Autonomy is the Key: From Smart Towards Intelligent Textiles

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Abstract

Electronic textiles become smart by embedding circuits and sensors which offer some passive or active capabilities. Smart textiles become intelligent due to their computational abilities allowing awareness of their environment, extract input data from it, and consequently demonstrate untaught behaviours. Intelligent systems require machine intelligence through artificial intelligence algorithms to complete these input data manipulations. However, producing intelligent electronic textiles is a current research challenge. Hypothesising their eventuality and ubiquity, challenges such as remote communication, power generation, data processing, security, and ethics arise. In what remains we focus on the ethical implications and approaches to risk mitigation.

Keywords

Smart textiles, e-textiles, electronic textiles, artificial intelligence, autonomous systems, ethics.

ACM Classification Keywords

• Human-centered computing~Ubiquitous computing • Hardware~Sensor devices and platforms

Introduction

Intelligent systems are being integrated with textile surfaces, changing the perspective of how smart electronic textiles could be. With intelligence – using machine learning, for instance – electronic textiles have the capability of engaging users via feedback and construction of a contextual framework of users' behaviour. However, this position paper argues that transitioning smart textiles to truly intelligent textiles can only be facilitated if they become autonomous systems, and we consider the potential challenges ahead. Likely applications include monitoring and data collection and processing, such as in medical and smart home environments. Through autonomy however, challenges such as remote communication, power generation, security, and ethical considerations arise.

Machine Learning for Intelligent Textile Interactions

Machine learning algorithms have been used to quantify movement of smart textile garments; e.g., to convey different data output compared to its input [1]. Zhang and Harrison used Electrical Impedance Tomography (EIT) to measure the electrical impedance of the inner forearm to decipher hand gestures and finger-thumb pinches in real-time for non-verbal communication to control a smart watch [1]. Computer vision software was programmed to recognise the hand and finger gestures. Support vector machine (SVM) algorithms were used to combine the recognised gestures with the impedance measurements to make decisions on what was communicated. Machine learning algorithms that can build intuitive relationships between data, based on the categorization of this extracted data, can change user's perspective on interaction intelligence. Simple gestures with slight variability could be made distinct due to SVM classification [1], allowing the EIT system to recognise 378 additional features of the gestures – evidencing the advantage of machine learning to introduce more context and understanding to pre-defined conditions. Arguably, artificial intelligence algorithms used by intelligent textiles can provide understanding about the data it receives. Autonomous behaviour is important in this context as the intelligent textile would showcase independent and trusted decision-making. Autonomous actions based on a deep understanding of the data it handles can improve its user's actions, environment, and relationships with other 'connected' objects if connected to The Cloud.

Other uses of machine learning in wearable systems include the support of assisted living in smart homes. Smart textiles are gaining preference over wearable hardware devices for their compactness, softness, and flexibility [2]. A smart textile made from piezo-resistive material was worn on a finger to detect changes in pressure and strain [2]. Via a smartphone app, the system could recognise flexes of the piezoresistive finger sleeve with high precision to provide an eye-free interaction and control of connected devices. This technology could widen the user-demographic of the assisted living industry, and potentially enable those with physical and mental impairments to control their environment with greater ease.

Personal Interactivity with Intelligent Textiles

For a textile to be intelligent, it must display decision-making attributes, which involves behavioural analysis based on input data and communicate it to its user(s) [3]. Interacting with intelligent textiles can provide helpful behavioural feedback and information about its environment – which can promote engagement, quantity of collected data, and the increase of contextual understanding. Machine learning techniques have been used in the ‘affective computing’ domain to attain more knowledge on how emotions form and change over time [4]. Such knowledge can reveal physiological and mental states of an individual in both intensity and whether the state is positive or negative [5]. Nardelli used heart rate variability (HRV) as an indicator of emotional arousal and valence to categorise emotions quantitatively. Specifically, musical sounds were used to encourage emotional responses and feature selection algorithms, such as the Leave-In-Leave-Out, were further used to teach the machine intelligence within the system to eventually create an automated classification of emotion recognition. If further interaction with an intelligent smart textile increased its intelligence, it could build its knowledge [6] and begin to extrapolate how existing data would be applied to new contexts [7].

Furthermore, accelerometer and gyroscope sensors can be embedded into intelligent smart textiles to gain data through movement. Accelerometer data analysed by machine learning algorithms such as SVMs, Naïve Bayesian Networks, and other instance-based learning algorithms can also be applied to intelligent smart textile bed mattresses for applications such as acquiring sleep posture patterns [8]. Emotions during sleep can affect quality of sleep and subsequently overall wellbeing [9]. Using intelligent smart textiles in this way, with the possibility to gain more personalised intelligence through radio frequency identification (RFID) tagging to aid assisted living in different locations [10], could help formulate a wellness sensor network [11]. This would create a wireless collective of shared knowledge within the network, improving conclusions, knowledge, and judgements to increase levels of intelligence and autonomy.

Final Considerations

Deploying digital governance [12] on the intelligent behaviours produced by intelligent smart textiles, requires attention. Necessary security measures to protect those interacting with these textiles are imperative for ethical reasons – to establish what they can reveal and to whom. Moreover, they require reciprocal interactions [13] which are dependent on usability, user-acceptance [14], and perceived trustworthiness [15]. However, as interactivity becomes invisible [16], a ubiquitous data security framework is needed. The extent the user can decide which behaviour they want monitoring needs to be defined. Additionally, how the deductions the machine learning algorithms - which gives the smart textile intelligence - makes about the user will be used by an external party.

In conclusion, intelligent smart textiles will enable soft, flexible, and novel interfaces. Achieving these truly integrated intelligent smart textiles with unobtrusive electronics requires the establishment of reliable manufacturing methods [17]. This paper provides a vision of autonomous intelligent electronic textiles supporting assisted living. Contextual information can be added via location tagging, RFID, and with more interaction patterns can be enhanced by the machine intelligence to create personalised feedback. Though, if intelligent textiles could demonstrate autonomy in the future there are risks and challenges to consider. Further, the efficiency of autonomous intelligent smart textiles requires sufficient user-interaction to give machine learning algorithms enough data to learn about its environment and user. Additionally, the security implications on what the collected data can be used for and with. Nevertheless, the potential creation of intelligent smart textiles is this – with artificial intelligence capabilities it could make textiles autonomous 'computational skin' on a body or object. Potentially, this could turn any interaction with a textile into an intelligent communication of data.

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