From Wearables to Thinkables - Deep Learning, Nanobiosensors and the Next Generation of Mobile Devices

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Abstract Summary: Wearables will be transformed into Thinkables offering continuous, cognitive, real-time analytics of measured biometric and biological data at the point of sensing. Thereby ultra-low power neuromorphic platforms - such as IBM’s recently introduced TrueNorth chip - could play a key role in connecting on-body nanobiosensors directly with deep-learning technology for instant analytics, prediction and interfacing with artificial intelligence systems.

Introduction: Wearables allow measurement of biometric parameters through systems attached to the human body and either store the collected data on the device or send it to the cloud for offline analysis. As the Wearable revolution unfolds a rapidly increasing number of parameters can be monitored simultaneously making data storage and transmission unfeasible. Moreover, as measurement data becomes more complex and diverse cognitive methods such as for example deep-learning-based pattern and feature recognition will replace conventional analytical schemes. Thus, technologies for continuously correlating, contextualising and filtering data in real-time at the point of sensing are needed to empower artificial intelligence systems to instantly and proactively interact with the wearer creating novel ways of support, guidance and intervention. The architecture of such autonomously operating, always-on cognitive sensors will be minimum-footprint nanobiosensors [1] feeding into low-power deep-learning pipelines with a closed-loop interface back to the wearer. By providing the analytics power of the most advanced supercomputers on an ultra-low power system the size of a stamp, IBM’s recently introduced neuromorphic TrueNorth chip [2] constitutes the means to transform a Wearable into a Thinkable. Linking advances in nanobiosensing, brain-inspired computing and deep-learning [3,4] we expect first Thinkables to emerge in the field of applied neuroscience for monitoring and interpreting brain activity, diagnostics and predictive prevention in epilepsy and mental illness, deep-brain-stimulation, brain-machine-interfacing [5], and bionics.

Cognitive Sensing: In recent years, there has been a tremendous improvement in machine learning methods capable of surpassing human performance in tasks like image and speech recognition thanks to the development of Deep Learning. Meanwhile, IBM has introduced a novel technology called SyNAPSE which is based on a brain-inspired chip called TrueNorth. At 5.4 billion transistors it is the largest chip IBM has ever built. TrueNorth is a so called neuromorphic chip capable of performing a fundamentally new type of computing which replaces conventional processing steps with brain-inspired operations. This allows TrueNorth to analyse large amounts of data much more efficiently than any conventional state-of-the-art platform [6]. We are merging Deep Learning and TrueNorth into a new technology which we call Cognitive Sensing. Cognitive Sensing will allow low-power, predictive high-accuracy analytics of big and diversified sensor data in real-time at the point of sensing thus forming the core of a novel cognitive data analytics platform with applications in remote sensors, autonomous systems and wearable devices.
Novel Nanobiosensors: A broad spectrum of novel wearable nanobiosensor/actuator platforms in various stages of technical maturity has recently been demonstrated or is currently under development [7]. We regard the following selected techniques as suitable candidates for incorporation in a first generation of Thinkables: Neural Implants: Retinal stimulation electrodes for bionic eye applications [8], EEG and ECOG electrodes for brain activity monitoring [9], for deep brain-stimulation [10], and for controlling prostheses through thought [11], as well as artificial skin for robotic prostheses [12]. Tattoo Sensors: smart contact lenses for blood sugar and biomarker measurement [13], electrochemical tattoo batteries [14], low-cost integrated circuit patches [15], and always-on EEG electrode tattoos [16]. Molecular Sensors: biomarker detectors [17], portable DNA-sequencers [18], functionalised nanoparticles [19], and smart pills containing nanobiosensors [20].

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