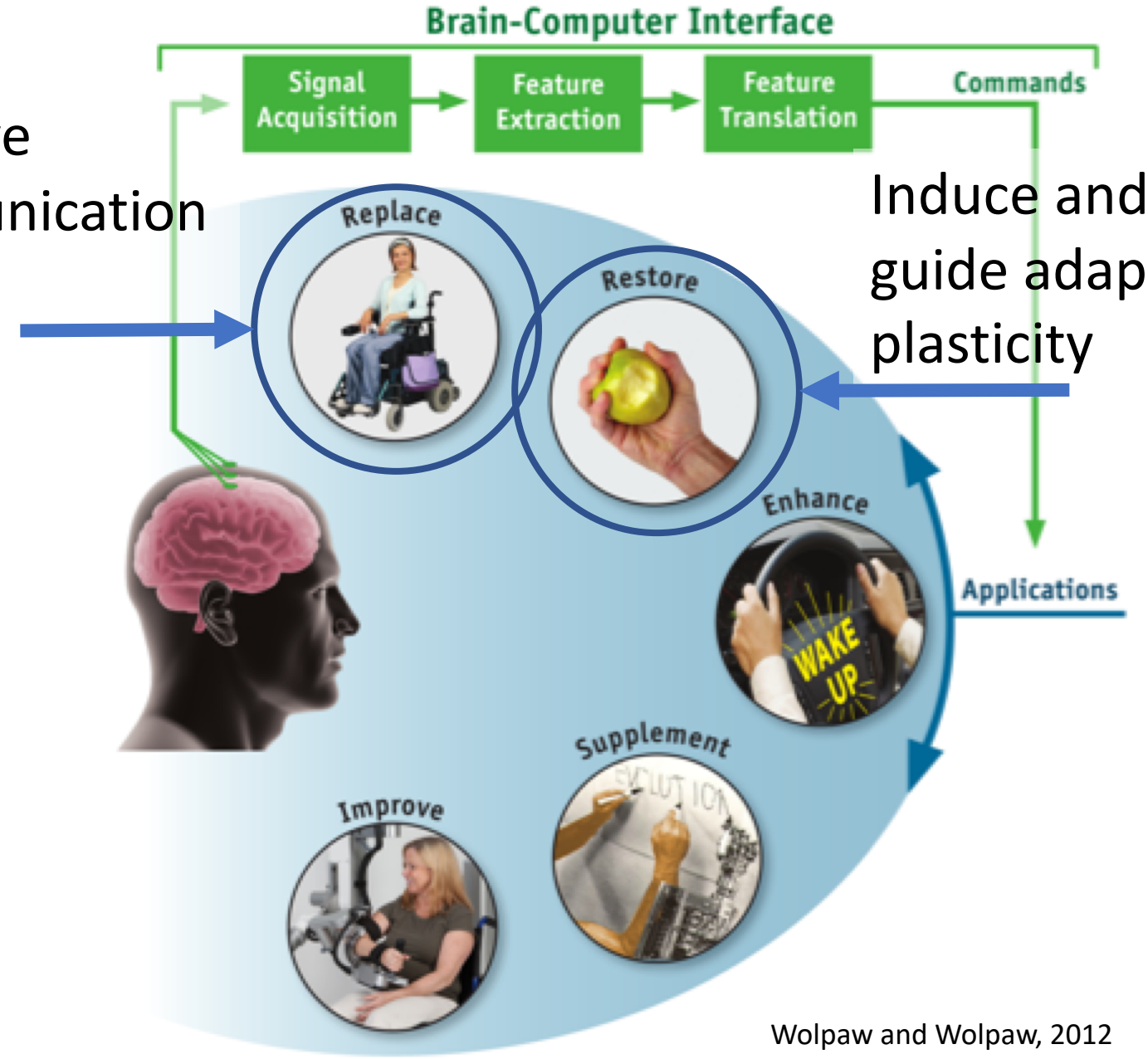
LSL Contributions

- Apps

Device Name	Manufacturer	App
1608-FS (maybe others)	MCC	MeasurementComputing
Unreal Engine 4	Epic Games	/SachsLab/lsl-ue4
Epoc+	EMOTIV	emotiv
g.USB, g.HIamp, g.Nautilus	g.tec	g.Tec/gNEEDaccess
Wiimote, Wii balance board	Nintendo	wiimote
Various VR systems	Valve, HTC, various	OpenVR

- Cross-platform build system (cmake)
- Devops
- Language wrappers (Python, C# - Unity)
- XDF
- Support on GitHub and Slack

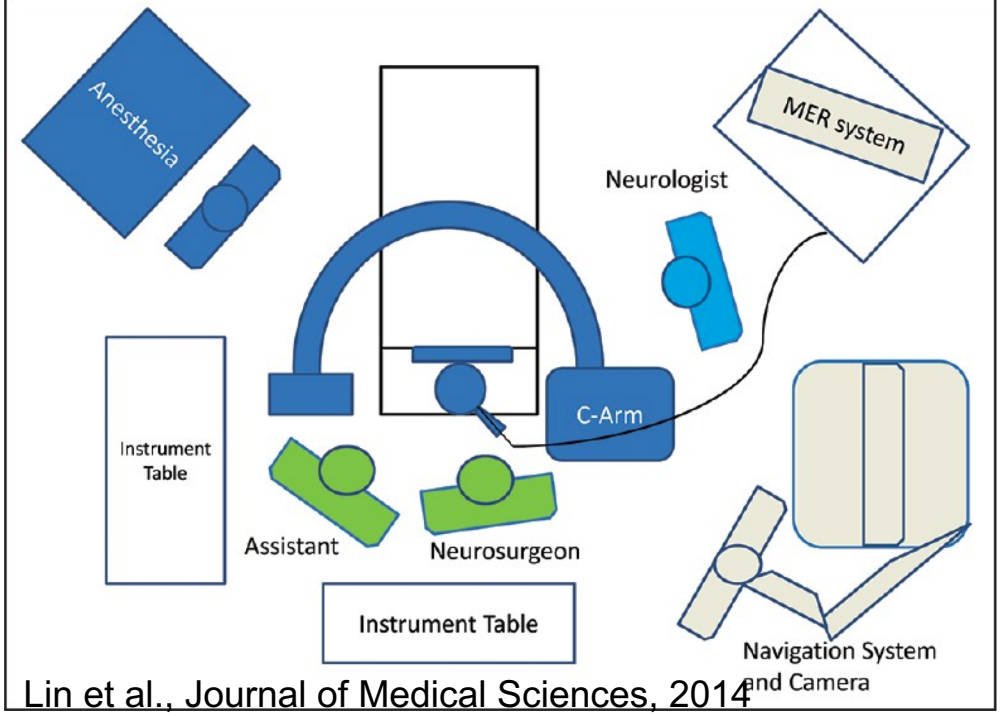
Assistive communication device



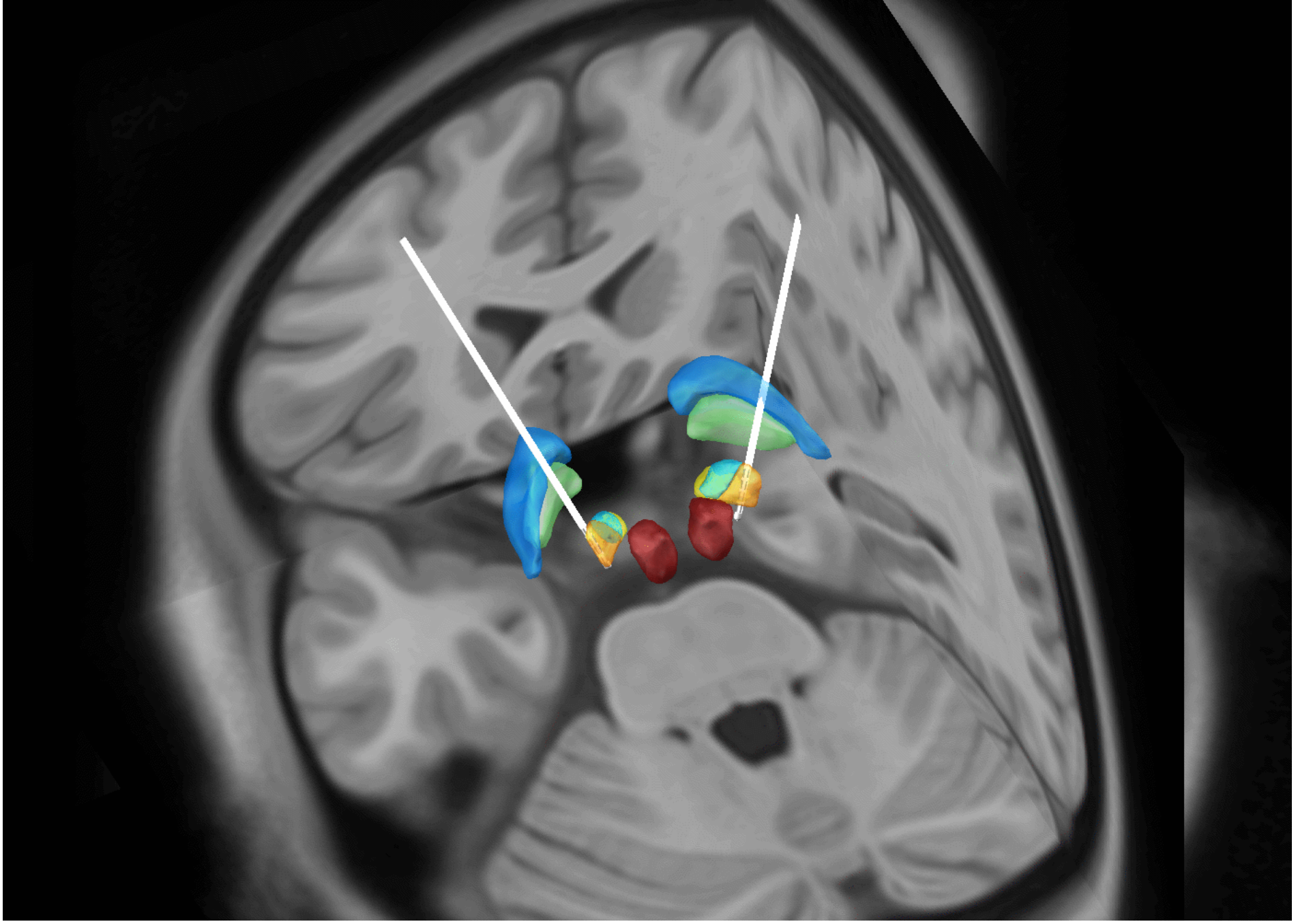
Induce and guide adaptive plasticity

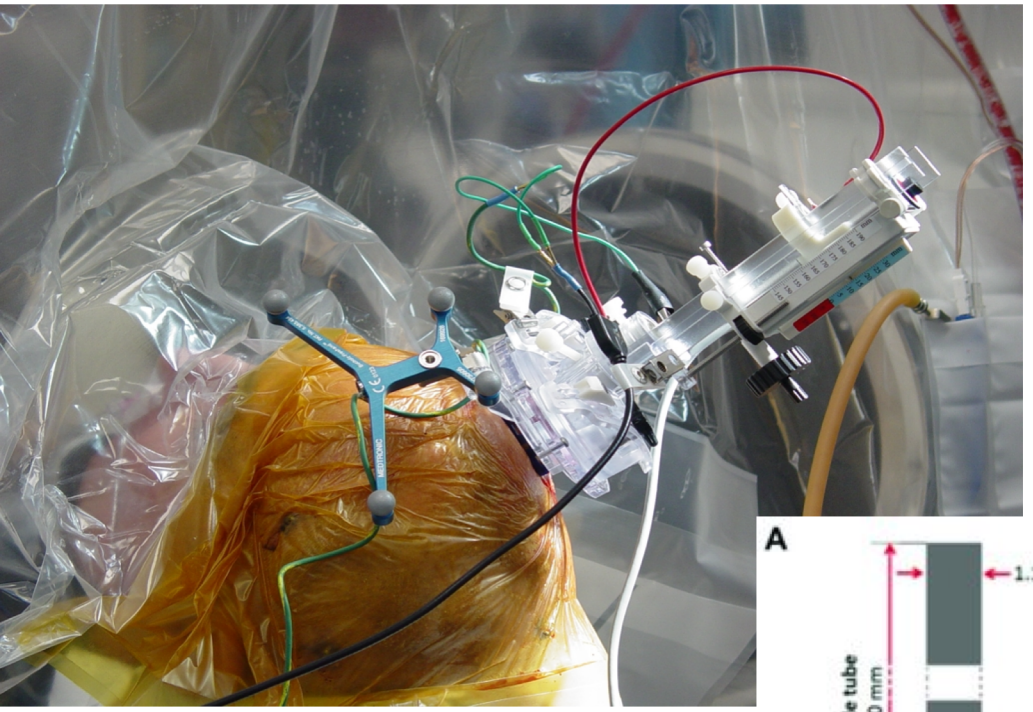
Wolpaw and Wolpaw, 2012

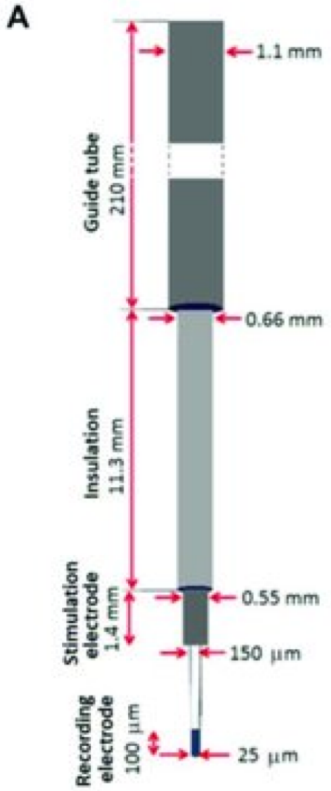
Clinical & Research Setting 1

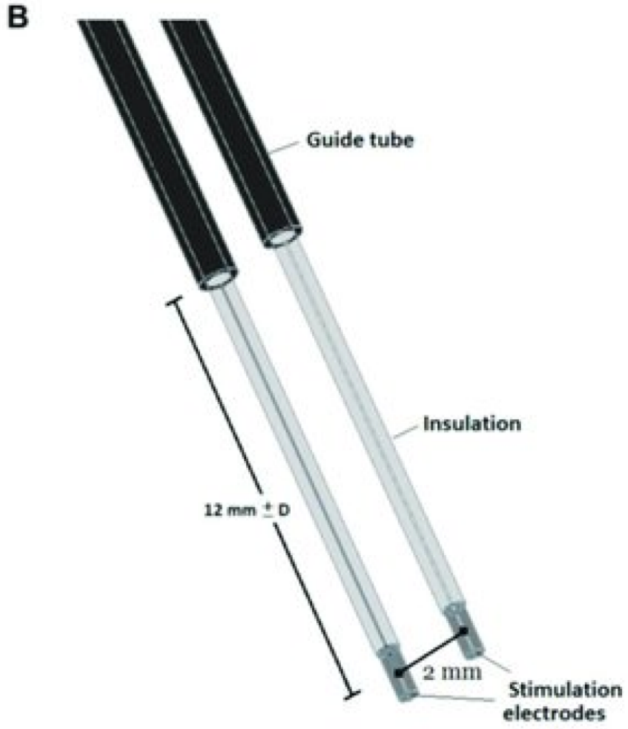


Lin et al., Journal of Medical Sciences, 2014



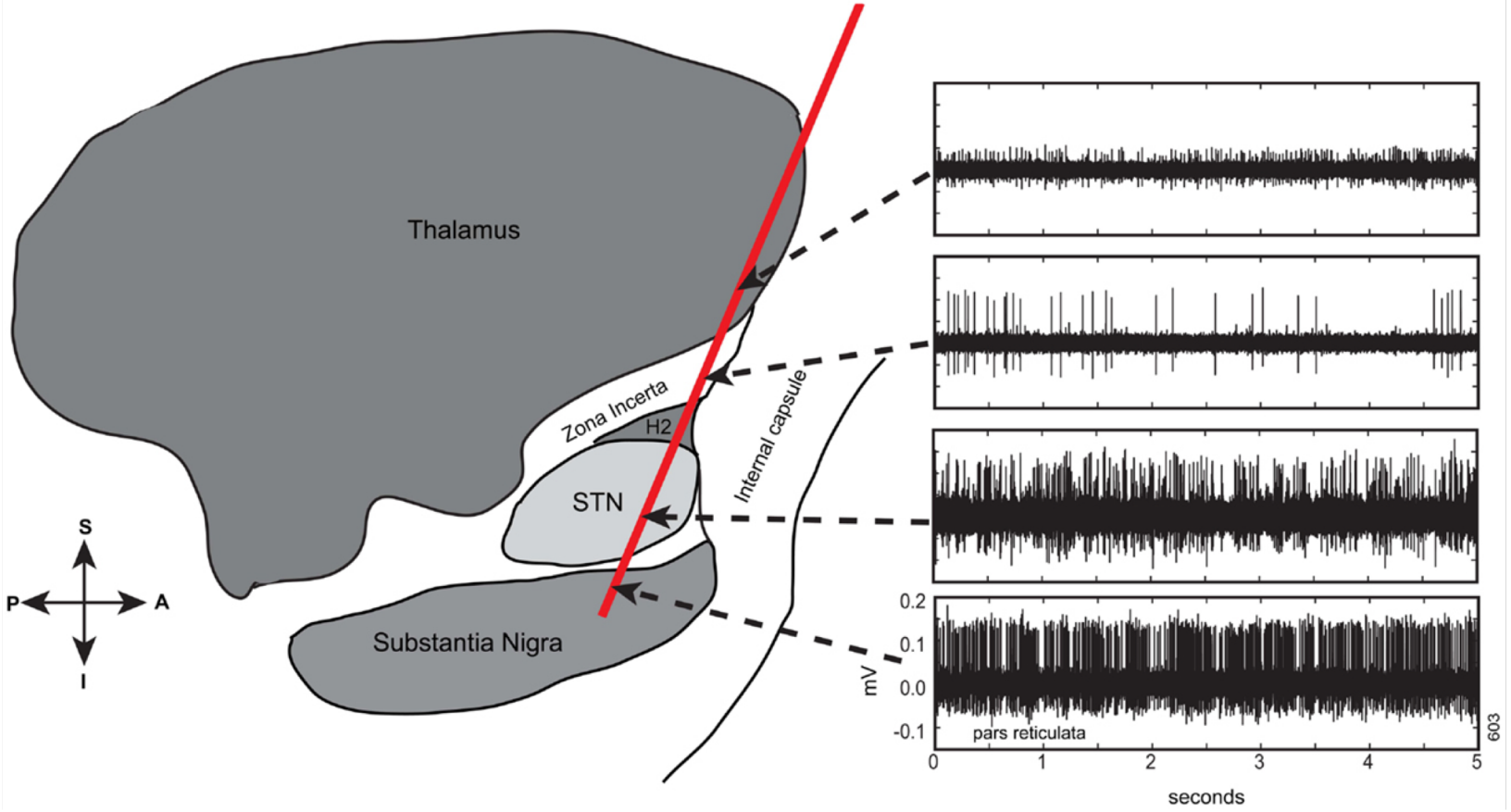




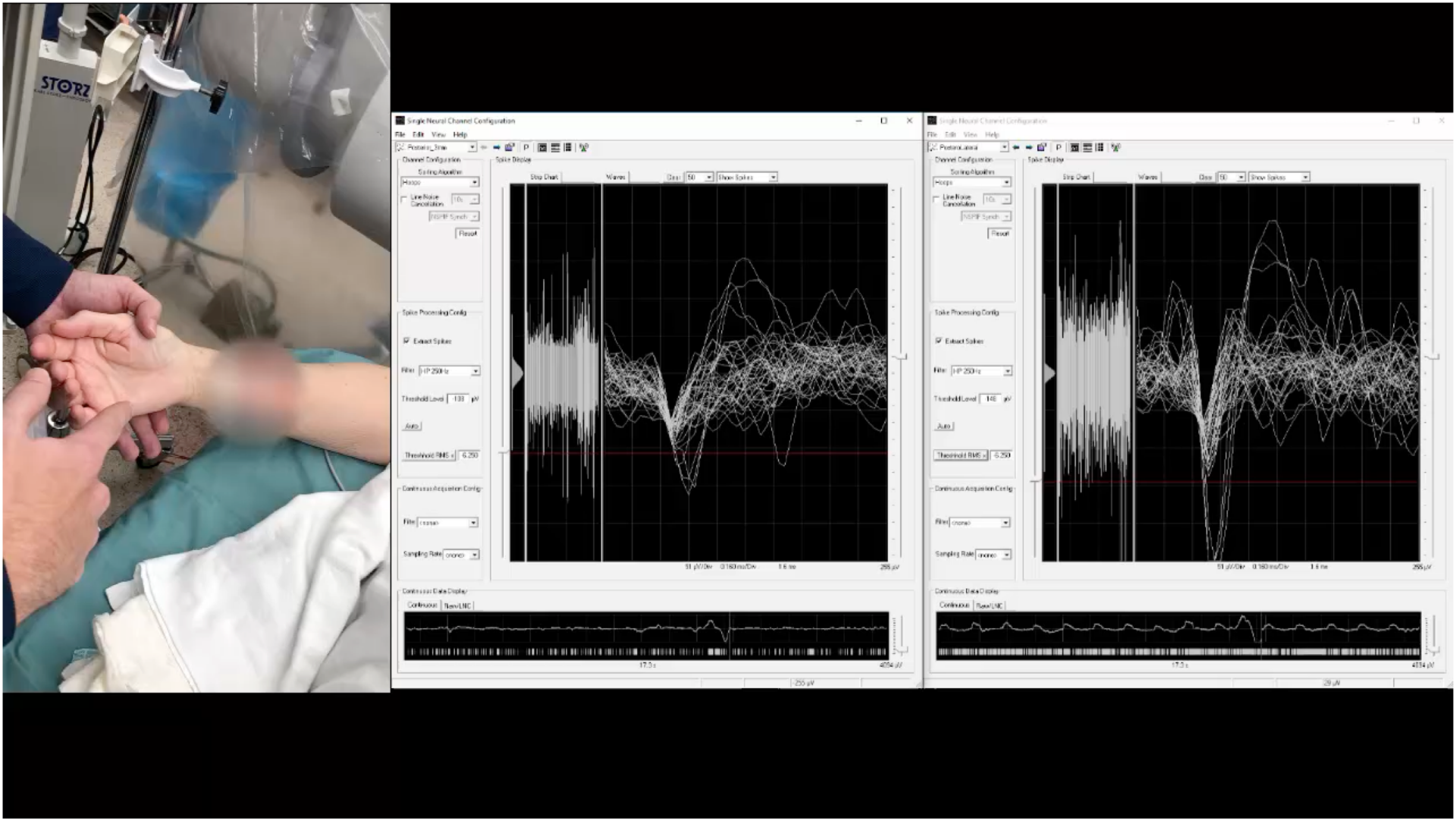


Alonso et al., 2018

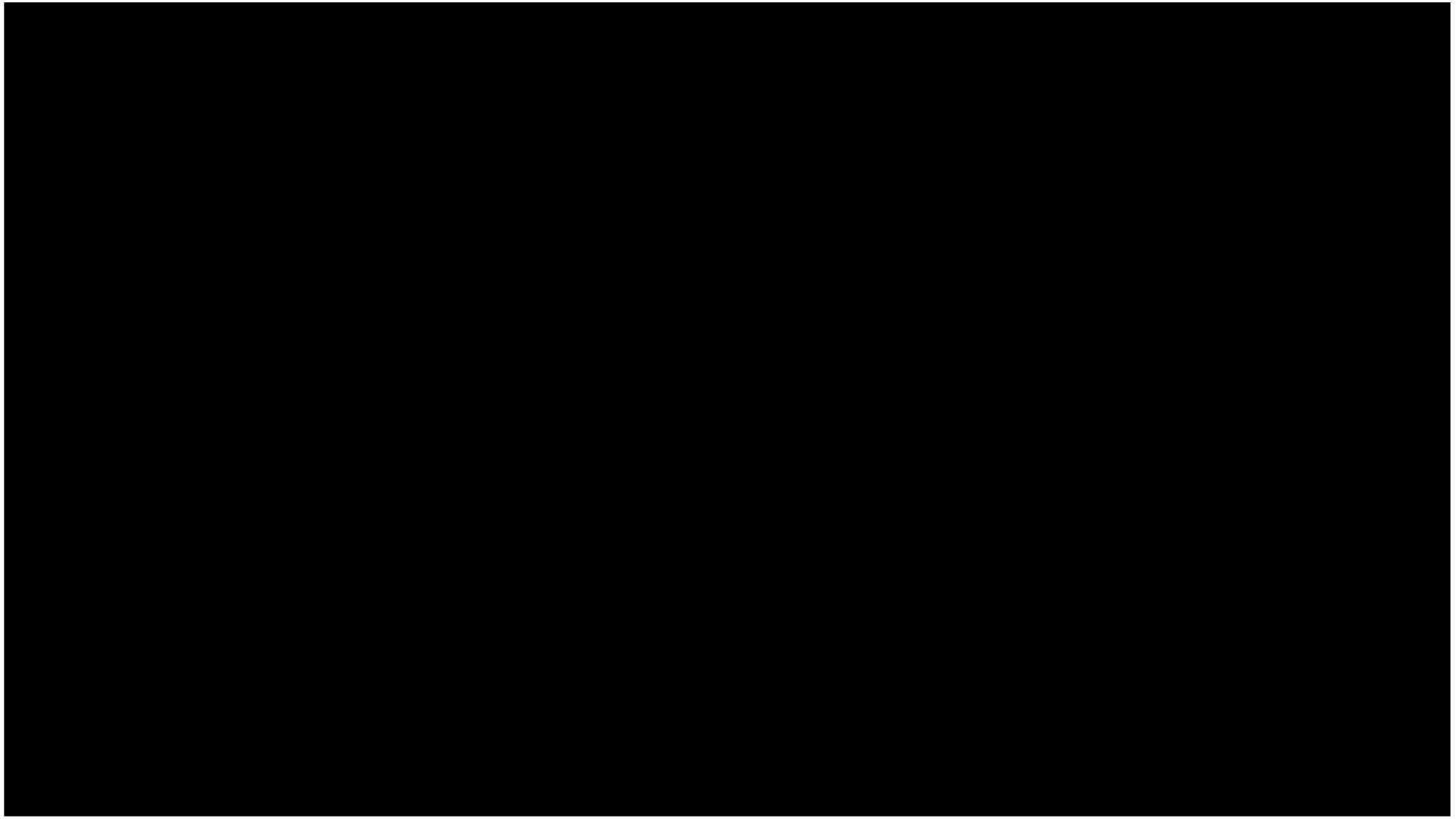
Microelectrode Mapping



Camalier et al., Front. Neurol. 2014


STORZ
Single Neural Channel Configuration
File Edit View Help
Channel Configuration
Sorting Algorithm
Hoops
Line Noise Cancellation
Reset
Spike Processing Config
Extract Spikes
Filter
Threshold Level
Auto
Threshold RMS x
6.250
Continuous Acquisition Config
Sampling Rate
Spike Display
Strip Chart
Waves
Clear
Show Spikes
Continuous Data Display
Continuous
Raw/LNC
Single Neural Channel Configuration
File Edit View Help
Channel Configuration
Sorting Algorithm
Hoops
Line Noise Cancellation
Reset
Spike Processing Config
Extract Spikes
Filter
Threshold Level
Auto
Threshold RMS x
6.250
Continuous Acquisition Config
Sampling Rate
Spike Display
Strip Chart
Waves
Clear
Show Spikes
Continuous Data Display
Continuous
Raw/LNC

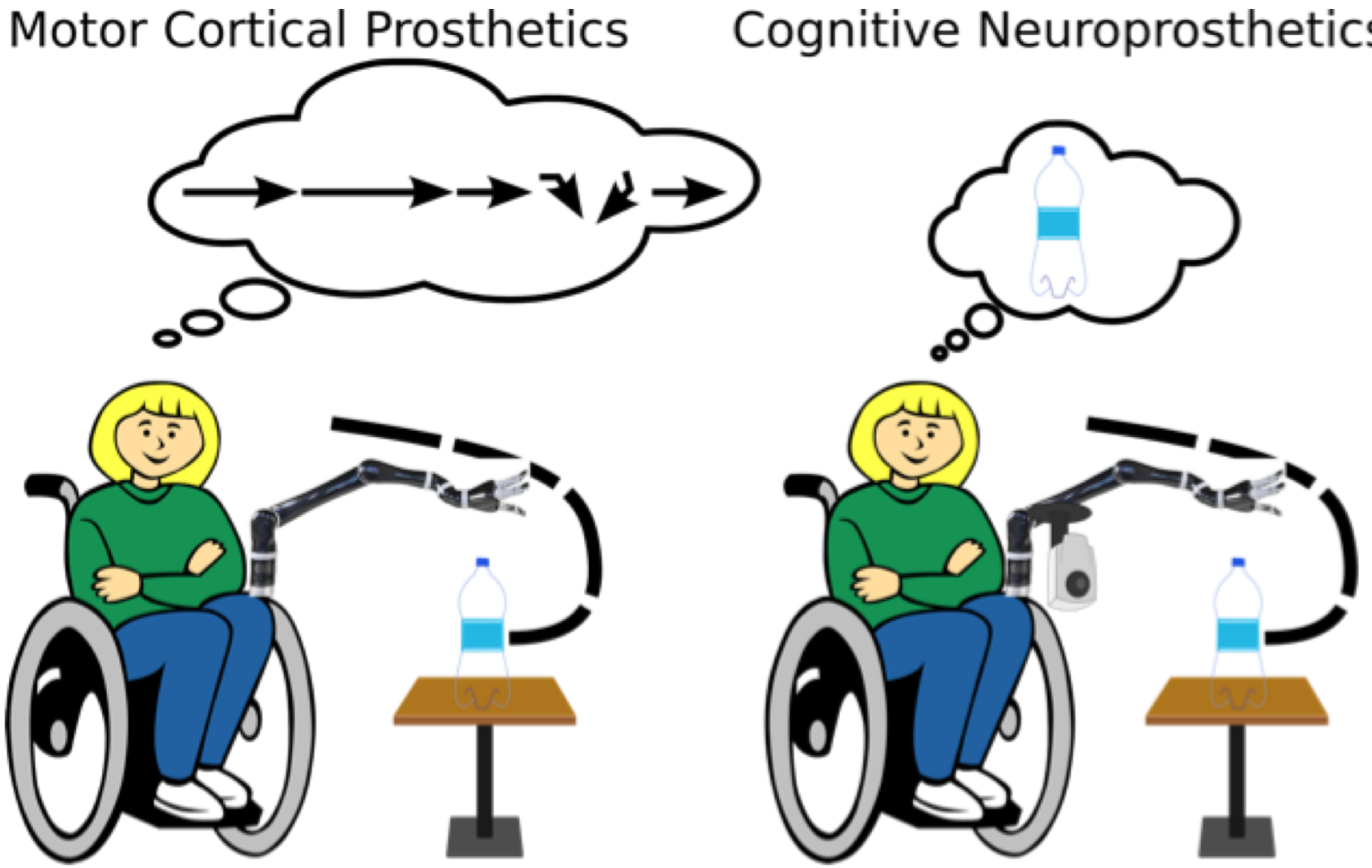
Michael Leung
Neuroscience MSc Student



Prototype from Justin Sutherland of the Realize Lab at OHRI/TOH

Clinical & Research Setting 2

Neuro Cognitive Communicator (NCC-1701)



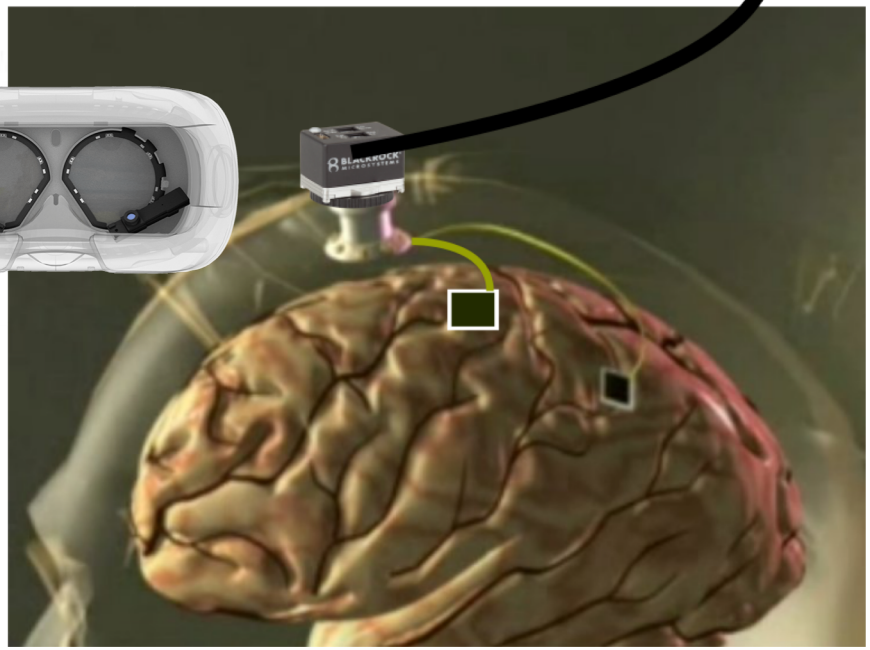

BLACKROCK MICROSYSTEMS
128-Channel Neural Signal Processor
ANALOG INPUTS
DIGITAL INPUTS
SERIAL I/O
DIGITAL OUTPUTS
SYNC
ANALOG OUTPUTS
AUDIO OUTPUTS
FIBER-OPTIC DATA LINK
1
2
3
4
5
6
7
8
9
10


BLACKROCK MICROSYSTEMS
Digital Hub 128
Source Status
Fiber-Optic Data Link
1
2
3
4
Power
ON
OFF


NETGEAR


htc

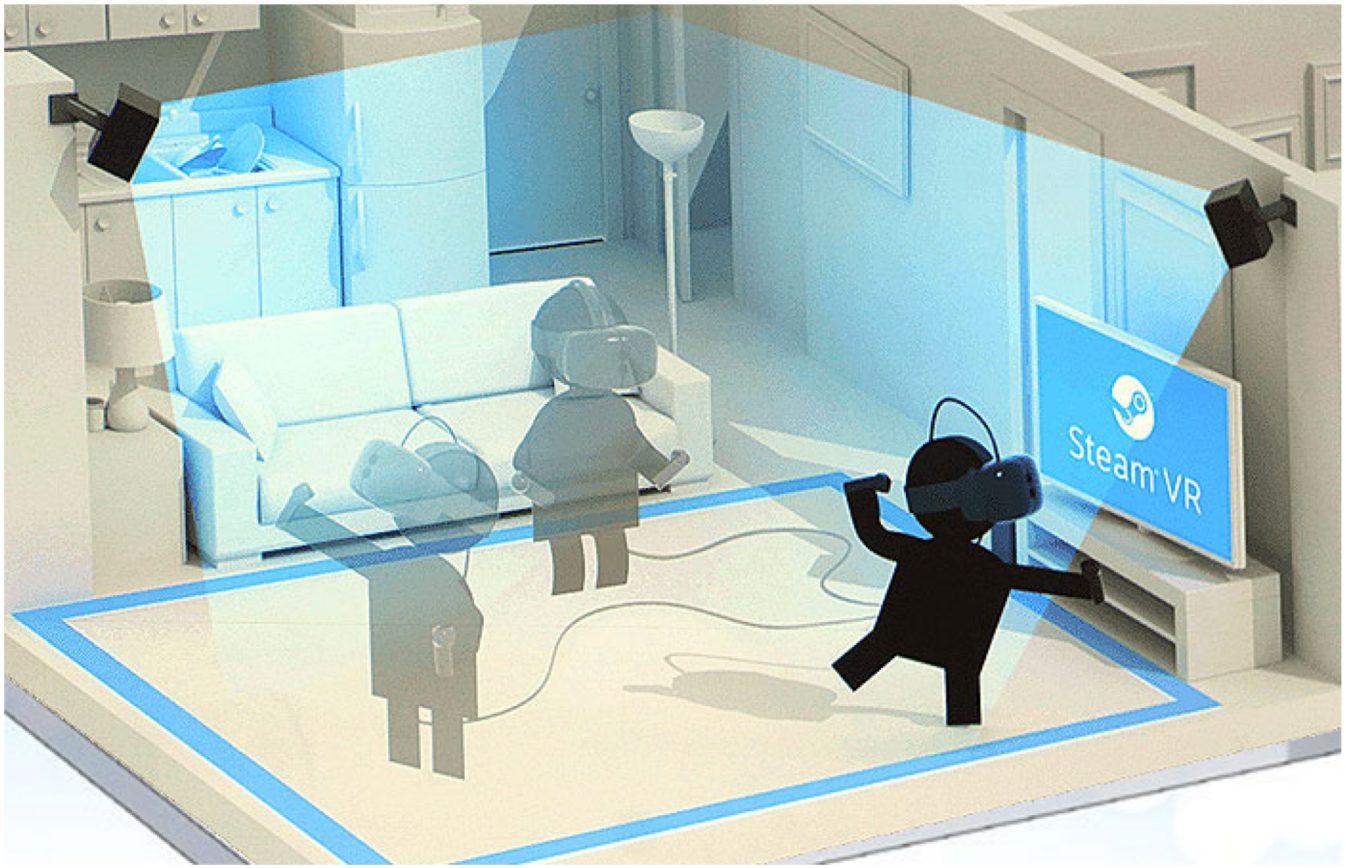
unity


BLACKROCK MICROSYSTEMS

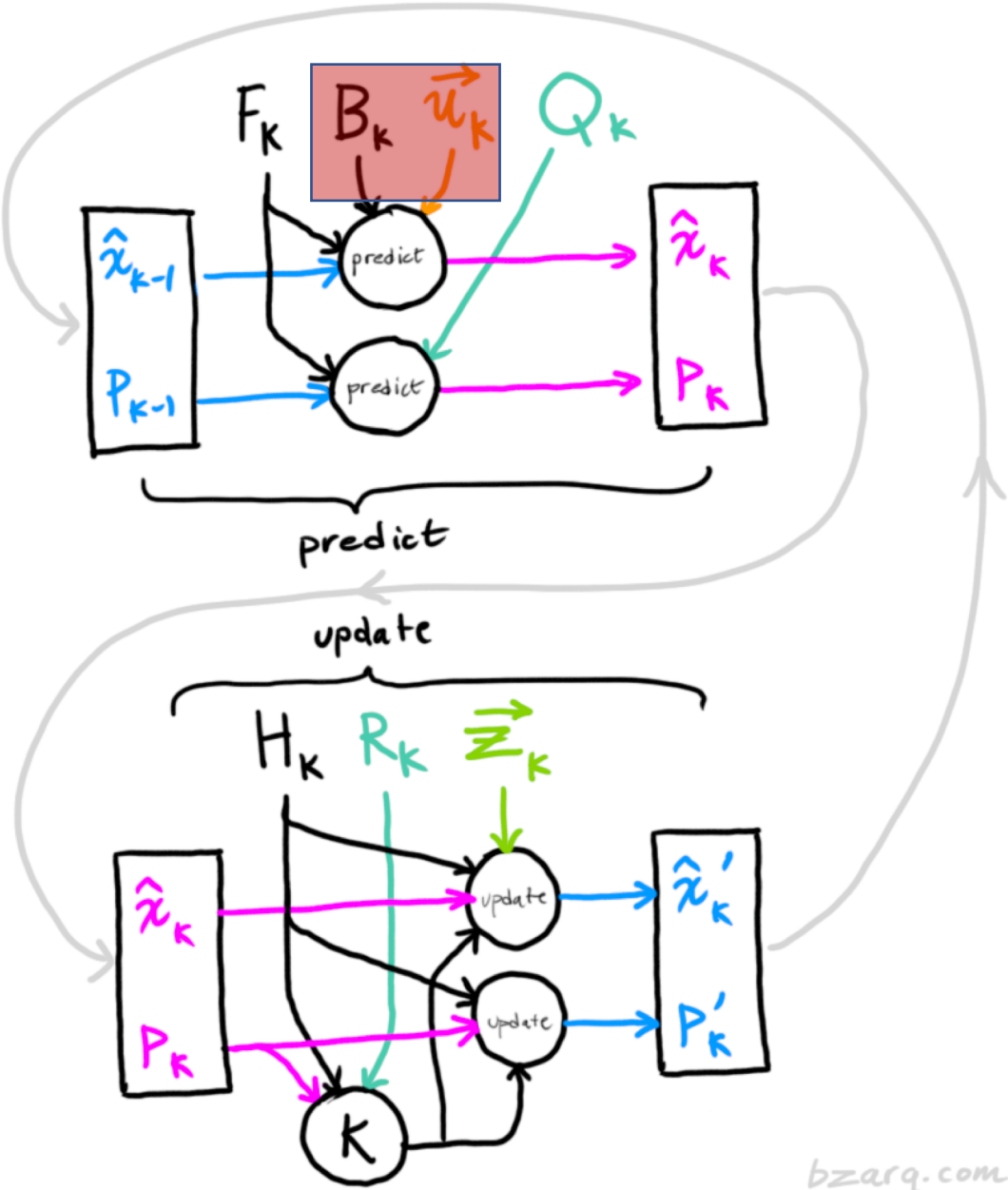
LSL Details

Motion Controllers

/labstreaminglayer/App-OpenVR



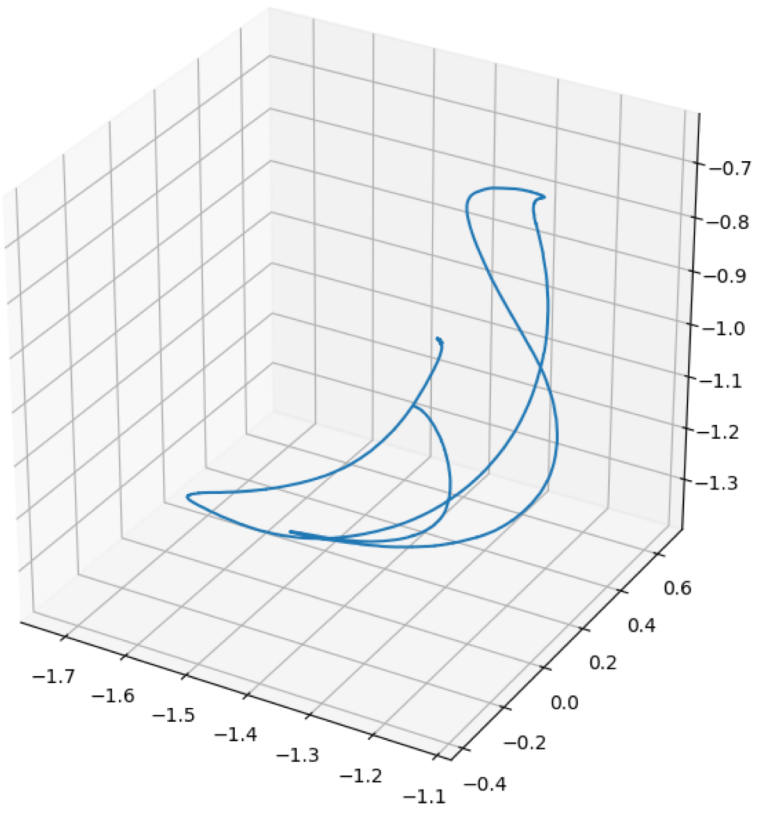
Kalman Filter Information Flow

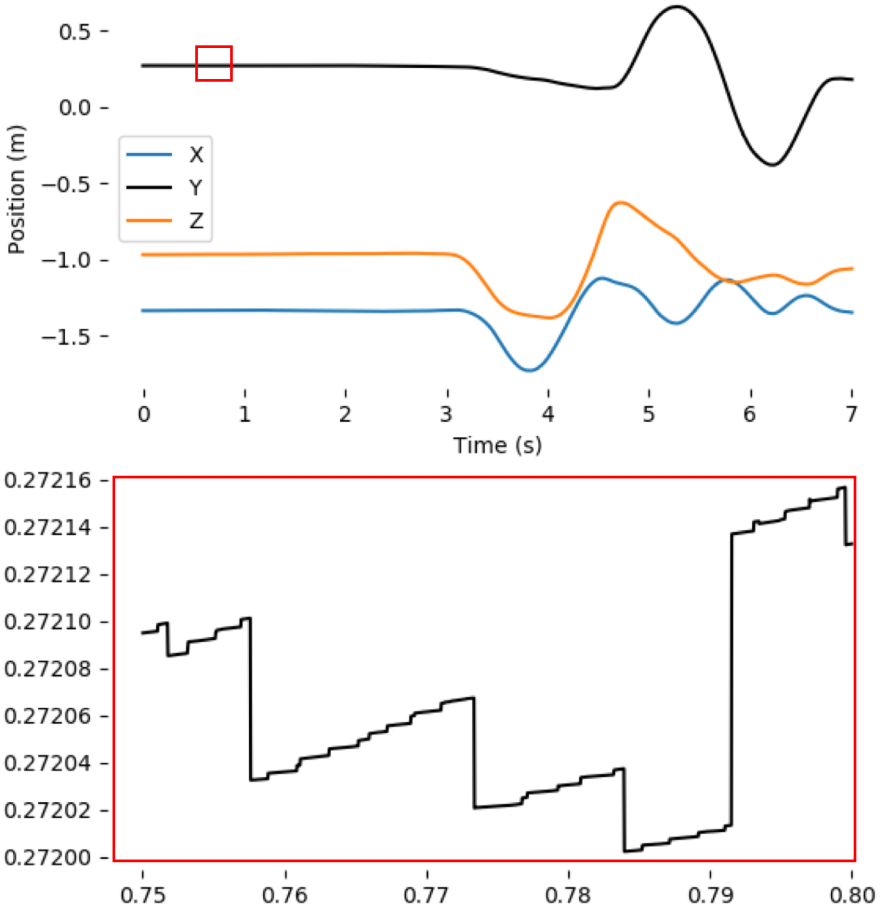


Device SDK (OpenVR→SteamVR) maintains internal model of kinematic behaviour and current state estimate.

Predicts state at **t** from current state at $\mathbf{t}_0$.

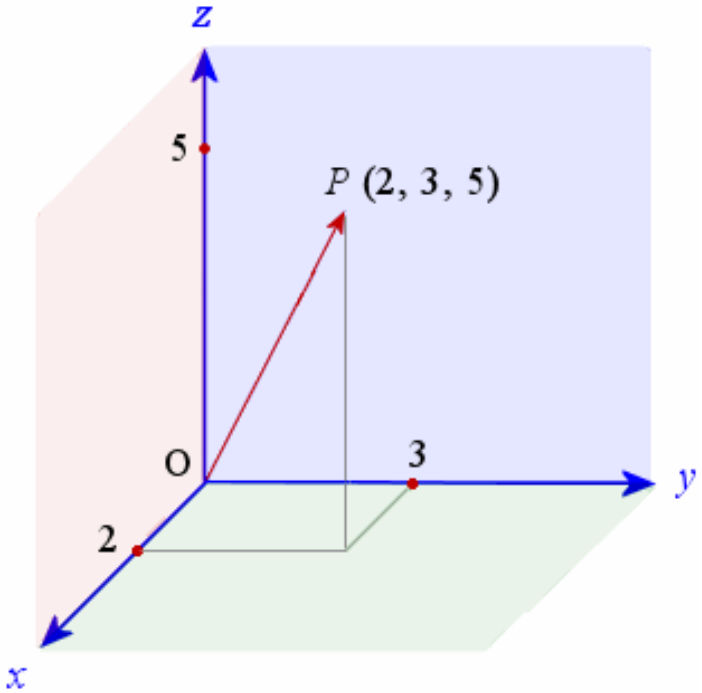
Updates state whenever it gets new sensor data.

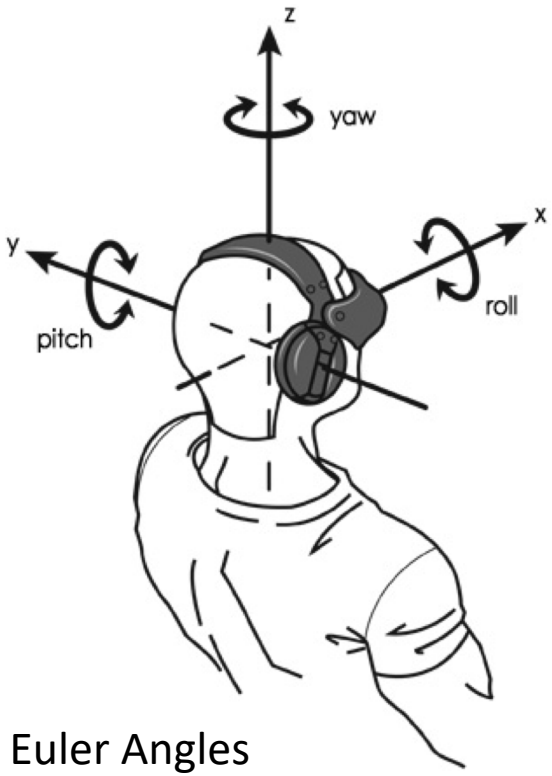




- IMU update ~ 500 Hz
- Optical update ~ 60 Hz

/labstreaminglayer/App-OpenVR





Euler Angles

Pose = P_x, P_y, P_z, O_y, O_p, O_r

$$\begin{bmatrix} 1 & 0 & 0 & Translation.x \\ 0 & 1 & 0 & Translation.y \\ 0 & 0 & 1 & Translation.z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(\theta) & -\sin(\theta) & 0 \\ 0 & \sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \dots \begin{bmatrix} Scale.x & 0 & 0 & 0 \\ 0 & Scale.y & 0 & 0 \\ 0 & 0 & Scale.z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} Transform\_XAxis.x & Transform\_YAxis.x & Transform\_ZAxis.x & Translation.x \\ Transform\_XAxis.y & Transform\_YAxis.y & Transform\_ZAxis.y & Translation.y \\ Transform\_XAxis.z & Transform\_YAxis.z & Transform\_ZAxis.z & Translation.z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

```
poseChanLabels
                << "00" << "01" << "02" << "X"

                << "10" << "11" << "12" << "Y"

                << "20" << "21" << "22" << "Z";
```

Summary

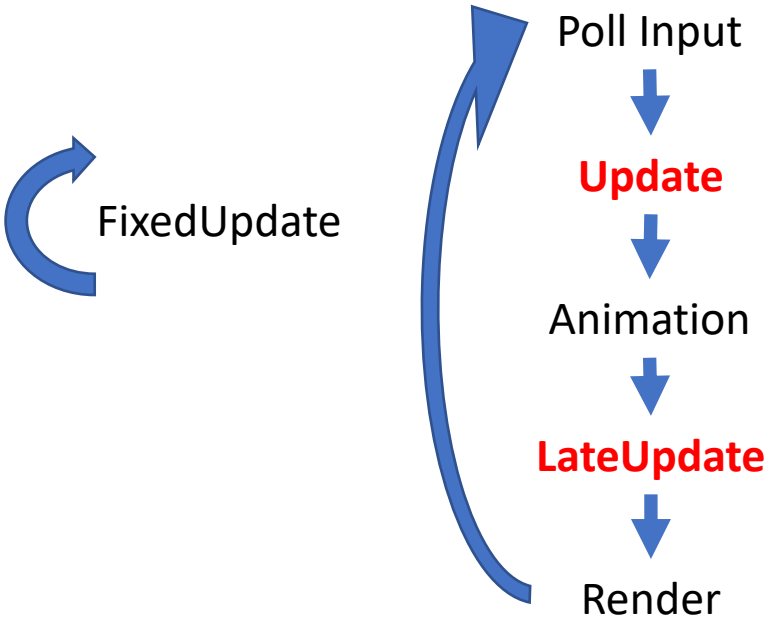
- https://github.com/labstreaminglayer/App-OpenVR 
- Pose represented as 12-channel (per device) stream
  - 12-channels reshape to 3x4 transformation matrix
  - Because it's easy to use,
  - Also that's what OpenVR gives us.
- Sampling rate is flexible, 1 kHz more than adequate.
- Samples are actually "predicted" poses

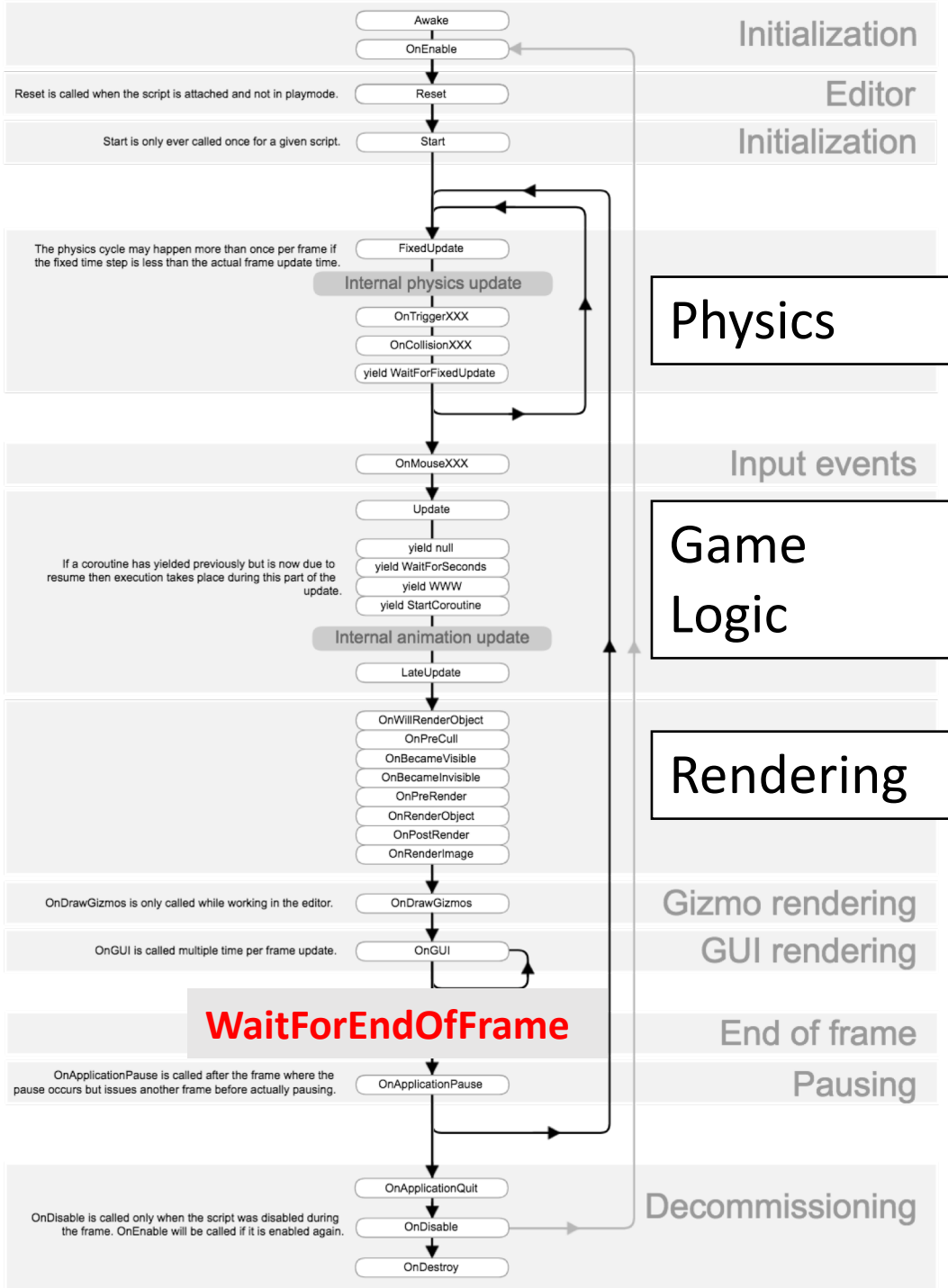
Game Engine Events

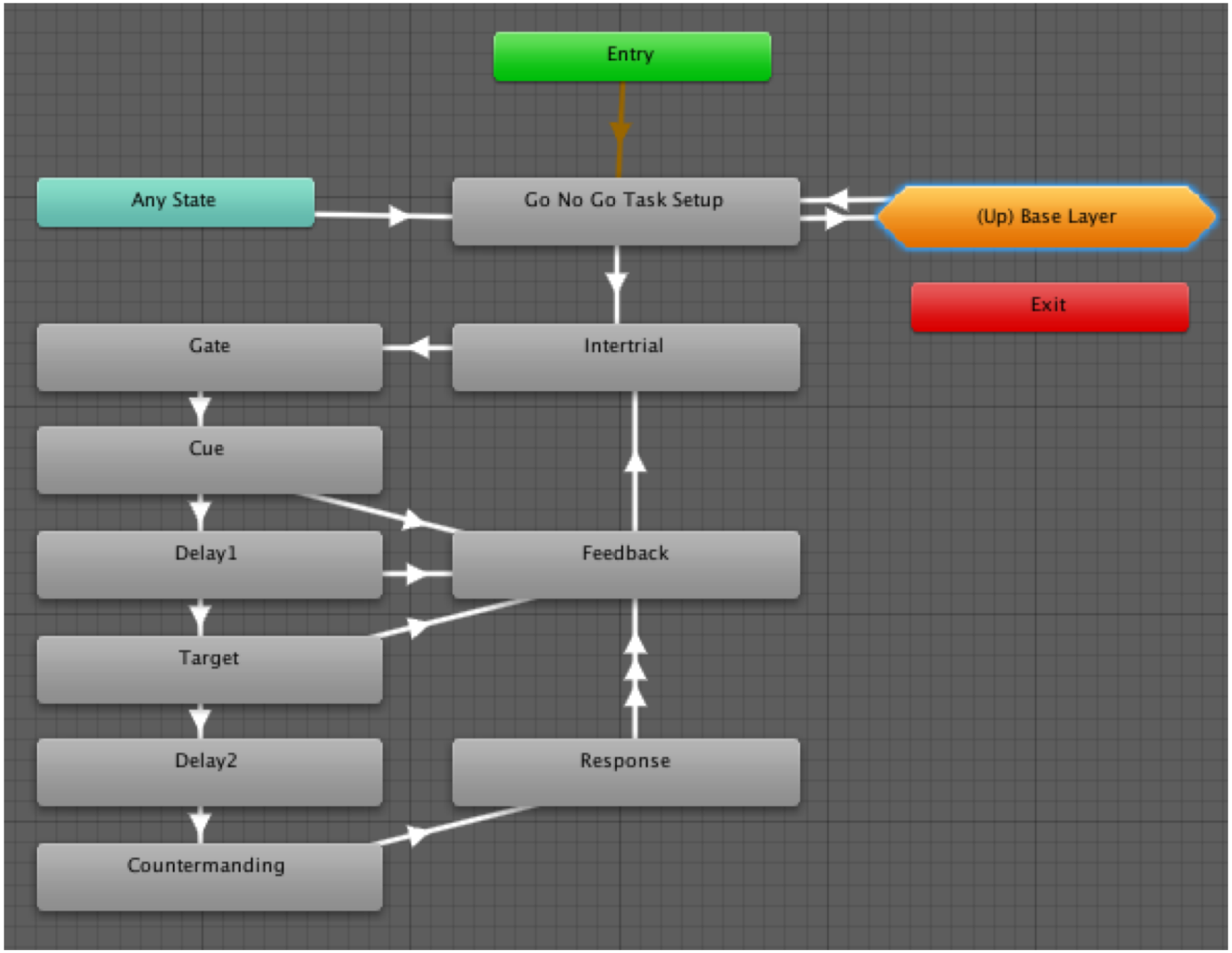
/labstreaminglayer/liblsl-Csharp

/xfleckx/LSL4Unity

Developer Entry Points:

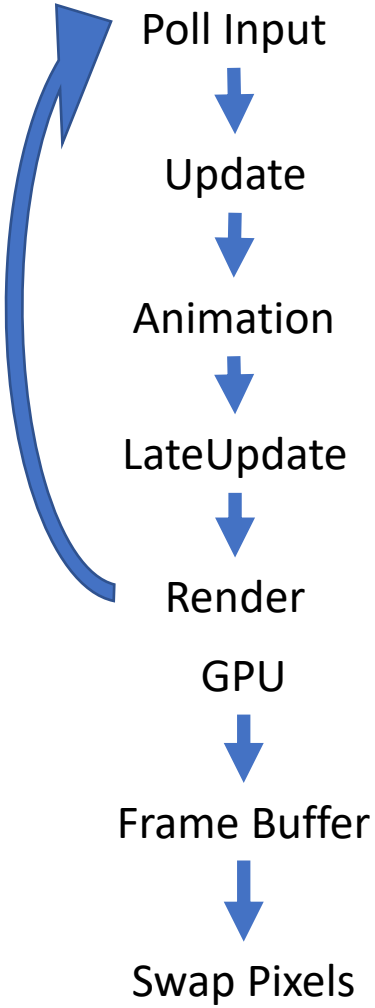




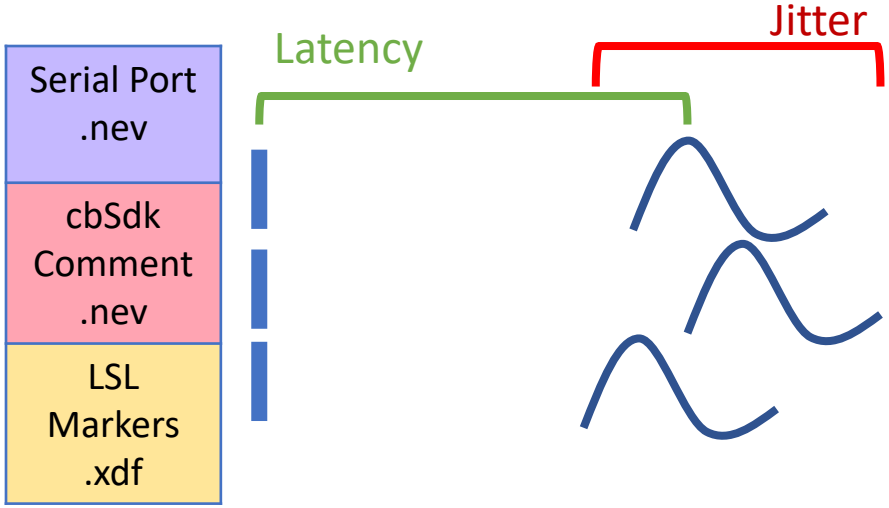


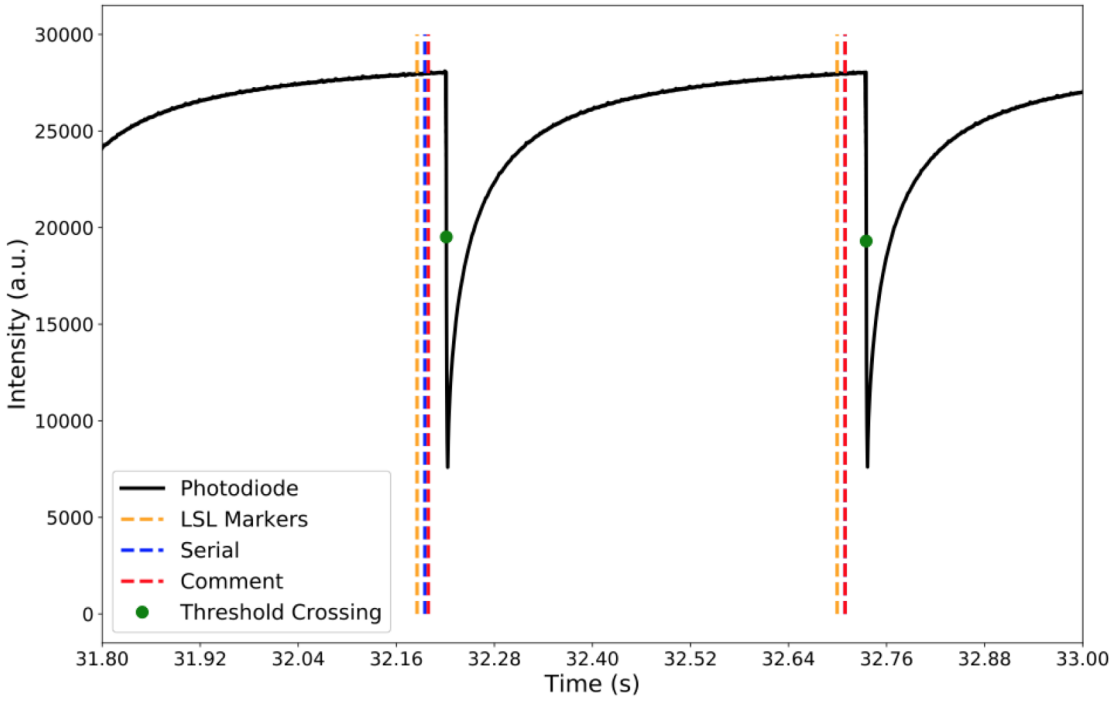
Each state transition generates a JSON string which is emitted over LSL.


unity

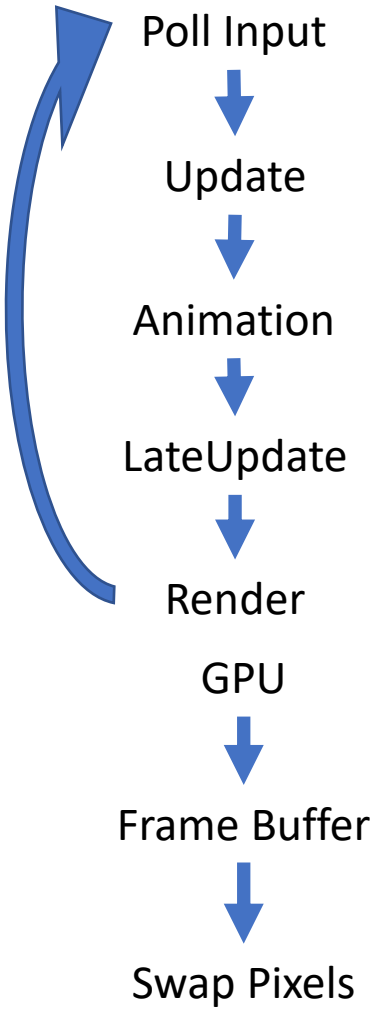

Poll Input
Update
Animation
LateUpdate
Render
GPU
Frame Buffer
Swap Pixels

Photodiode

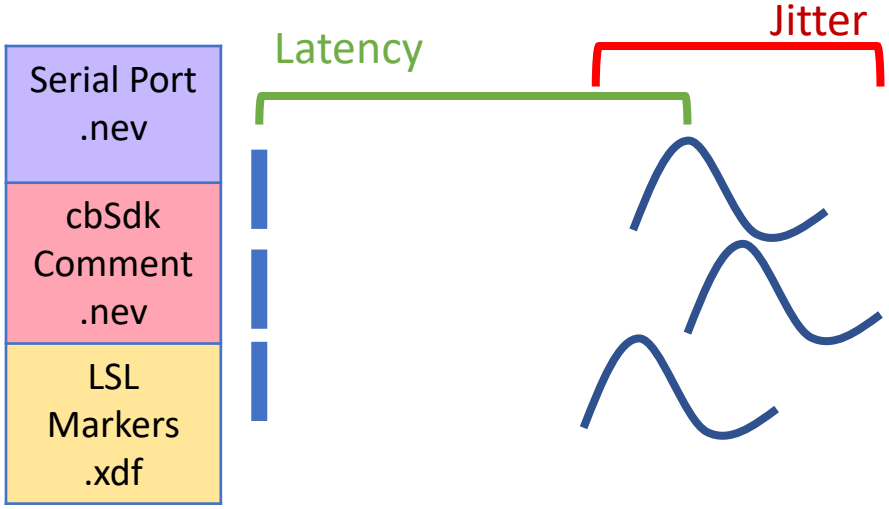

Serial Port
.nev
cbSdk
Comment
.nev
LSL
Markers
.xdf
Latency
Jitter

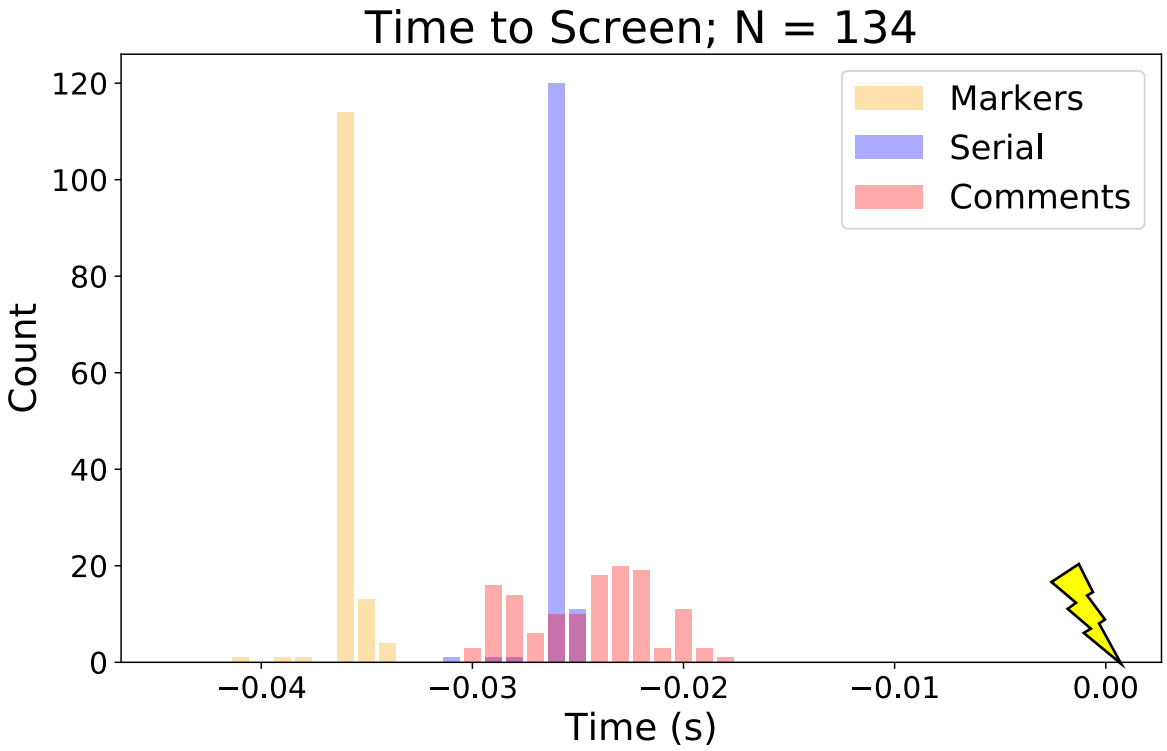

30000
25000
20000
15000
10000
5000
0
Intensity (a.u.)
31.80
31.92
32.04
32.16
32.28
32.40
32.52
32.64
32.76
32.88
33.00
Time (s)
Photodiode
LSL Markers
Serial
Comment
Threshold Crossing


unity

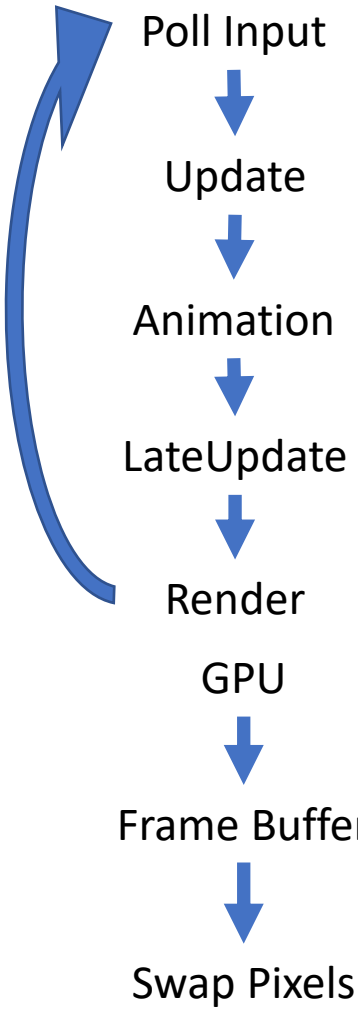

Poll Input
Update
Animation
LateUpdate
Render
GPU
Frame Buffer
Swap Pixels

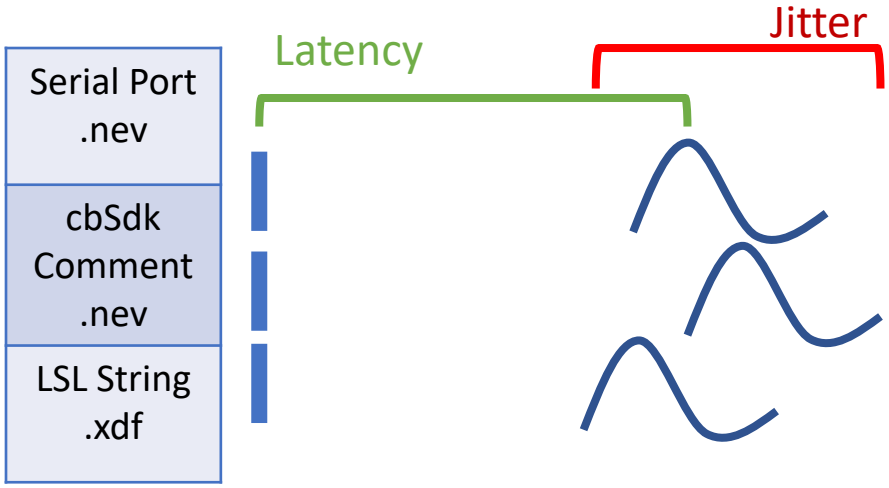
Photodiode

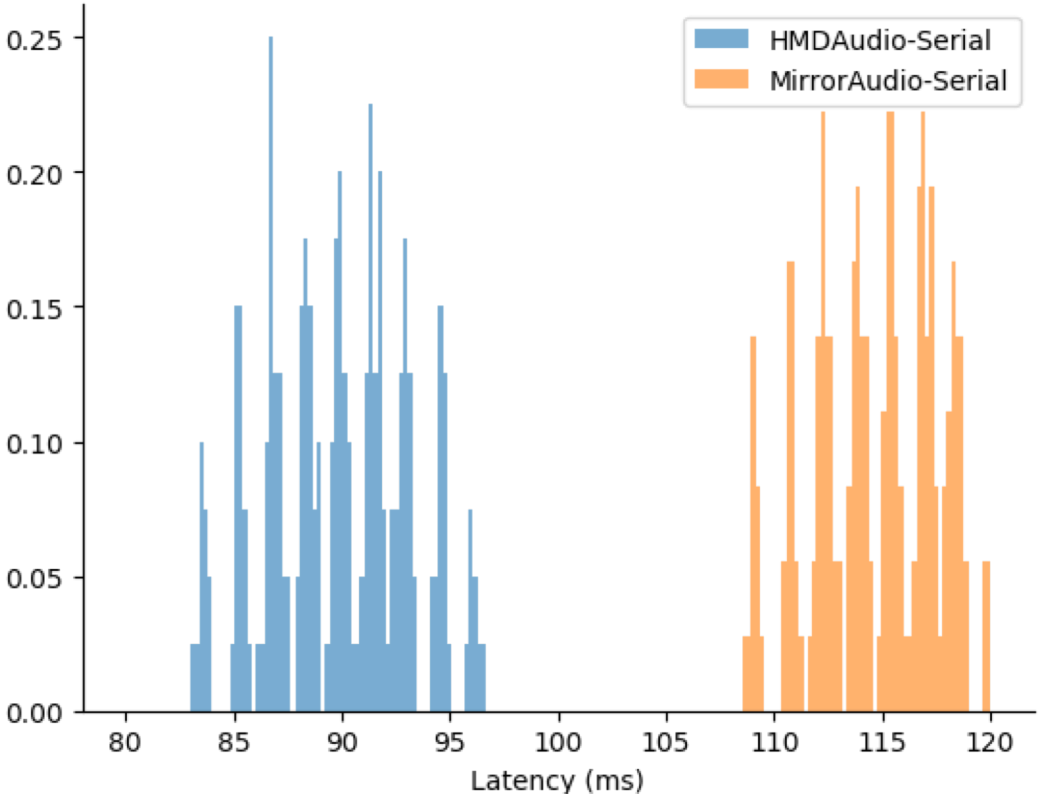

Serial Port
.nev
cbSdk
Comment
.nev
LSL
Markers
.xdf
Latency
Jitter


Time to Screen; N = 134
Markers
Serial
Comments
Count
120
100
80
60
40
20
0
−0.04
−0.03
−0.02
−0.01
0.00
Time (s)

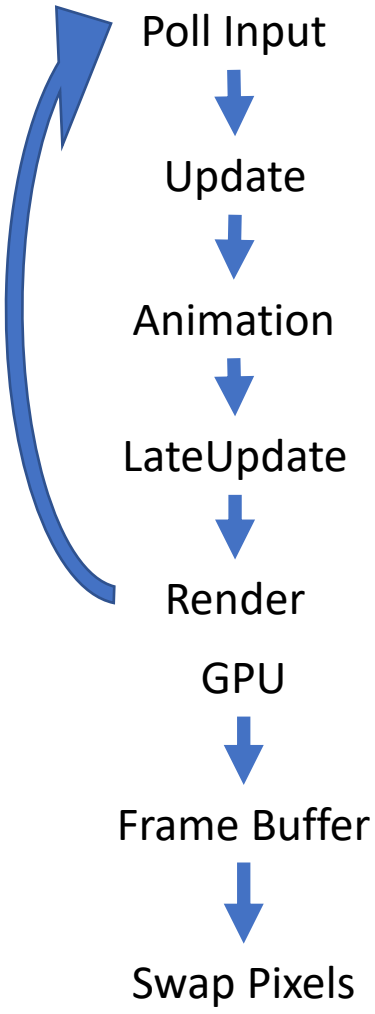

unity

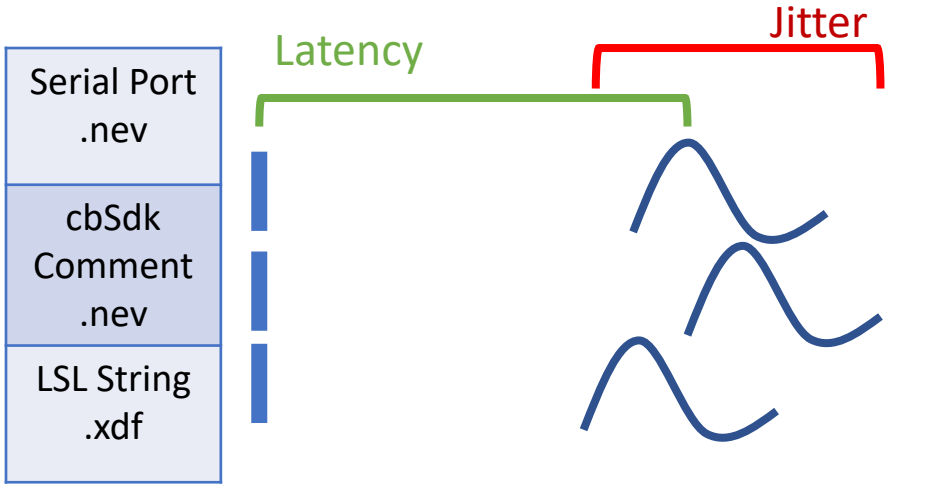

Poll Input
Update
Animation
LateUpdate
Render
GPU
Frame Buffer
Swap Pixels

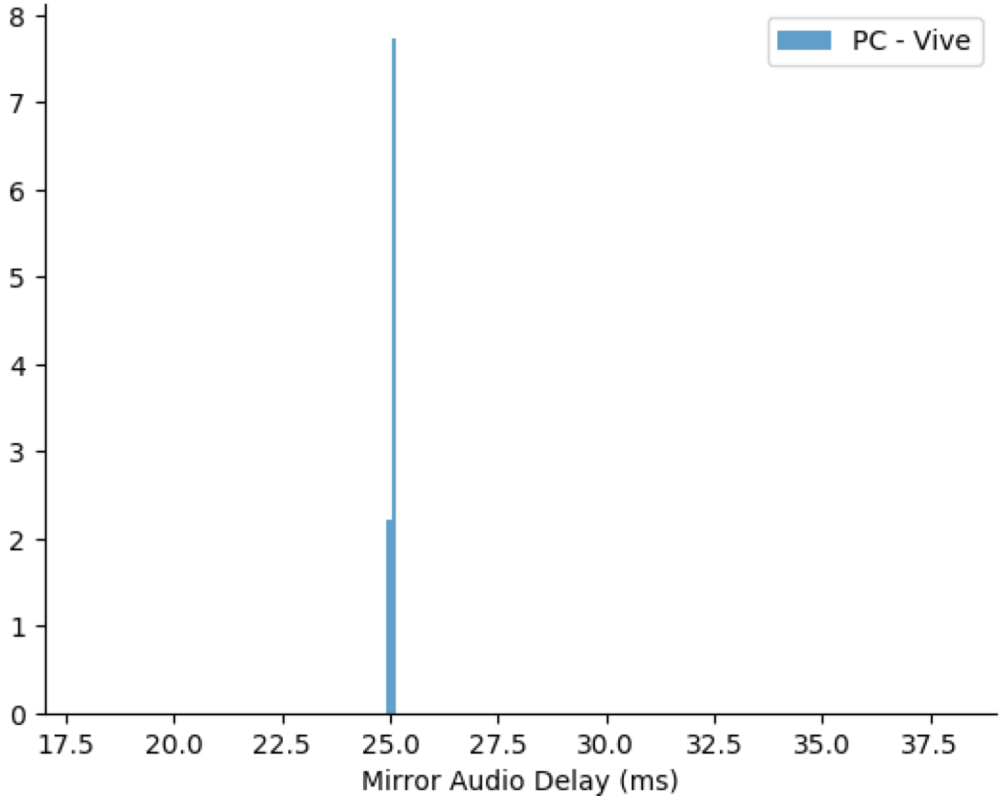

Serial Port
.nev
cbSdk
Comment
.nev
LSL String
.xdf
Latency
Jitter


HMDAudio-Serial
MirrorAudio-Serial
0.25
0.20
0.15
0.10
0.05
0.00
80
85
90
95
100
105
110
115
120
Latency (ms)


unity


Poll Input
Update
Animation
LateUpdate
Render
GPU
Frame Buffer
Swap Pixels


Serial Port
.nev
cbSdk
Comment
.nev
LSL String
.xdf
Latency
Jitter


PC - Vive
0
1
2
3
4
5
6
7
8
17.5
20.0
22.5
25.0
27.5
30.0
32.5
35.0
37.5
Mirror Audio Delay (ms)

Summary

- Use waitForEndOfFrame hooks to send triggers.
- LSL markers good enough for video onset.
  - But characterize total delay first!
- Audio events should be recorded (with mirror)
- Not shown: Audio latency can be made more consistent by having the engine continuously output audio.
  - But still bad.

Eye Tracker

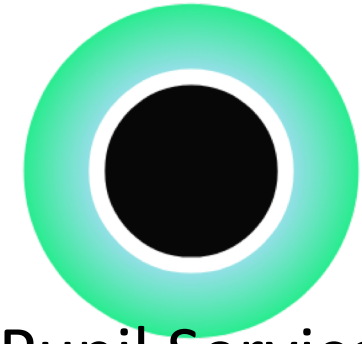

BLACKROCK MICROSYSTEMS
128-Channel Neural Signal Processor
ANALOG INPUTS
DIGITAL INPUTS
SERIAL I/O
DIGITAL OUTPUTS
SYNC
ANALOG OUTPUTS
AUDIO OUTPUTS
FIBER-OPTIC DATA LINK


BLACKROCK MICROSYSTEMS
Digital Hub 128
Source Status
Fiber-Optic Data Link
Power
ON
OFF


NETGEAR

unity

/pupil-labs/pupil



Pupil Service

Plugin Interface

LSL

Subscribe

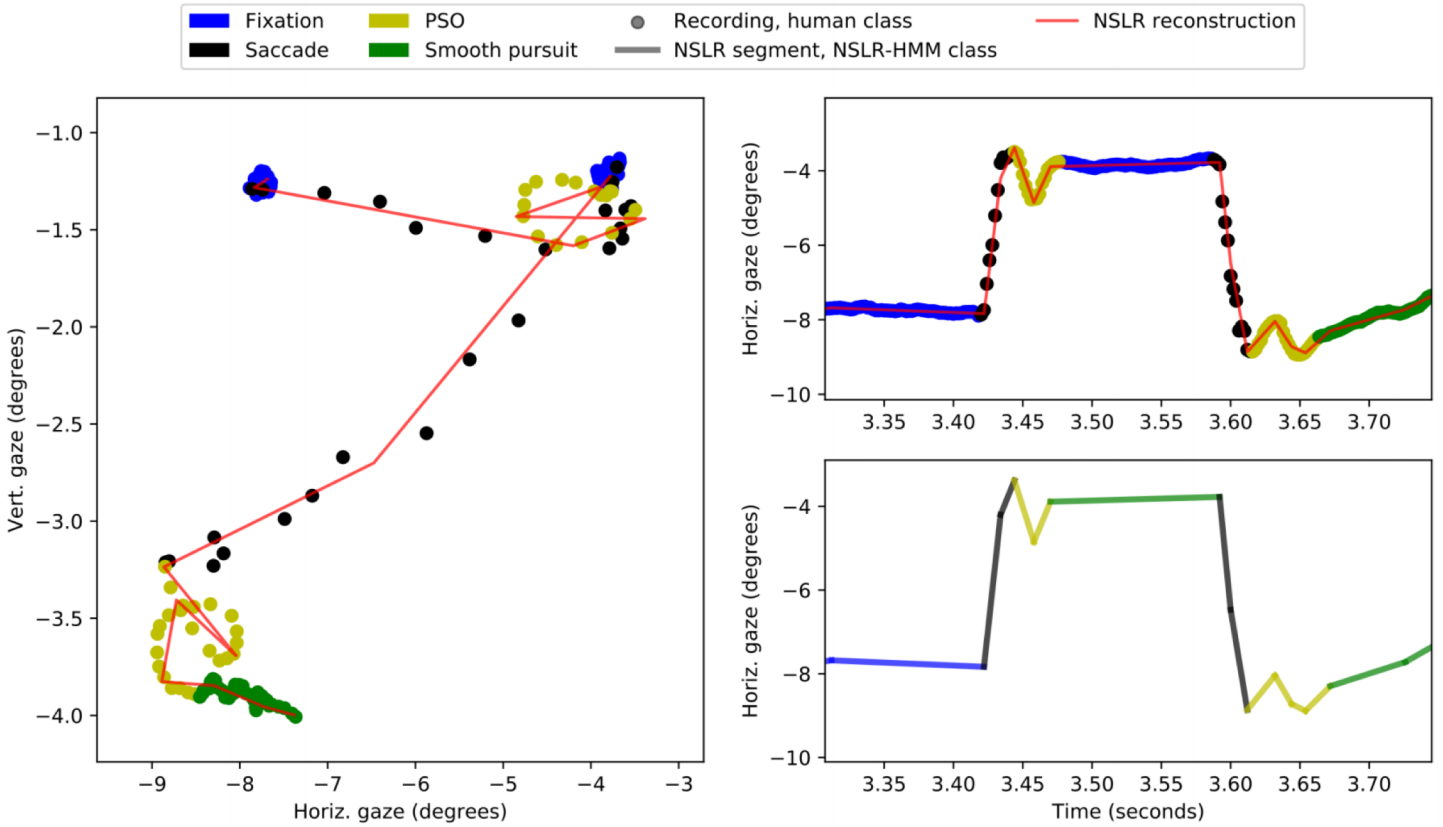
/pupil-labs/hmd-eyes

/labstreaminglayer/App-PupilLabs

1 Stream, 22 channels:
Confidence, gaze on screen, gaze in world, pupil diameter, etc.

- https://github.com/labstreaminglayer/App-SMIEyetracker
- https://github.com/labstreaminglayer/App-Tobii
- https://github.com/labstreaminglayer/App-TobiiPro

SachsLab/custom_neuropype/NSLRHMM.py



SCIENTIFIC REPORTS

OPEN

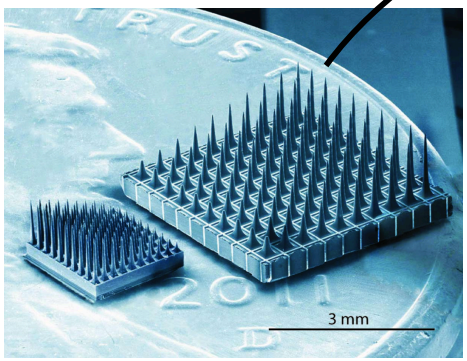
A new and general approach to signal denoising and eye movement classification based on segmented linear regression

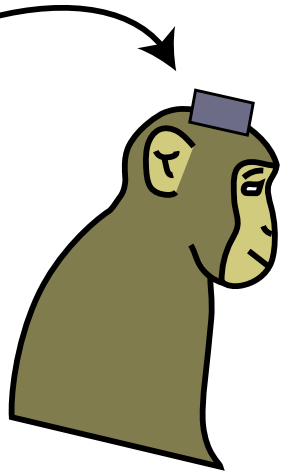
Received: 18 September 2017
Accepted: 4 December 2017
Published online: 18 December 2017

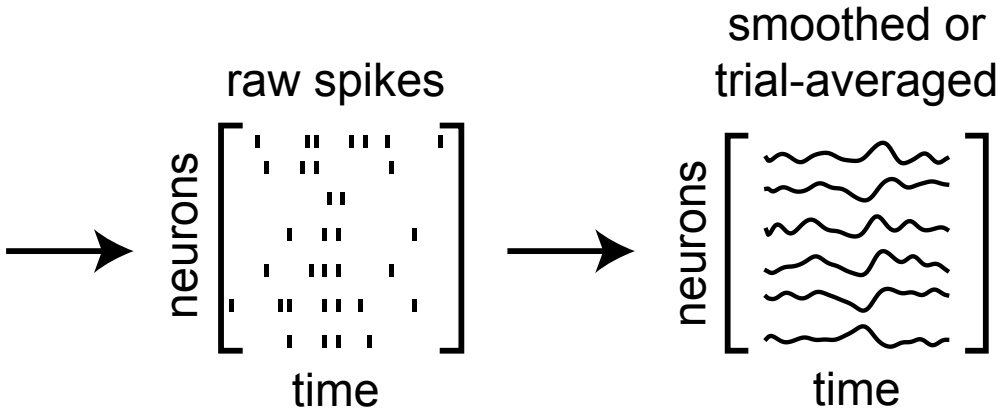
Jami Pekkanen & Otto Lappi

Streaming Intracranial Neurophysiology

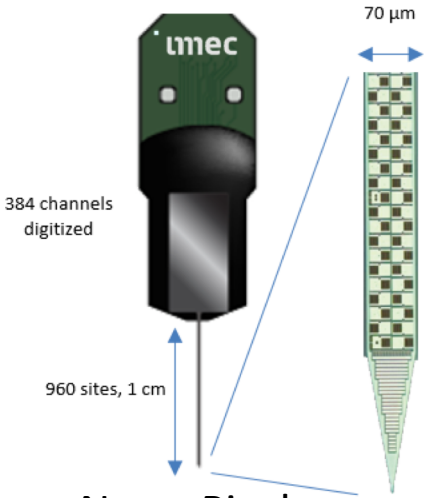
Neural data can be high dimensional



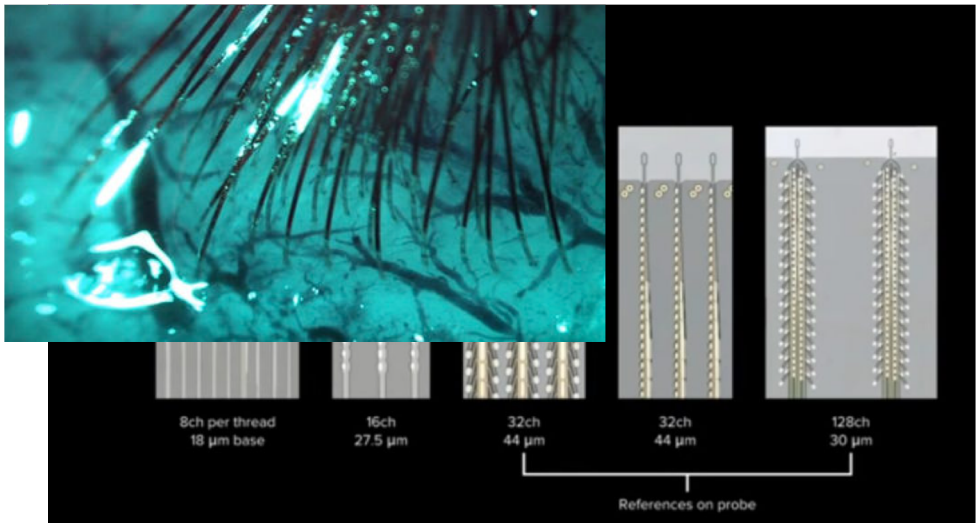




https://github.com/ahwillia. @ItsNeuronal

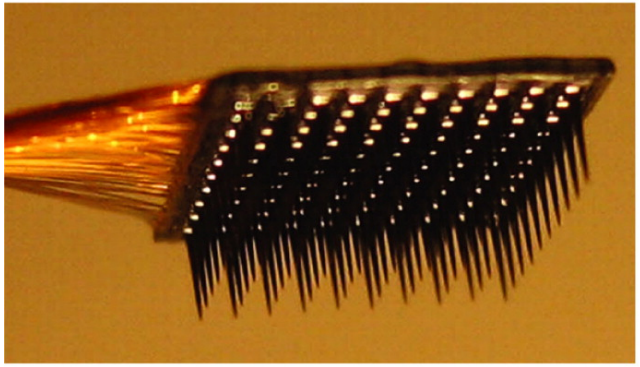


NeuroPixel

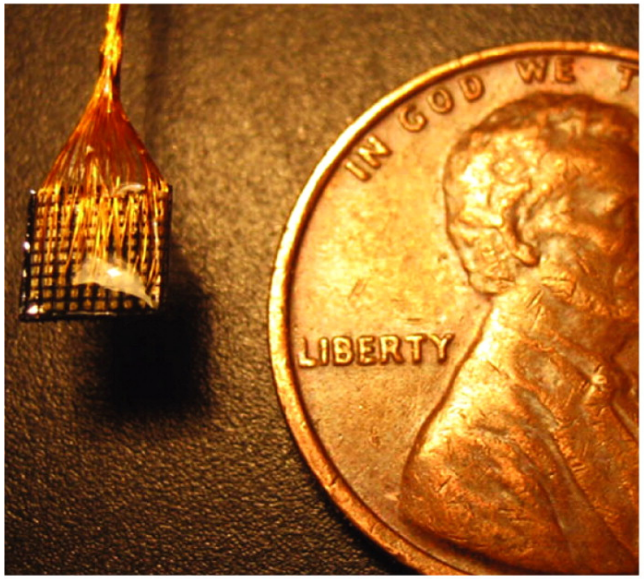


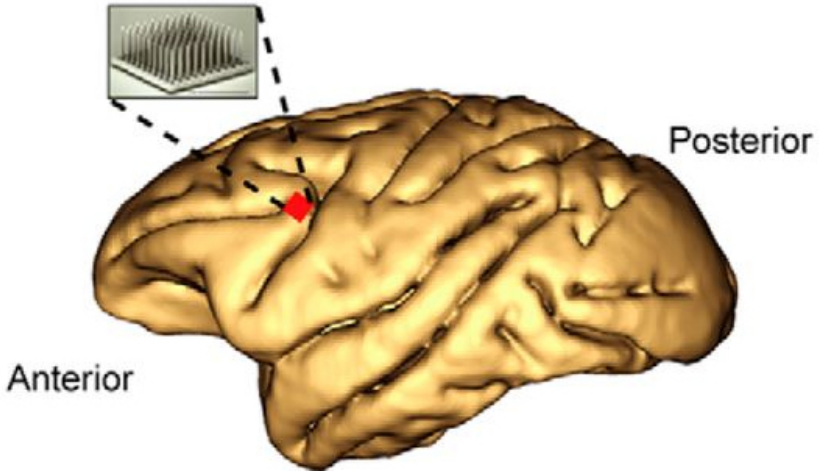
Neuralink

Neural data can be high dimensional



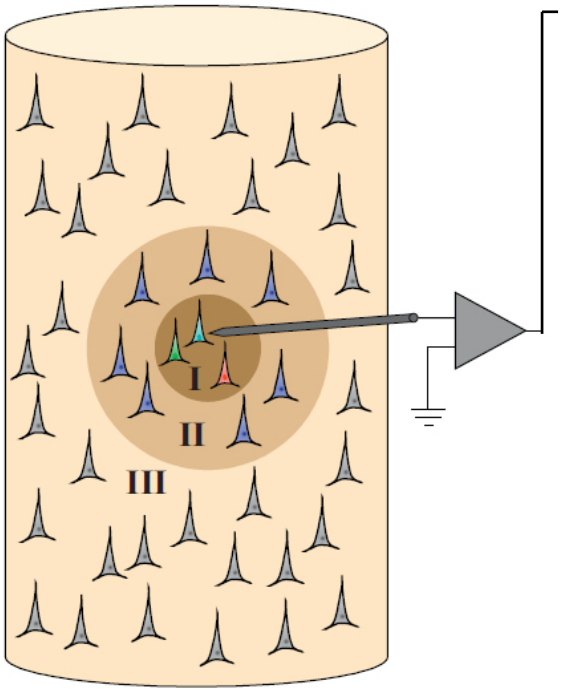
Recordings from a 96/128 channel Utah Arrays in the lateral prefrontal cortex and/or primary motor cortex.



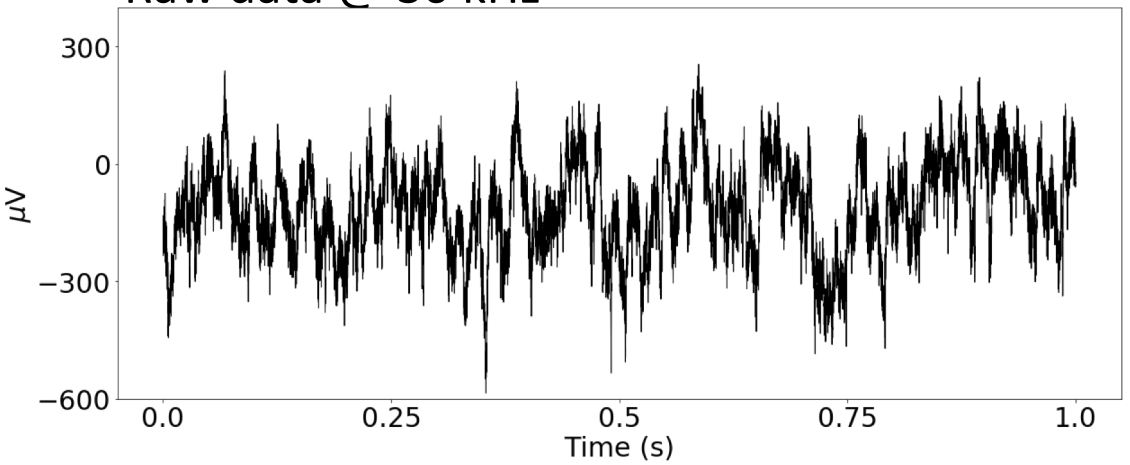


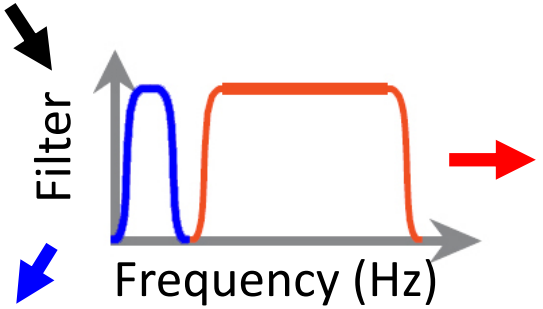
Invasive Source Considerations

- Huge amount of data
  - 256 channels * 30 kHz * 16 bits = 15.36 MB/s
  - Can your network handle it?
  - Can your data storage handle it?
- How to represent the different types of data?
  - LFP
  - Spike events
  - Waveforms

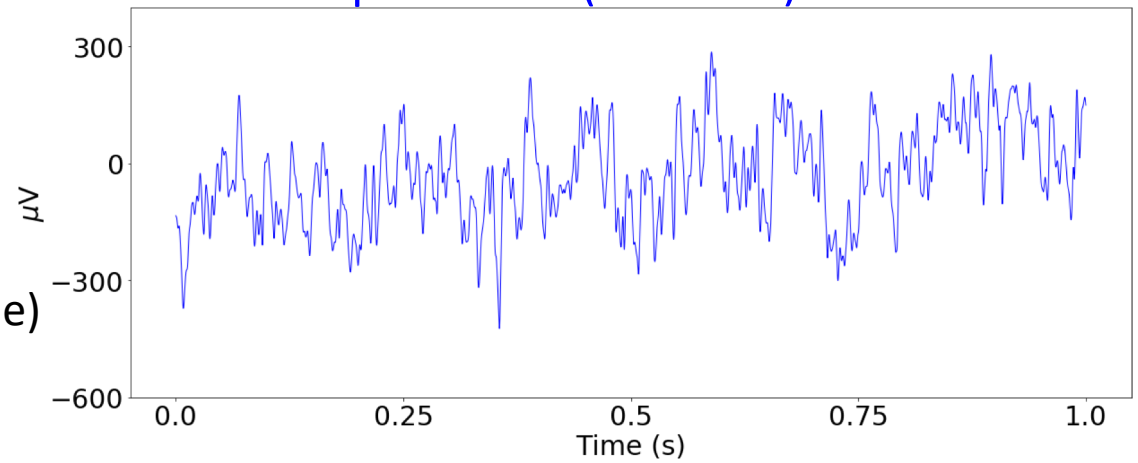


Raw data @ 30 kHz



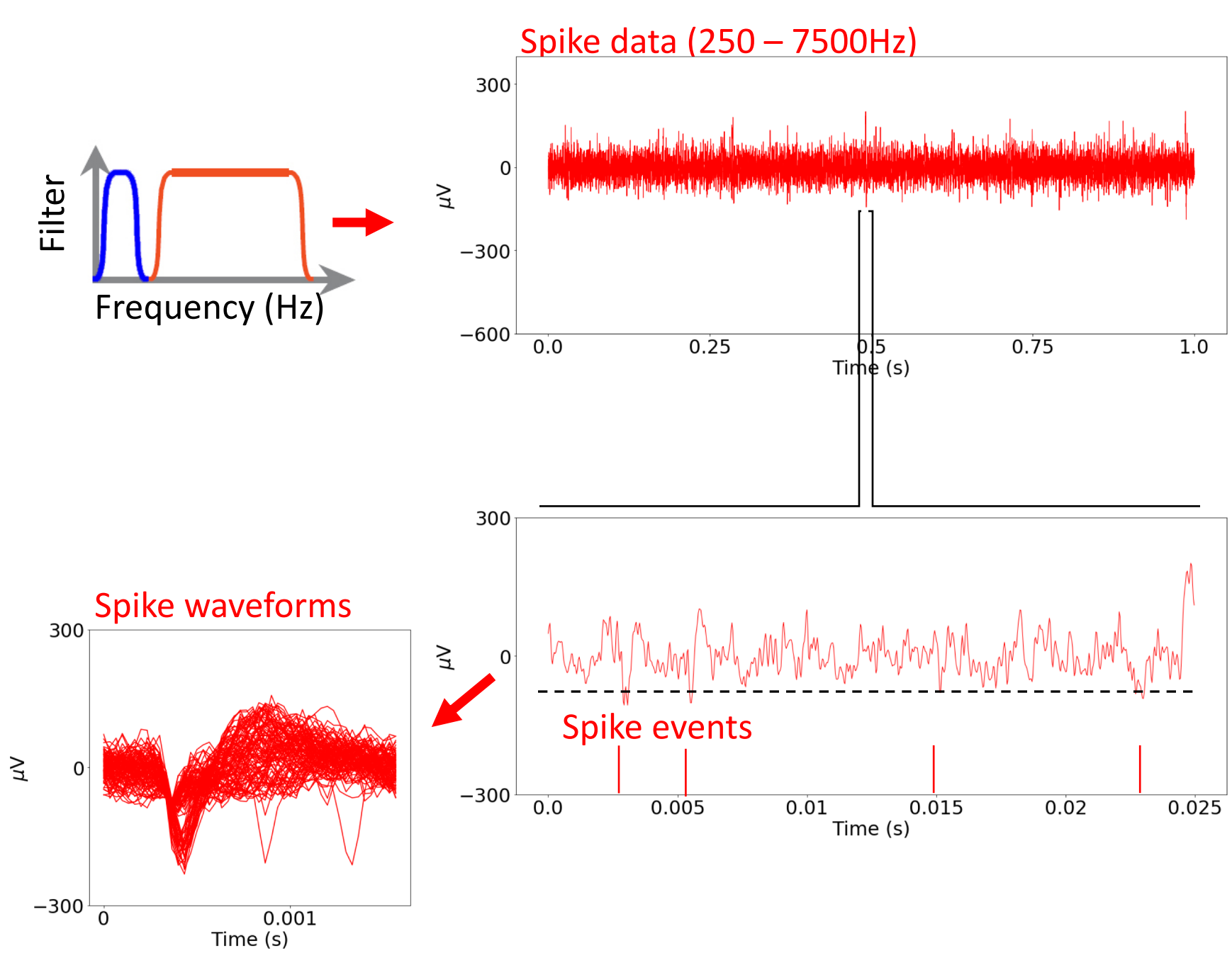


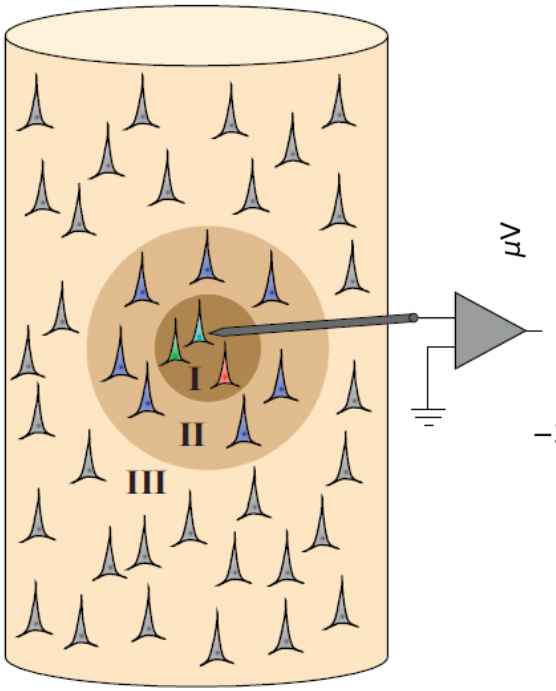
Local field potentials (≤ 250 Hz)



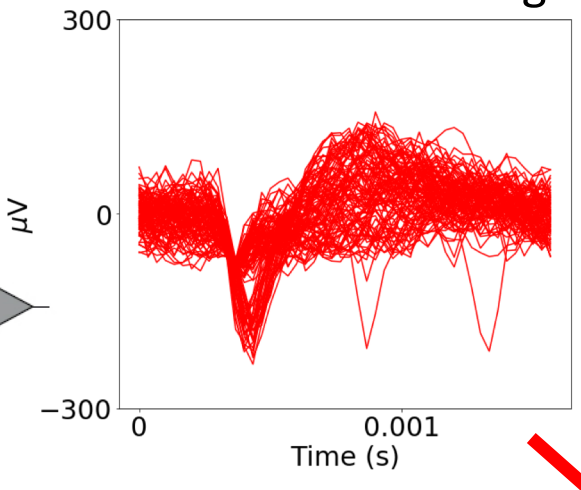
LFP Stream:

- 1 kHz
- N channels
  - (1 channel per electrode)

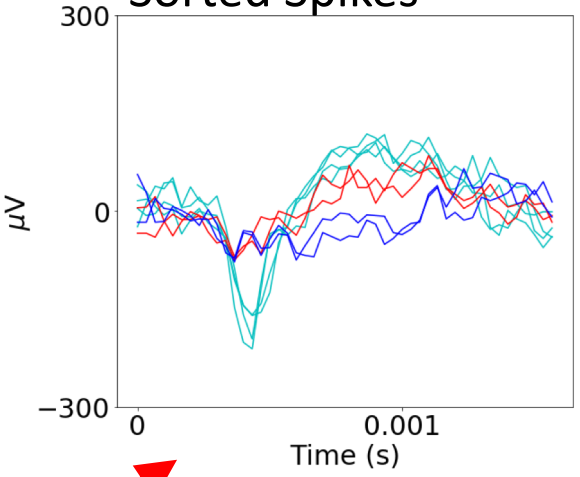

Spike data (250 – 7500Hz)
Filter
Frequency (Hz)
300
0
−300
−600
μV
0.0
0.25
0.5
0.75
1.0
Time (s)
Spike waveforms
300
0
−300
μV
0
0.001
Time (s)
Spike events
0.005
0.01
0.015
0.02
0.025



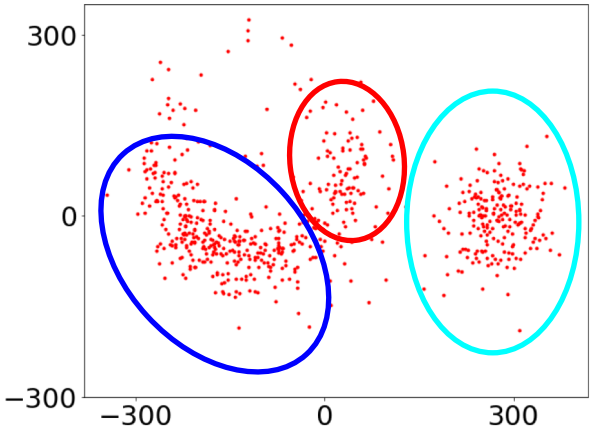
Threshold crossings

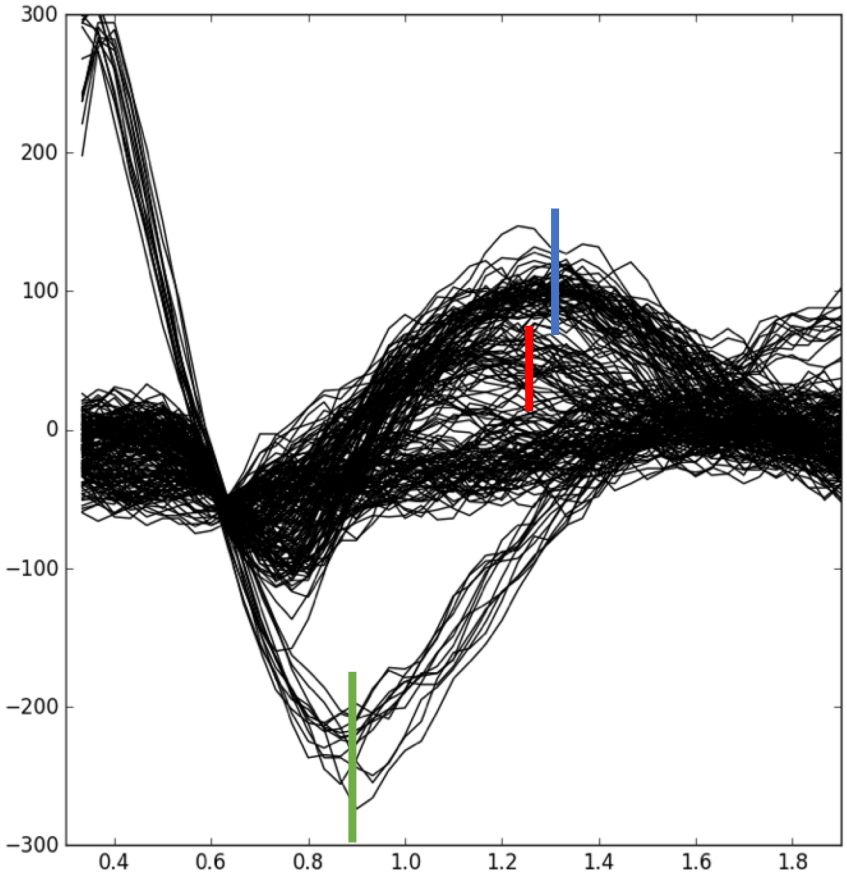


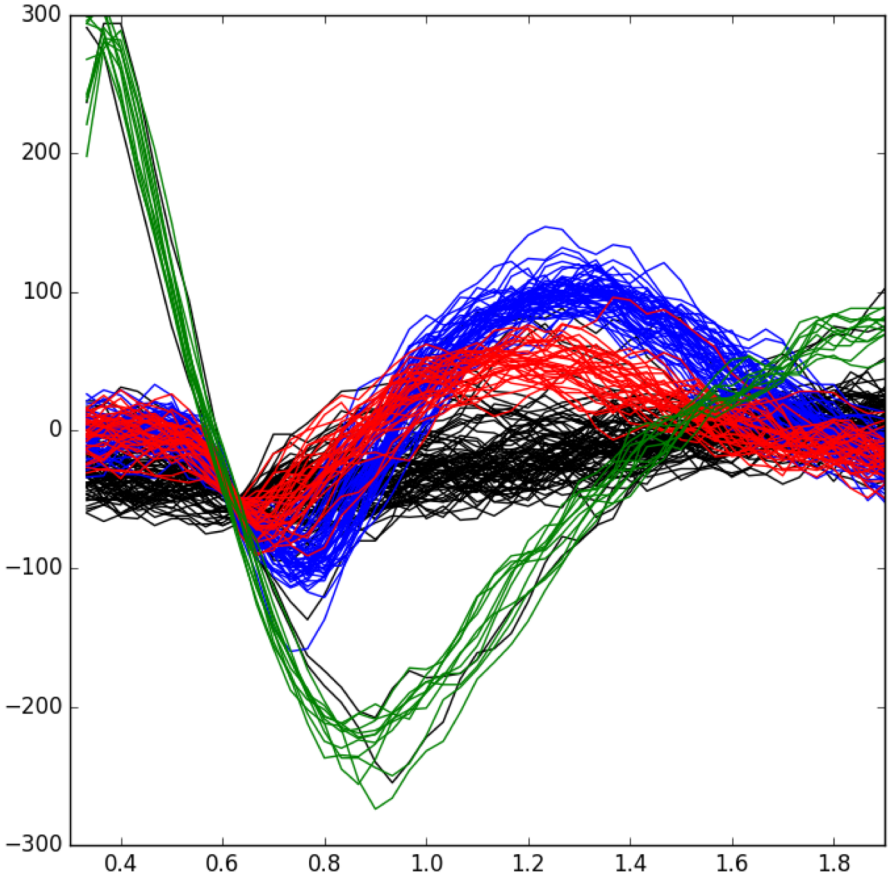
Sorted Spikes



Principal components



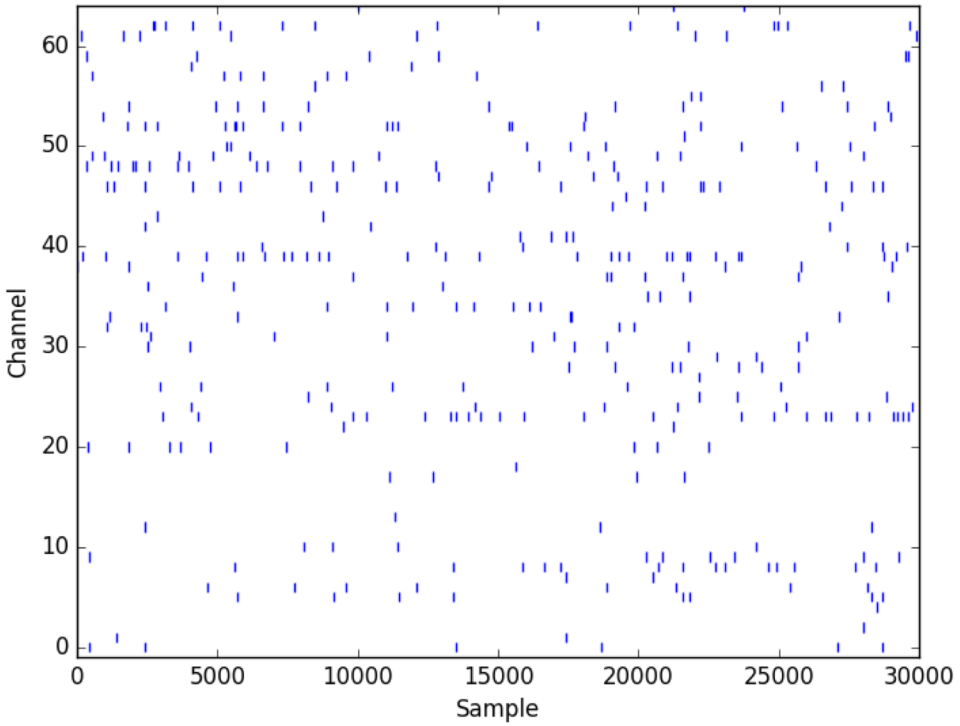




Waveform stream:

- Int16
- irregular rate → one sample per waveform
- 50 “channels” → electrode_id, waveform_id (1-5), 48 time points

Spike Events



$$\begin{bmatrix} 0 & 0 & 3 & 0 & 4 \\ 0 & 0 & 5 & 7 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 2 & 6 & 0 & 0 \end{bmatrix}$$

Sparse Matrix

Row	0	0	1	1	3	3
Column	2	4	2	3	1	2
Value	3	4	5	7	2	6

Channel

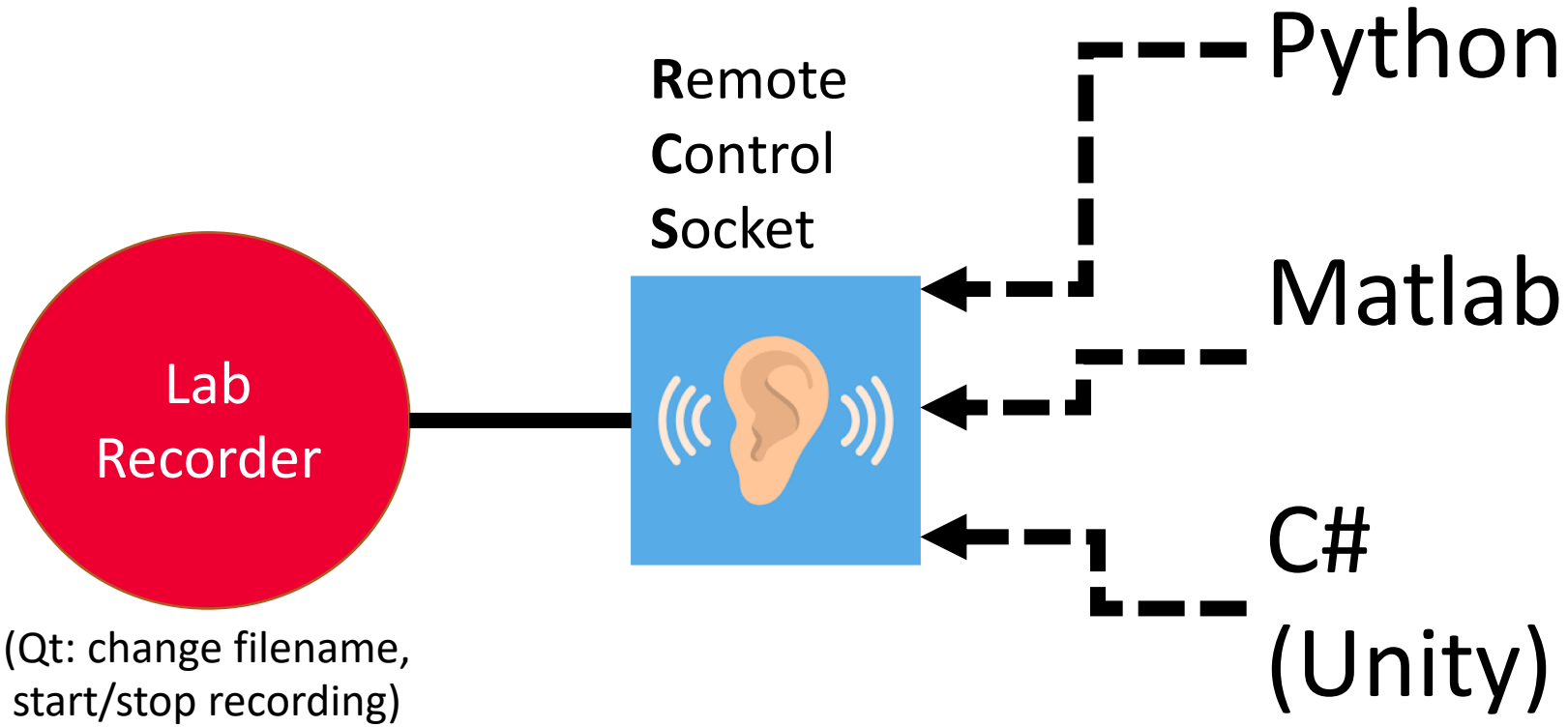
Samp. Ind.

2-channel Int32 stream (~40 hrs of unique samp. inds.)

Invasive Source Summary

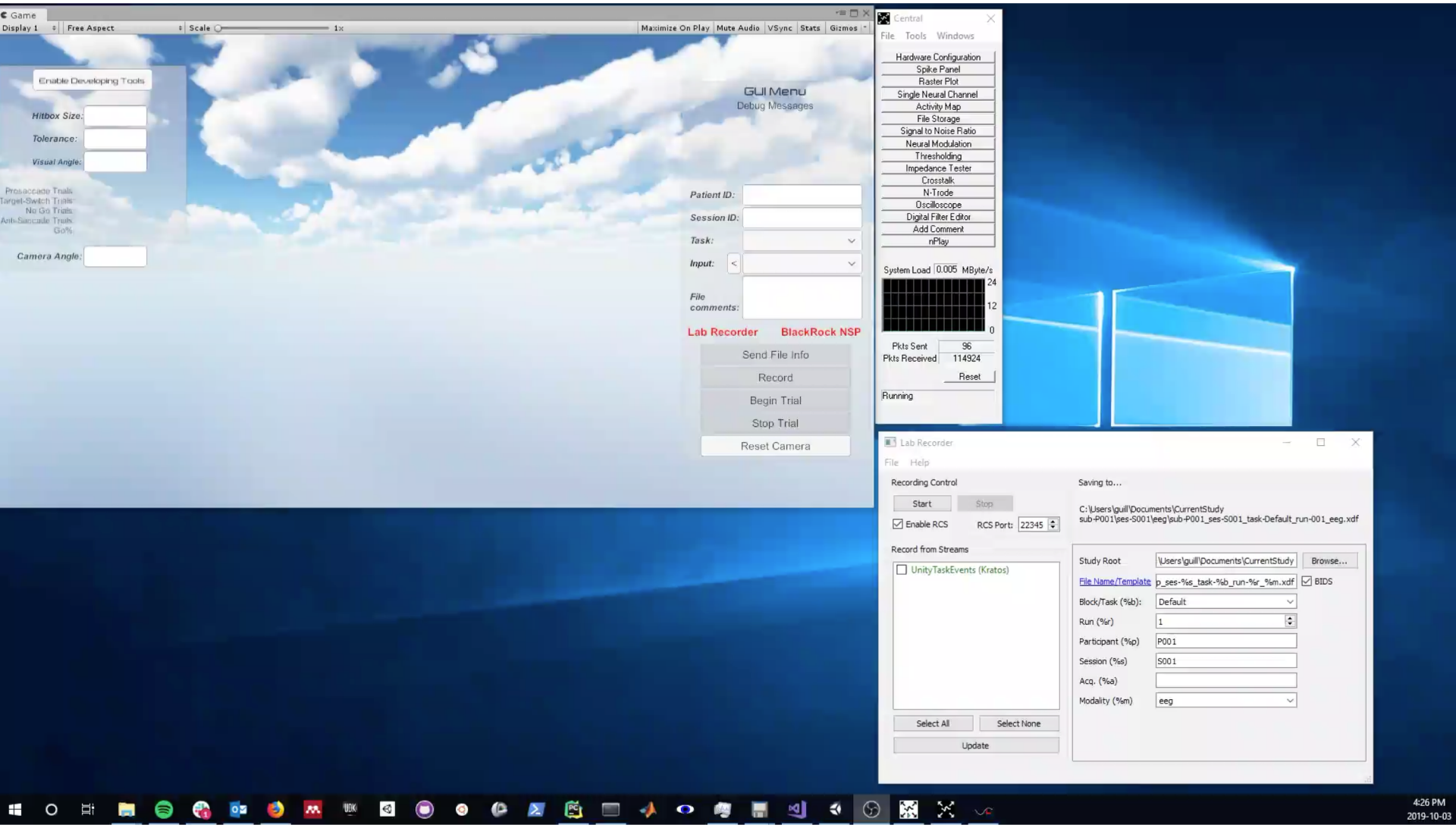
- Huge amount of data
  - 256 channels * 30 kHz * 16 bits = 15.36 MB/s
  - Can your network handle it?
  - Can your data storage handle it?
- Data are already accessible on the network
  - https://github.com/dashesy/CereLink
- https://github.com/labstreaminglayer/App-BlackrockTimestamps
  - Streams hardware sample number with LSL timestamps.

Remote Control LabRecorder



```
ipe = new IPEndPoint(IPAddress.Parse(LRInIP), LRInPort);
lrSocket = new Socket(ipe.AddressFamily, SocketType.Stream,
                      ProtocolType.Tcp);
lrSocket.Connect(ipe);
string msg = "start\n";
Byte[] bytesSend = Encoding.UTF8.GetBytes(msg);
lrSocket.Send(bytesSend);
```

Postdoctoral Fellow
Guillaume Doucet


Game
Display 1
Free Aspect
Scale
1x
Maximize On Play
Mute Audio
VSync
Stats
Gizmos
Enable Developing Tools
Hitbox Size:
Tolerance:
Visual Angle:
Prosaccade Trials:
Target-Switch Trials:
No Go Trials:
Anti-Saccade Trials:
Go%:
Camera Angle:
GUI Menu
Debug Messages
Patient ID:
Session ID:
Task:
Input:
File comments:
Lab Recorder
BlackRock NSP
Send File Info
Record
Begin Trial
Stop Trial
Reset Camera
Central
File
Tools
Windows
Hardware Configuration
Spike Panel
Raster Plot
Single Neural Channel
Activity Map
File Storage
Signal to Noise Ratio
Neural Modulation
Thresholding
Impedance Tester
Crosstalk
N-Trode
Oscilloscope
Digital Filter Editor
Add Comment
nPlay
System Load
0.005
MByte/s
24
12
0
Pkts Sent
96
Pkts Received
114924
Reset
Running
Lab Recorder
File
Help
Recording Control
Start
Stop
Enable RCS
RCS Port:
22345
Saving to...
C:\Users\guill\Documents\CurrentStudy
sub-P001\ses-S001\eeg\sub-P001_ses-S001_task-Default_run-001_eeg.xdf
Record from Streams
UnityTaskEvents (Kratos)
Select All
Select None
Update
Study Root
\Users\guill\Documents\CurrentStudy
Browse...
File Name/Template
p_ses-%s_task-%b_run-%r_%m.xdf
BIDS
Block/Task (%b):
Default
Run (%r)
1
Participant (%p)
P001
Session (%s)
S001
Acq. (%a)
Modality (%m)
eeg
4:26 PM
2019-10-03

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  - uOttawa Parkinson Research Consortium
  - uOttawa Brain and Mind Research Institute