

RESEARCH TRENDS - 2024

Internet of Things meets Brain-Computer Interface

Or how to understand these *complicated* notions more easily —————

Internet of Things, Brain-computer Interface?



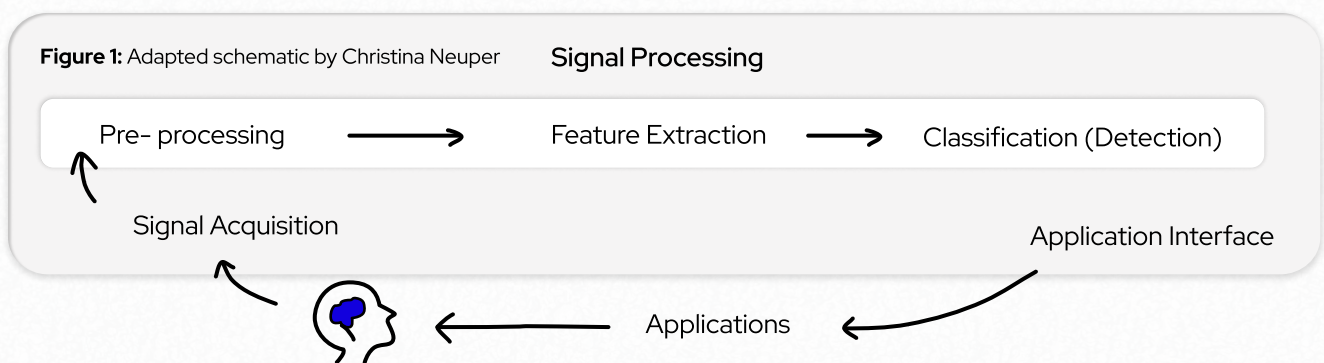
What is BCI?

A Brain-Computer Interface (BCI) enables user intentions to be registered, featured, classified and translated into machine commands for communication with a device and services around or in the Internet. [6]

BCI works through the acquisition of brain signals and analyzes and translates them into commands that are relayed to actuation devices for carrying out desired actions, as seen in figure 1.

BCI can empower individuals to directly control objects such as smart home appliances or assistive robots directly via their thoughts.

BCI is built on the foundation of IoT and IoE.



What about IoT?

IoT (Internet of Things) paradigm emphasizes M2M (Machine to Machine) communication. IoT consists of smart devices collecting data, relaying the information to each other, and processing the information collaboratively using cloud computing and similar technologies. Finally, either humans will be prompted to take action, or the machines themselves will act automatically.

Simplified: IoT = Network + Things

According to Cisco, in 2009, the number of objects on the internet exceeded humans. Today more things than humans are connected to the internet. In the near future, the number of connected devices will be tens or hundreds of times larger than the number of connected people. Today, the number hovers between 3.6 - 15 devices per person, with North America leading the numbers.

Turning the sea of data into useful contexts and wisdom is extremely critical. So this brings us to IoE - This paradigm shift creates numerous challenges and opportunities for engineering. **IoE** - is a concept that emphasizes people-to-machine (P2M) and people-to-people (P2P) connections via the Internet. As of 2023, this was considered a novel term, and an extended version of IoT.

Simplified: IoT = Network + Things + People + Data + Process

Now that it is clearer...

What does BCI x IoT rely upon?

The trend appears on different media: neuro & tech blog, companies' trials and mainly in research papers. We highlighted 4 research and 1 trial concretely explaining the combined use of BCI and IoT.

1. _____

Internet of Things Meets Brain-Computer Interface: A Unified Deep Learning Framework for Enabling Human-Thing Cognitive Interactivity [1]

🔍 Integration of BCI with IoT to enable cognitive interactivity, focusing on EEG signals.

➡ **novel deep learning framework** outperforming several SOTA methods

➡ successful two cases studies: a **brain typing system** and a **cognitive robot**

2. _____

BCI Control in a Virtual Reality Environment and Applications for the Internet of Things [2]

🔍 Integration of BCI tech to control home devices, with Unity.

➡ combination of **BCI, Unity (VR), and IoT devices** opens up lots of possibilities

3. _____

Designing Functional Prototypes Combining BCI and AR for Home Automation [3]

🔍 New trend: BCIs used as interaction media for the general public. Showcased integration of BCIs and AR in home automation platforms

➡ **new architecture** and methodology by integrating **AR**

➡ has limitations (cumbersome, performance issues...), but **lays foundation for future development**

4. _____

Providing Facilities in Health Care via Brain-Computer Interface and Internet of Things [4]

🔍 BCI and IoT for healthcare support and enhanced autonomy. Experiment: participants imagined making a fist with their hand to then control a light bulb

➡ potential of **BCI-IoT** integration to **enhance autonomy and quality of life**

5. _____

Company x University trials: BCI Lets You Control IoT Devices [5]

🔍 "Researchers at Brown University joined forces with a Utah-based company, Blackrock Microsystems, to create a brain-computer interface **that lets you send commands to the Internet of Things around you.**

A brain-computer interface can give paralysed people the power to control TVs, computers and wheelchairs with their thoughts. A device that let them run all IoT devices, home and at work. Allows them to control autonomous cars. Or even communicate with other people, across the world." [5]

From a very specific to a large public?

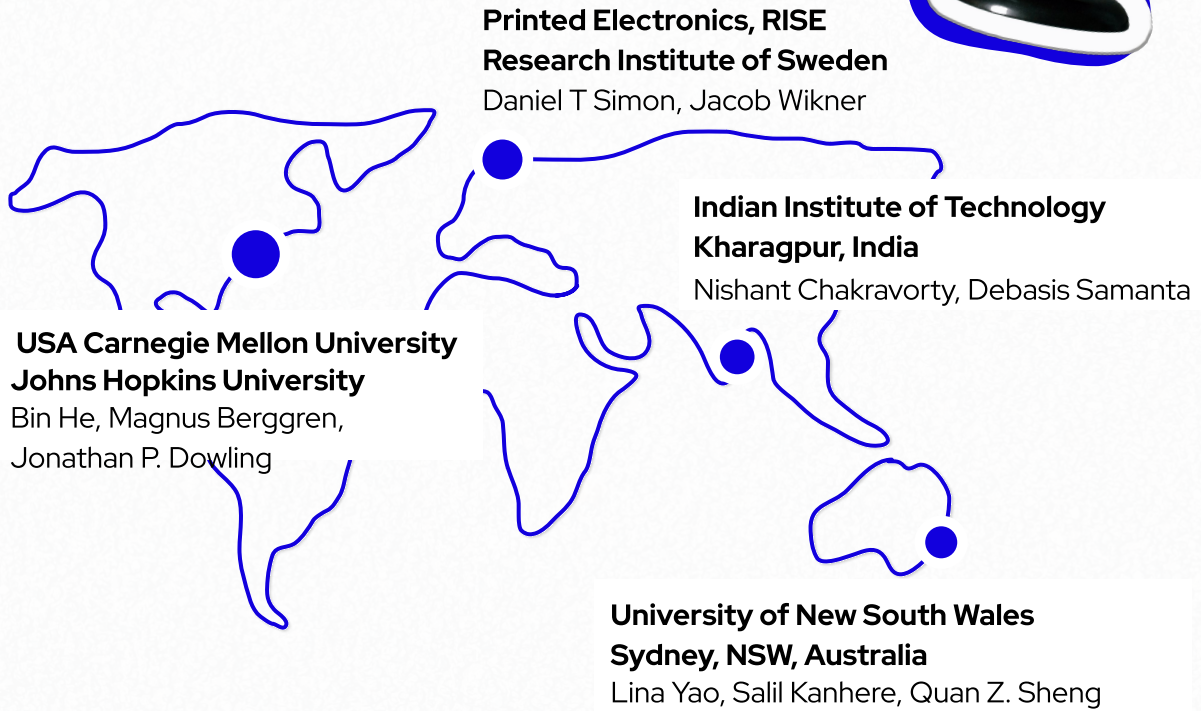
BCI x IoT first focused on people with disabilities to make their quality of life better. However, research suggests that this trend is now moving on to being used for the general public, in a global way.



Key researchers

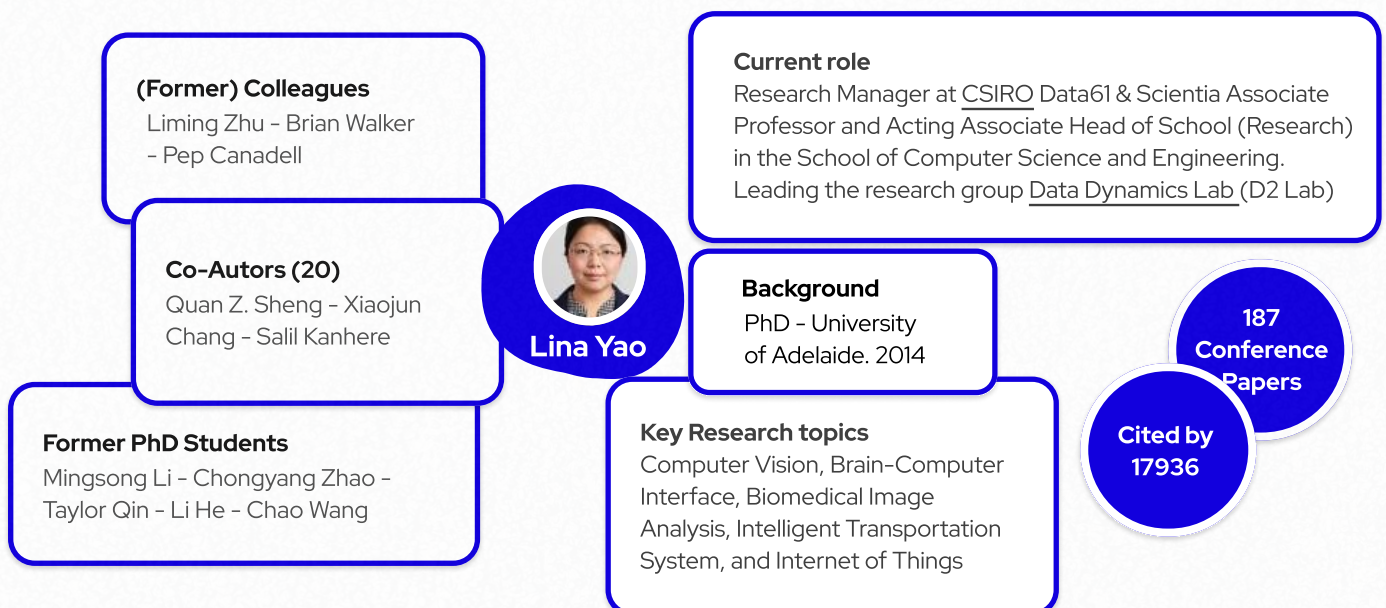
Who carry the research?

BCI x IoT does not only have one main group of researchers. We identified 4 areas from all around the world where this trend is widely mentioned.



Lina Yao

BCI x IoT is a male-dominated field. For all that, Lina Yao is a key researcher that we decided to highlight. Her work is notable in this trend, showed by an impressive amount of awards.



Key venues - key conferences

Where does the magic happen?

BCI x IoT do not have a venue dedicated to the combination of both. However, plenty of conferences highlights each of them, again all over the world.



IoT Tech Expo

"leading event for IoT, Digital Twins & Enterprise Transformation, IoT Security IoT Connectivity & Connected Devices, Smart Infrastructures & Automation, Data & Analytics and Edge Platforms."

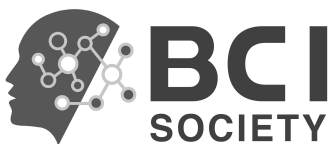
<https://www.iottechexpo.com/europe/>



IEEE Brain

"IEEE Brain Technical Community unites engineering and computing expertise across IEEE Societies and Councils relevant to neuroscience"/ "facilitate bringing neurotechnology to market in an ethical and responsible manner."

<https://brain.ieee.org/about-ieee-brain/>



BCI Society Meetings

"The purpose of the BCI Society is "to foster research leading to technologies that enable people to interact with the world through brain signals.""

<https://bcisociety.org/bci-definition/>



Graz BCI Conference (a local one!)

Graz BCI Conference has the BCI Society as a partner. They are having the 9th edition this year after successful previous editions.

<https://www.tugraz.at/institute/ine/graz-bci-conferences/9th-graz-bci-conference-2024>



Workshop outcome

Where do we see that trend going?

zZzero Stress: a Design Fiction

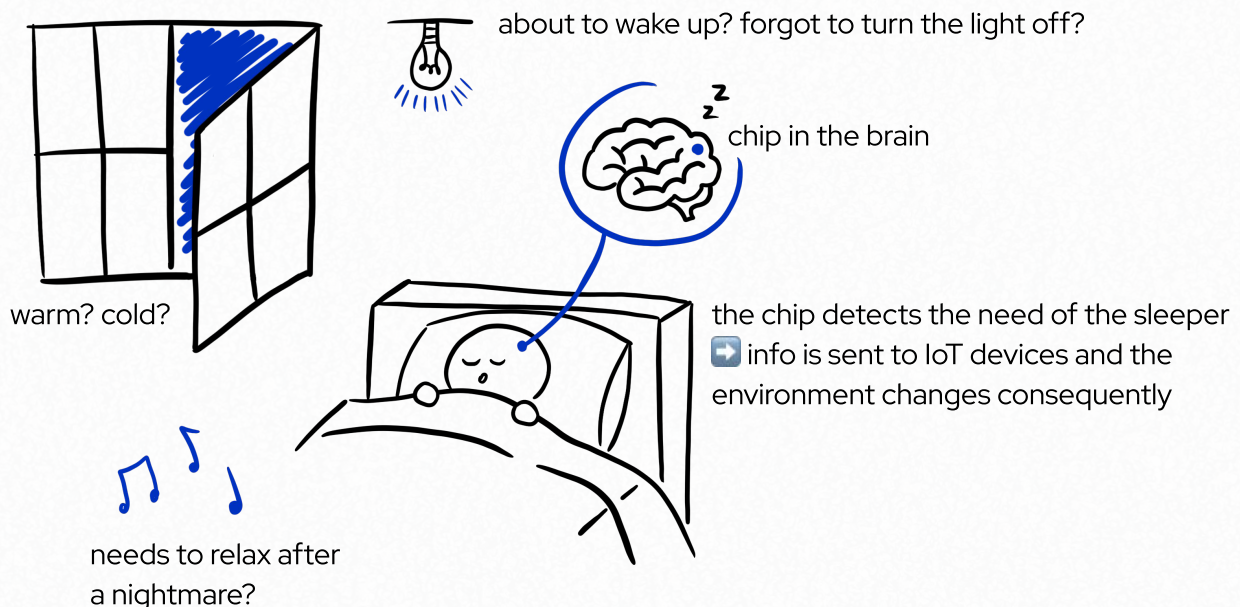
During a night of fitful sleep, you suddenly wake up because it's too hot in your room. You go back to bed, but sleep does not find you. So you get up again, scroll on your phone, and see an ad for **zZzero Stress™**.

Intrigued, you click on it and see a video of a man who is funnier than he is attractive, passionately telling you that the solution to all your sleep problems can be found in **an implant the size of a grain of rice**.

What does **zZzero Stress™** do?

- **Temperature Control:** It monitors your bodily temperature, and as soon as your delta and theta brain waves weaken, it signals your AC to turn on, lowering the temperature.
- **Natural Wake-Up:** It gently increases the light in your room to simulate a natural sunrise, helping you wake up feeling more refreshed.
- **Noise Cancellation:** It detects external noises and generates counteracting white noise to cancel out disturbances.

The makers of **zZzero Stress™** are currently testing Hocus Focus™, which analyzes your focus levels and suggests optimal times for breaks to enhance productivity and prevent burnout.



Shortcomings

As usual, it has limitations!



It's not all smooth sailing in the world of BCI. Let's highlight some shortcomings:

Frustrating nature of technology:

Kristina Höök: "Internet of Things is not a solely technical endeavor; it is dependent on understanding new uses, user needs and innovative, desirable design, because in spite of its importance in our lives, technology is still frequently frustrating, dehumanizing, or just plain boring. While our everyday life is saturated with technology, our relationship to it is still very far from perfect." [7]

Standardization

"To build a successful M2M ecosystem, it is crucial to have unified standards for everyone to follow." However, major standards are still under development and many emerging applications are using their own standards [8].

Interpretation of Data

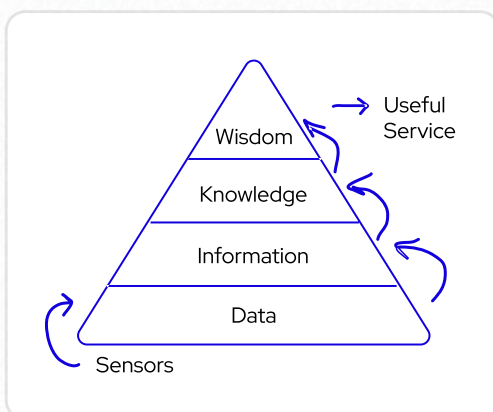
Accurately interpreting the intent of the individual from the raw brain signals that are often of low fidelity and subject to noise is a challenging endeavor. Moreover, preprocessing brain signals and the subsequent feature engineering are both time-consuming and highly reliant on human domain expertise [1].

Consumer Trust

"...the risk of a failure for IoT was strongly connected to situations where consumers cannot trust the companies (or governments) with their data. IoT thrives off data, without data there are no services" Kristina Höök [7].

Servicing cost

With gargantuan amounts of sensors being deployed, servicing costs are a major concern. Hardware needs minimal or zero effort to deploy and maintain and this is how many projects have failed because of poor sensor deployment. Battery replacement is also a concern because it is almost impossible to replace sensor batteries once in the field... or in your brain. [8]



Process of transforming sea of raw data into information, knowledge, and finally wisdom [8]

Ethics? What about autonomy and self-agency?

The development of sensors, decoder algorithms and translation methods require an extensive design undertaking in which engineers need to make hundreds of decisions and the ethical issues that come up when considering each process. BCI is a promising tech, but they are not yet developed enough to be used outside of strictly controlled clinical trials [9].

References

If you want to know more...



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[3] Hakim Si-Mohammed, Coralie Haumont, Alexandre Sanchez, Cyril Plapous, Foued Bouchnak, et al.. Designing Functional Prototypes Combining BCI and AR for Home Automation. *EuroXR 2022 International Conference on Virtual Reality and Mixed Reality*, Sep 2022, Stuttgart, Germany. pp.321, 10.1007/978-3-031-16234-3_1 . hal-03928273

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[5] <https://blog.adafruit.com/2016/03/30/brain-computer-interface-lets-you-control-iot-devices/>

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[8] - Chen, Yen-Kuang. (2012). Challenges and opportunities of internet of things. 383-388. 10.1109/ASPAC.2012.6164978.

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