cogniLink: A Non-Invasive Brain-Computer Interface That Enables Seamless Execution of Commands Through Thought Recognition

Project cogniLink

Abstract

Although great strides have been achieved in making computers more accessible, its indisputable that there remains huge prospects for improvement. Given that technology is designed for the masses, it offers every individual a platform to do what is needed; this includes, but isnt limited to, support for individuals with motor, dexterity, and/or speech impairments. In this proposal, we will discuss cogniLink, a tool that assists developers in making computers more accessible for persons with afflictions. cogniLink is a brain-computer interface that allows the user to trigger the execution of a command simply by thinking of the trigger. A training data set is to be collected from n-users in order to train n-models using an ElectroEncephaloGram (EEG). Each model is programmed to recognize one or more trigger thoughts. The same model interacts with a stack of software which allows it to map positive outputs from the model and transform it into an actionable command. For the purpose of demonstration, the model will be trained to recognize commands from one user which will be mapped to a virtualHID in such a way that allows the user to play Super Mario Bros. After an extensive process of training n-models, a universal model (UM) will be trained using data from the aforementioned n-models in order to have a simpler training process for new users. cogniLink will allow disabled people to execute commands in a very seamless and orderly fashion, thus making computers more accessible to persons with digital input impairments. Two of cogniLinks long term goals are to allow an amputee to be able to effortlessly be able to control a wheelchair in real time, and for someone suffering from Locked-In Syndrome to be able to interact with the world around them with ease.

1 Implementation

1.1 Tool Chain

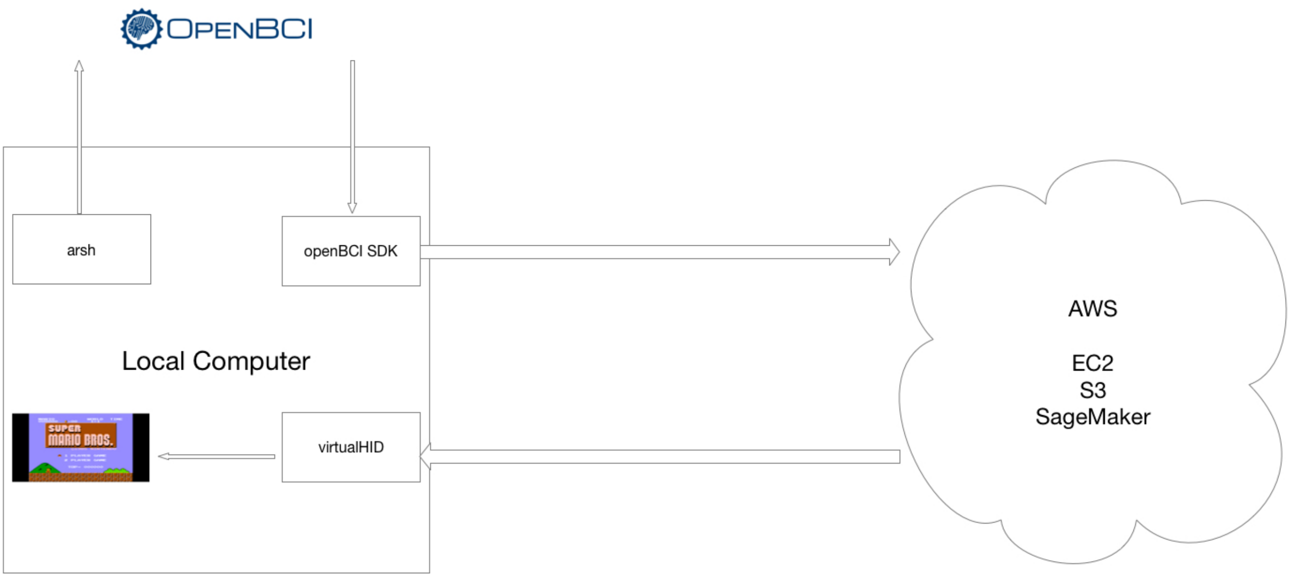

Figure 1: Tool Chain Diagram

Text about tool chain here Figure 1.

1.2 Project work plan

Work package description

Work package number	**WP1**		**Starting week**	1
Work package title	**Virtual HID, Data Collection, and ML Code**			
Participant number	**1**			
Short name	**georgio**			
Person-weeks	**2**			

Objectives

This work package has the following objectives:

1. To develop a Virtual Human Interface Device;
2. To develop an API that gathers raw data from the Cyton board and feeds it to a CSV file;

3. To write code needed to efficiently store and manage datasets;
4. To write code needed to start training Model 1 on Command A.

Description of work

Task T1.1: Task1 (W1-W1)
The virtualHID will be created using macOS' IOKit Library.

Task T1.2: Task2 (W1-W1)
The Cyton board will be programmed using arsh.

Task T1.3: Task3 (W1-W1)
API to gather data from Cyton Board will be built

Task T1.4: Task4 (W1-W2)
Code to manage raw EEG data will be done here.

Task T1.5: Task5 (W2-W2)
EC2, S3, and SageMaker instances will be configured.

Task T1.6: Task6 (W2-W2)
Code to feed raw data to S3 bucket will be done here.

Task T1.7: Task7 (W2-W2)
Code to start training the model will be done here.

Deliverables

D1.1 WP1 W1 Progress Report. **(W1)**

D1.2 Demonstration of APIs **(W2)**

D1.3 WP1 Code+Tools Merged to master. **(W2)**

D1.4 Main Report with full progress accomplished after the end of WP3. **(W2)**

Work package number	**WP2**	**Starting week**	2
Work package title	**Model 1 Command A**		
Participant number	**1**		
Short name	**georgio**		
Person-weeks	**4**		

Objectives

1. To collect training, validation, and test datasets for Model 1 Command A;
2. Training Model 1 using aforementioned data;
3. Testing/Patching Model 1.

Description of work

Task T2.1: Task1 (W2-W3)
Ways to efficiently collect data with high accuracy will be looked into; validated datasets will be used (if found) as a point of reference.

Task T2.2: Task2 (W3-W4)
The training dataset will be collected.

Task T2.3: Task 3 (W4-W5)
Model 1 will be trained using the aforementioned dataset.

Task T2.4: Task 4 (W4-W5)
Test and Validation datasets will be collected.

Task T2.5: Task 5 (W4-W5)
Test and Validation datasets will be collected.

Task T2.6: Task 6 (W4-W5)
All collected datasets will be uploaded to an AWS S3 Bucket.

Task T2.7: Task 7 (W4-W5)
Accuracy of trained model will be studied.

Task T2.8: Task 8 (W5-W6)
Patches and optimizations will be pushed in attempt to improve model accuracy, if possible.

Deliverables

D2.1 Report 1 about the data collection process and initiation of the first round of training. **(W4)**

D2.2 First iteration of the model. **(W5)**

D2.3 Report 2 about model accuracy after inputing initial test and validation datasets. **(W5)**

D2.4 (W6) Report 3 will include a comparative view of accuracy for each patch/iteration of the model.

D2.5 Second iteration of the model. **(W6)**

D2.6 Main Report update with full progress accomplished after the end of WP2. **(W6)**

D2.7 Video demonstration of thought recognition process. **(W6)**

Work package number	WP3		Starting week	6
Work package title	Model 1 n Commands			
Participant number	1			
Short name	georgio			
Person-weeks	6			

Objectives

This work package has the following objectives:

1. Link the output from the Model to the virtual HID created in WP1;
2. Map trigger thoughts to button presses;
3. Play a game of 1P Super Mario Bros.

Description of work

Task T3.1: Task1 (W6-W12)
Code for linking model to virtual HID will be rechecked and finalized.

Task T3.2: Task2 (W6-W12)
Model 1 will be trained for command B, and other commands simultaneously.

Task T3.3: Task3 (W12-W12)
A game of 1P Super Mario Bros will be played.

Deliverables

D3.1 A demonstration of the execution of alternating commands, after successful training of the second command to model 1. **(W8)**

D3.2 Report 1 on findings made while training new commands. **(W11)**

D3.3 Report 2 will comapre the variation of latency between the model and the virtual HID for each code patch. **(W12)**

D3.4 Code for virtual HID and updated Model 1 with multiple command recognition will be pushed to master. **(W12)**

D3.5 A demonstration of the ability to play a game of 1P Super Mario Bros using cogniLink. **(W12)**

D3.6 Main Report update with full progress accomplished after the end of WP3. **(W12)**

Work package number	WP4		Starting week	12
Work package title	Model 2 n Commands			
Participant number	1			
Short name	georgio			
Person-weeks	6			

Objectives

This work package has the following objectives:

1. Replicate all steps in WP2 and WP3 so that we get a Model 2 for a different individual trained on n the same n Commands as Model 1;
2. Play a game of 2P Super Mario Bros.

Description of work

Task T4.1: Task1 (W12-W18)
A new Model 2 will be created, repeting the steps from previous WPs, in such a way that it is trained using data gathered from a different individual for the same n-Commands.

Task T4.2: Task2 (W12-W13)
The ability to switch between models will be added to the virtual HID code, for testing purposes.

Task T4.3: Task3 (W18-W18)
Models 1 and 2 will be published.

Task T4.4: Task4 (W18-W18)
A game of 2P Super Mario Bros will be played.

Deliverables

D4.1 Merging model switching code to master. **(W13)**

D4.2 Report on the ability to use 2 models simultaneously as 2 virtual HID devices. **(W13)**

D4.3 Report on Model 2 Command 8. **(W15)**

D4.4 Report on training Model 2 for n-Commands. **(W18)**

D4.5 Merging code of Models 1 and 2 to master. **(W13)**

D4.6 A demonstration of the ability to play a game of 2P Super Mario Bros using cogniLink. **(W18)**

D4.7 Main Report update with full progress accomplished after the end of WP4. **(W18)**

Work package number	WP5		Starting week	18
Work package title	**Optimizations**			
Participant number	**1**			
Short name	**georgio**			
Person-weeks	**2**			

Objectives

This work package has the following objectives:

1. Optimizing the code in such a way that a trigger thought is recognized in realtime.

Description of work

Task T5.1: Task1 (W18-W20)
Code optimization with the main goal of reducing latency.

Deliverables

D5.1 Optimized code will be merged to master. **(W20)**

D5.2 Main Report update with full progress accomplished after the end of WP5, emphasizing on measures taken for optimizing code. **(W20)**

Work package number	**WP6**	**Starting week**	20
Work package title	**Real Life Application**		
Participant number	**1**		
Short name	**georgio**		
Person-weeks	**10**		

Objectives

This work package has the following objectives:

1. Implement cogniLink to work on a controller of a wheelchair, this task derives from cogniLink as a forked project;

2. Initiate research about Locked-in syndrome: Find suitiable use-cases and patients.

Description of work

Task T6.1: Task1 (W20-W22)
First Fork of cogniLink. A wheelchair controller/helper that can be fed command data as a replacement to the virtual HID will be designed and implemented.

Task T6.2: Task2 (W20-W30)
Initiation of formal research about Locked-in syndrome, patients, and practical use-case scenarios.

Deliverables

D6.1 Report about integration with wheelchair. **(W22)**

D6.2 Forking cogniLink and merging changes needed for wheelchair integration. **(W30)**

D6.3 Report about research findings and future steps towards integrating with a locked in patient. **(W30)**

D6.4 Main Main Report update with full progress accomplished after the end of WP6. **(W30)**

Work package number	**WP7**	**Starting week**	30
Work package title	**Universal Model, n Commands**		
Participant number	**1**		
Short name	**georgio**		
Person-weeks	**10**		

Objectives

This work package has the following objectives:

1. Integrating cogniLink with a Locked-in syndrome patient, in such a way for them to be able to mentally execute a command;
2. Designing, implementing, and training a universal model (UM).

Description of work

Task T7.1: Task1 (W30-W40)
Second fork of cogniLink: Training a new model with a Locked-in patient.

Task T7.2: Task2 (W30-W40)
Training UM using multiple models trained on multiple commands.

Task T7.3: Task3 (W30-W40)
Code optimization.

Deliverables

D7.1 Final Main Report update on Universal Model, Locked-in patient progress, and future plans for cogniLink. **(W40)**

D7.2 Publishing Universal Model. **(W40)**

D7.3 Publishing model trained on Locked-in patient. **(W40)**

D7.4 Merging optimized code to master. **(W40)**

List of work packages

Table 1.2b: List of work packages

Work package number	Work package title	Lead participant no.	Lead participant name	Person-weeks	Start week	End week
WP1	Virtual HID, Data Collection, and ML Code	1	georgio	2	1	2
WP2	Model 1 Command A	1	georgio	4	2	6
WP3	Model 1 n Commands	1	georgio	6	6	12
WP4	Model 2 n Commands	1	georgio	6	12	18
WP5	Optimizations	1	georgio	2	18	20
WP6	Real Life Application	1	georgio	10	20	30
WP7	Universal Model, n Commands	1	georgio	10	30	40
	TOTAL			40		

List of deliverables

[1]

Table 1.2c: Deliverable list

Deliverable number	Deliverable name	WP no.	Lead participant name	Nature	Dissemination Level	Delivery date (proj. week)
D1.1	WP1 W1 Progress Report.	WP1	georgio	R	PU	1
D1.2	Demonstration of APIs	WP1	georgio	D	PU	2
D1.3	WP1 Code+Tools Merged to master.	WP1	georgio	P	PU	2
D1.4	Main Report with full progress accomplished after the end of WP3.	WP1	georgio	R	PU	2
D2.1	Report 1 about the data collection process and initiation of the first round of training.	WP2	georgio	R	PU	4
D2.2	First iteration of the model.	WP2	georgio	P	PU	5
D2.3	Report 2 about model accuracy after inputing initial test and validation datasets.	WP2	georgio	R	PU	5
D2.4	Report 3 will include a comparative view of accuracy for each patch/iteration of the model.	WP2	georgio	R	PU	6
D2.5	Second iteration of the model.	WP2	georgio	P	PU	6
D2.6	Main Report update with full progress accomplished after the end of WP2.	WP2	georgio	R	PU	6
D2.7	Video demonstration of thought recognition process.	WP2	georgio	D	PU	6

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[1] If your action taking part in the Pilot on Open Research Data, you must include a data management plan as a distinct deliverable within the first 6 weeks of the project. This deliverable will evolve during the lifetime of the project in order to present the status of the project's reflections on data management. A template for such a plan is available on the Participant Portal (Guide on Data Management).

D3.1	A demonstration of the execution of alternating commands, after successful training of the second command to model 1.	WP3	georgio	D	PU	8
D3.2	Report 1 on findings made while training new commands.	WP3	georgio	R	PU	11
D3.3	Report 2 will comapre the variation of latency between the model and the virtual HID for each code patch.	WP3	georgio	R	PU	12
D3.4	Code for virtual HID and updated Model 1 with multiple command recognition will be pushed to master.	WP3	georgio	P	PU	12
D3.5	A demonstration of the ability to play a game of 1P Super Mario Bros using cogniLink.	WP3	georgio	D	PU	12
D3.6	Main Report update with full progress accomplished after the end of WP3.	WP3	georgio	R	PU	12
D4.1	Merging model switching code to master.	WP4	georgio	P	PU	13
D4.2	Report on the ability to use 2 models simultaneously as 2 virtual HID devices.	WP4	georgio	R	PU	13
D4.5	Merging code of Models 1 and 2 to master.	WP4	georgio	P	PU	13
D4.3	Report on Model 2 Command 8.	WP4	georgio	R	PU	15
D4.4	Report on training Model 2 for n-Commands.	WP4	georgio	R	PU	18
D4.6	A demonstration of the ability to play a game of 2P Super Mario Bros using cogniLink.	WP4	georgio	D	PU	18
D4.7	Main Report update with full progress accomplished after the end of WP4.	WP4	georgio	R	PU	18
D5.1	Optimized code will be merged to master.	WP5	georgio	P	PU	20
D5.2	Main Report update with full progress accomplished after the end of WP5, emphasizing on measures taken for optimizing code.	WP5	georgio	R	PU	20
D6.1	Report about integration with wheelchair.	WP6	georgio	R	PU	22
D6.2	Forking cogniLink and merging changes needed for wheelchair integration.	WP6	georgio	P	PU	30
D6.3	Report about research findings and future steps towards integrating with a locked in patient.	WP6	georgio	R	PU	30
D6.4	Main Main Report update with full progress accomplished after the end of WP6.	WP6	georgio	R	PU	30
D7.1	Final Main Report update on Universal Model, Locked-in patient progress, and future plans for cogniLink.	WP7	georgio	R	PU	40
D7.2	Publishing Universal Model.	WP7	georgio	P	CO	40
D7.3	Publishing model trained on Locked-in patient.	WP7	georgio	P	CO	40
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D7.4	Merging optimized code to master.	WP7	georgio	P	PU	40

1.3 Management and risk assessment

List of milestones

Table 1.3a: List of milestones

Milestone number	Milestone name	Related WPs	Estimated date	Means of verification
M1	Completed Development of Model 1 for Command A	WP 2	End of WP2 (add week number)	Execution of command using trigger thought
M2	Completed Development of Model 1 for Commands A and B	WP 3	mid WP3 (add week number)	Execution of alternating commands using trigger thoughts
M3	Completed Development of Model 1 for n-Commnands	WP 3	End WP3 (add week number)	Playing a game of 1P Super Mario Bros
M4	Completed Development of Model 2 for n-Commnands	WP 4	End WP4 (add week number)	Playing a game of 2P Super Mario Bros
M5	Transitioning from using virtual-HID on OpenEmu to Wheelchair in Realtime	WP 6	mid WP7 (add week number)	Driving a wheelchair with no hands
M6	Integration with Locked-In Patient	WP 6	End of WP7 (add week number)	Enabling a Locked-in patient to communicate using cogniLink
M7	Training Universal Model for n-Commands	WP 7	End of WP8 (add week number)	Ease of training models for new users

Critical risks for implementation

Table 1.3b: Critical risks for implementation

Description of Risk	WPs involved	Proposed risk-mitigation measures
The dedicated chip sent to fabrication is not functional.	WP **??**	Resort to Software simulations

Table 1.5a: Summary of staff effort

Partic. no.	Partic. short name	WP1	WP2	WP3	WP4	WP5	WP6	WP7	Total person weeks
1	georgio	**2**	**4**	**6**	**6**	**2**	**10**	**10**	40
Total		2	4	6	6	2	10	10	40

1.4 Consortium as a whole

1.5 Resources to be committed

Summary of staff efforts

Other direct cost items (travel, equipment, other goods and services, large research infrastructure)

Participant no. 1 (georgio)	Cost (EUR)	Justification
Travel	2500	3 pairwise meetings for 2 people, 2 conferences for 3 people, 3 internal project meetings for 3 people
Equipment	3000	CAD workstation for chip design
Other goods and services	60000	Fabrication of 2 VLSI chips
Total	65500	

Participant no. 1 (georgio)	Cost (EUR)	Justification
Large research infrastructure	400000	Synchrotron