IeMRC

Abstract

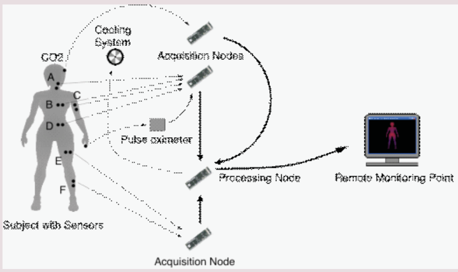
Studentship Project

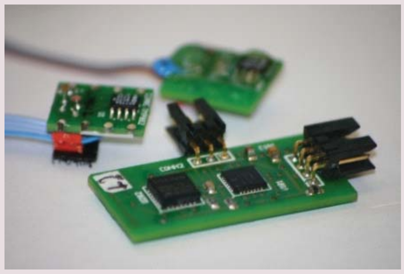
Investigation into the Use of Advanced Sensing Technologies for Protection Suits

John Kemp, Elena Gaura, James Brusey, Cogent Computing Applied Research Centre, Coventry University

Bomb disposal suits contain a large amount of padding and armour to protect the wearer's vital organs in the case of explosion. The combination of the heavy (roughly 40kg) suit (featured in left of figure above), physical exertion, and the environment in which these suits are worn tend to cause the wearer's core temperature to rise, potentially leading to Uncompensible Heat Stress (UHS). Current cooling systems used in the suits can be manually adjusted but this may be distracting to operate; additionally, battery life is limited and if cooling is left on, battery power will be exhausted well before the end of a normal mission. Furthermore, during our investigation, we found that CO2 levels in the helmet quickly rise to dangerous levels when the visor is closed.

The aim of this research was to investigate the use of wireless, body worn, instrumentation to help monitor the thermal state of the operative during a mission. A secondary aim was to develop an instrument that can be used to help the manufacturer better understand the physiological effects that the suit has on the operative either during missions or during training.





Towards the above, a wearable body sensor network system based on the Gumstix mote was produced which primarily allows: i) Sensing the temperature of the skin at specific sites; ii) acquiring other physiological data such as oxigenation levels and heart rate through the use of a pulse oximeter; iii) Sensing the CO2 levels in the helmet; iv) Sensing the orientation of torso and limbs and classifying the combined pose into one of nine broad activities commonly encountered in missions. Various application and suit related constraints impose a need for the system to be fully autonomous in its task of using the above sense data to: i) Derive an estimate of the thermal sensation and comfort of the operative; ii) Predictively and independently actuate the cooling systems within the suit (operative back and helmet) in order to maintain acceptable comfort levels for the subject and prolong cooling battery life, and; iii) Provide warnings, information and data on the current and predicted state of the operator to a remote monitoring point. The resulting prototype is a mixed wired-wireless system with 4 tiers of communication: multiple sensors are wired to three acquisition nodes (AN); the acquisition nodes communicate wirelessly to a processing node (PN) within the suit; the processing node provides wired actuation of the cooling system and also wirelessly communicates with a remote monitoring point. The system hardware architecture and the location of the sensors on the operative (middle) and the sensors used (right) are shown in the figure above. The safety-critical nature of the application imposed the need to architect, within the design, several fault detection and management mechanisms at sensor level, node level and end-to-end system level. Calibration algorithms, outlier rejection, Kalman filtering, predictive data alignment algorithms, link detection and information prioritization protocols are thus supported by the system.

The lack of prior art in characterizing the suit environment and its effect on the wearer meant that a new empirically derived real-time predictive model relating current thermal state to future thermal state needed to be developed and implemented on the processing node in order for the system to fulfill its actuation and remote monitoring aims.

The research has resulted in the production of a working prototype instrumentation system, successfully demonstrated in lab environments and further, used effectively for detailed analysis of the suit's physiological effects in protocols mimicking bomb disposal missions. The instrument complies with the application requirements and has been demonstrated to be an effective tool for monitoring the health of operatives.