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# Large-field study of gaze based ultra low-cost, non-invasive task level BMI

**William Welby Abbott and Aldo Ahmed Faisal**

The pursuit of an effective brain machine interface (BMI) holds the hope to enable patients with severe motor disorders to interact with their surroundings. Different approaches can be categorised as non-invasive cortical interfaces (e.g. EEG), invasive cortical interfaces, e.g. implanted multi-electrode arrays (MEA), or non-invasive and non-cortical interfaces (e.g. EMG). The clinical aim, however, remains the same: to extract an intention signal from a patient, for which conventional approaches such as joystick, mouse movement or sip and puff control are not possible. Current approaches however come at considerable clinical and post-clinical cost (Shih et al., 2012), while posing limitations for use in daily applications due to low information transmission bandwidths. Powered continuous wheelchair control requires, about 15.3 bit/s and full-finger hand prosthetics would require 54.2 bit/s, well beyond the reported performance of current BMI approaches (EEG 1.63 bit/s, cortical multielectrode arrays (MEA) - 3.3 bit/s, non-cortical non-invasive BMIs, e.g. EMG - 2.66 bit/s (Tonet et al., 2008).

We propose a non-invasive and ultra-low cost alternative - action intention decoding from 3D gaze signals (Abbott & Faisal, 2012). This enables real-time closed-loop control that outperforms invasive (and non-invasive) BMIs in terms of cost and read-out data rates (Abbott & Faisal, 2012) - and hence has enabled robotic arm control in conjunction with other low data-rate signal sources (EMG (Corbett, Kording, & Perreault, 2013), EEG (Onose et al., 2012) or tongue-flick-switches (Buckley, Vaidyanathan, & Mayol-Cuevas, 2011). As we have previously estimated, our GT3D approach could yield bit rates up to 43 bit/s at a system cost of <30 USD and we have framed this performance within a comparison of BMI approaches in terms of cost and information throughput (Abbott & Faisal, 2012). Although eye-tracking and even low-cost eye-tracking is nothing new (Li, Babcock, & Parkhurst, 2006; San Agustin, Skovsgaard, Hansen, & Hansen, 2009; Schneider, Bex, Barth, & Dorr, 2011), we showed that gaze location, particularly in 3D and at high-data rates (matching those of eye movements) provides a real-time decodable and graded control signal that should be utilised in the BMI field.

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William Welby Abbott
Imperial College London, Dept. Bioengineering, UK
Aldo Ahmed Faisal
Imperial College London, Dept. of Computing and Dept. Bioengineering, UK

Our system demonstrated a clear improvement on these low-level measures of BMI performance, but such technical measures mask the complexities of learning to use and operate BMIs in the clinic and daily-life. Thus building on our previous work, we present here a large field study (N=2224 subjects) that aimed to understand how efficient our approach is at allowing subjects, from first use, to operate our BMI on the Pong BMI benchmark task. To achieve this we built an eye controlled arcade booth that allowed members of the public to walk up and then simply "sit", "scan" (calibrate) and "play". Within the first 30 seconds of first time use, the majority of subjects were able to successfully play the arcade game pong against a computer. Subjects made on average 6.6 +- 6.2 ball returns compared to the chance level of 2.6+-2.5 obtained without input (mean +- SD). Almost 20% of players even managed to beat the computer, despite having never used their eye-movements as a control input. This performance was achieved with members of the public at a scientific engagement event, not in stringent lab conditions and with minimal system calibration (30s) and negligible user control learning (5s countdown before ball released). This demonstrates the intuitive nature of gaze control and thus the clinical applicability of our approach.

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