The Next-Generation Connected and Smart Cyber-Fire Fighter System

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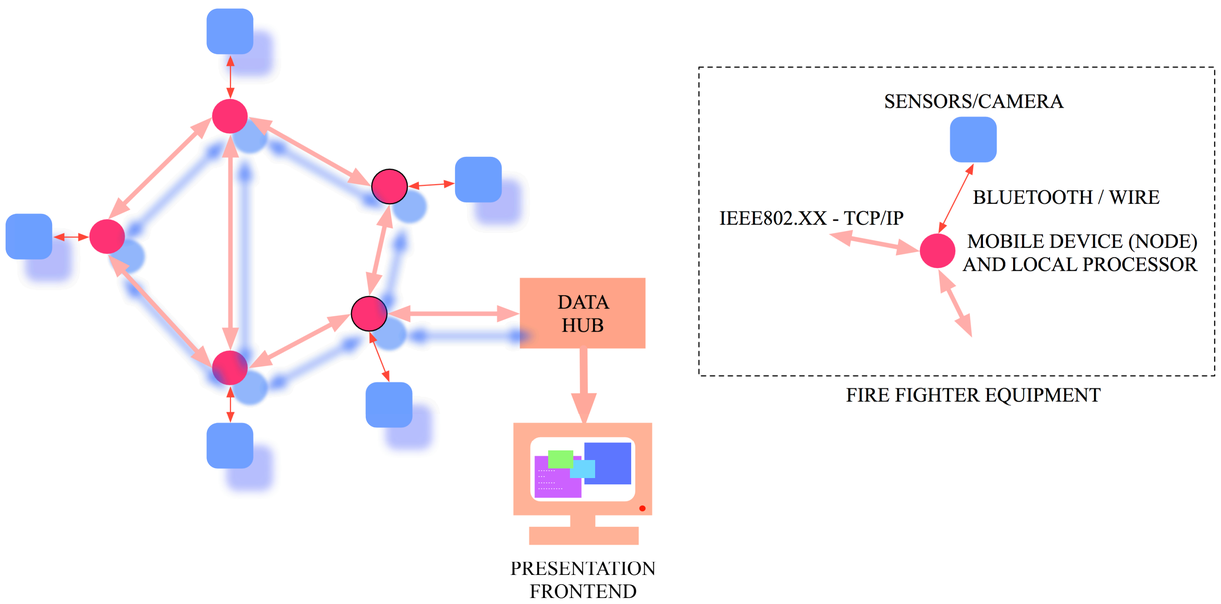
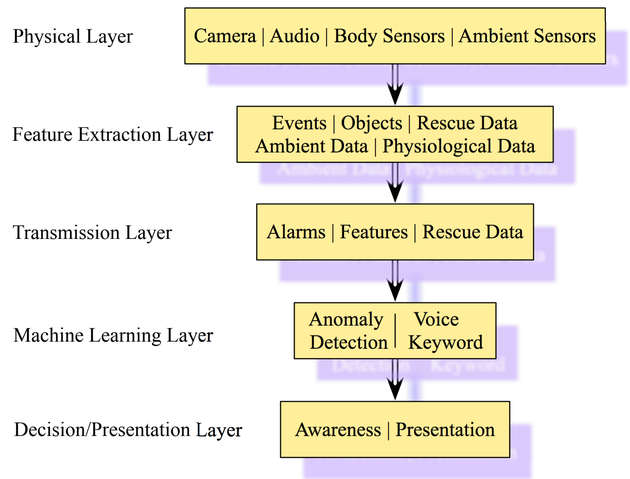
Summary: According to the U.S. Fire Administration, 91 firefighters died while on duty in the year of 2014. Being a fire fighter becomes more and more dangerous disregarding significant advances in various areas of science and technology. In the proposed research, we investigate a new connected and smart infrastructure that allows the development of next-generation first responder coordination protocols.

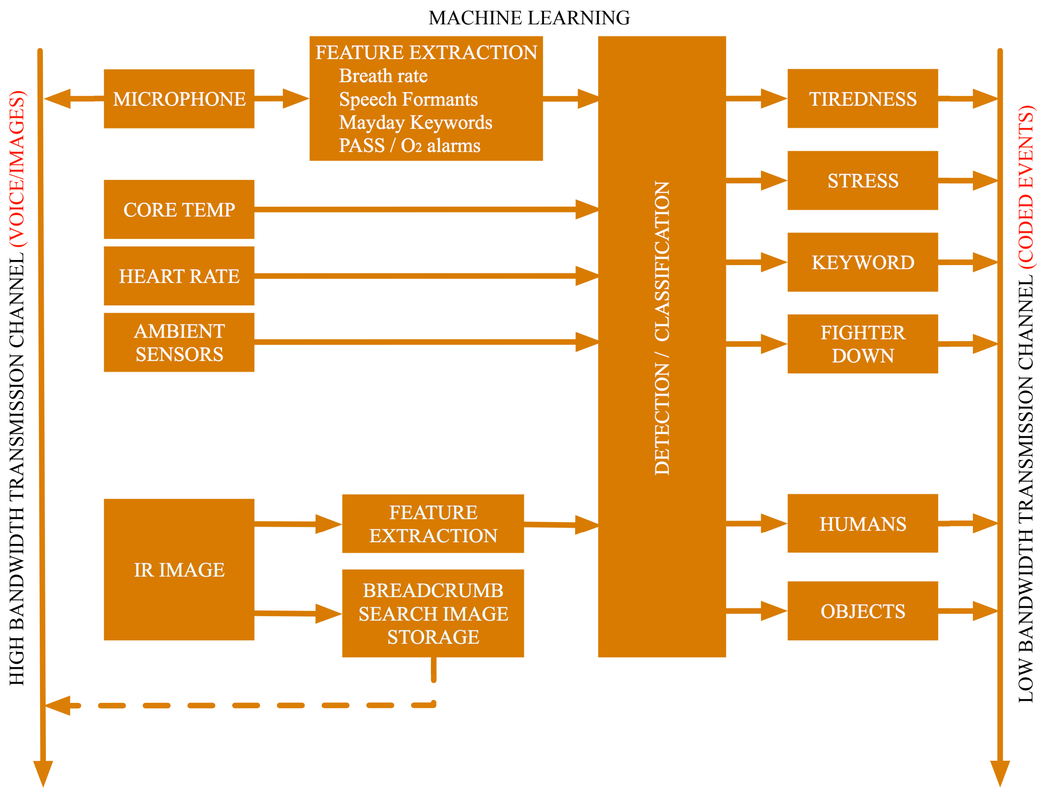
Participants: Electrical and Computer Department, Exercise and Sport Science Department, UNM; City of Santa Fe Fire Department; National Fire Protection Association.



The proposed structure is based on a grid of nodes (mobile devices) connected through TCP/IP. Each node is connected to a set of sensors and the IR camera using a Bluetooth channel. The mesh is connected to a hub that carries out the information processing and the awareness presentation to the operation commander.



The logic pile has 5 layers. 1: **Physical devices** for data collection from the sensors, microphones and camera. 2: **Feature extraction** coding the presence of bodies, objects or rescue operation data (from the IR camera), physiological information (tiredness, fear, stress), alerts (fighter down, low O2) ambient data (gas or heat detection, events detected from noise). 3: **Transmission** of coded features and voice/image (upon request). 4: **Machine Learning** for important event detection. 5: **Decision** based on awareness, and **presentation**.



The machine learning structure is intended to detect features of interest as the condition of the fire fighter (tiredness, stress, MayDay or emergency keywords, a fighter down), and the presence of objects of interest (hot objects, doors, fire, victims). These features can be coded and transmitted using a very low bandwidth transmission channel. Voice is processed using algorithms robust to noise and interferences to detect the fighter condition from the breath rate and the first voice formants.

RESPIRATION RATE
ROBUST FORMANT DETECTION

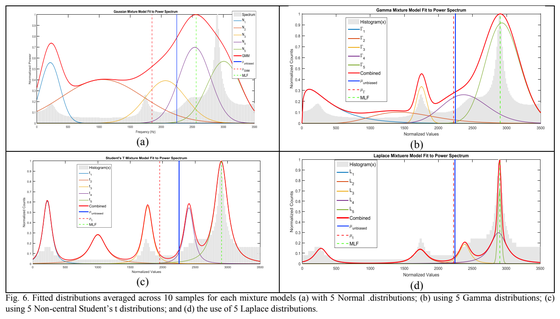
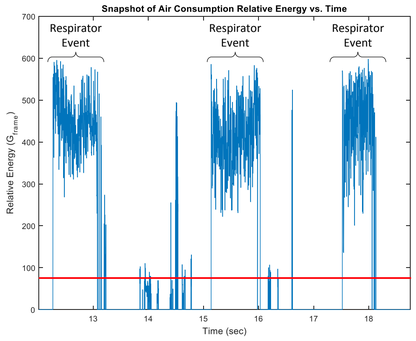
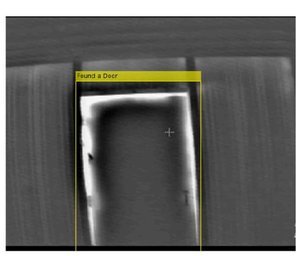


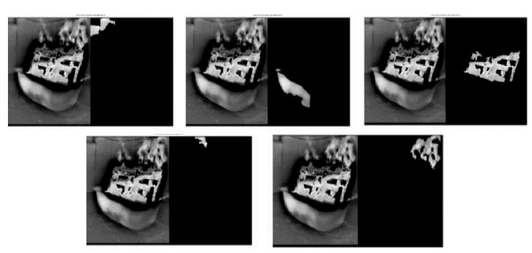
Fig. 6. Fitted distributions averaged across 10 samples for each mixture models (a) with 5 Normal distributions; (b) using 5 Gamma distributions; (c) using 5 Non-central Student's t distributions; and (d) the use of 5 Laplace distributions.

The respiration, heart rate and temperature are combined with a robust voice formant parametric estimate that uses a convex combination of adequate kernels to produce estimates of the position and power of the voice formants. The position of the formants is an indicator of certain conditions as stress and tiredness.



A fast spectral analysis is used to separate voice signals from the sound produced by respiration, to further estimate the breath rate and the average air flow. This serves as an indicator of tiredness and oxygen usage.





We use standard image processing techniques and deep learning to detect objects in the emergency scenario, in particular human bodies in arbitrary positions. The detection is performed continuously and the detection time series is further processed to maximize its likelihood.

Conclusion. Sensor hardware and software under development. Two data collection procedures have been submitted to the Institutional Review Board to obtain experimental data about tiredness and stress with volunteers, and to record and analyze voice in fire fighters during fire training. All feature extraction procedures with body sensors and IR imagery have been initiated. The communications mesh is under development. Two journal papers are under development. Two PhD dissertations are initiated. Many graduate students have expressed interest in this project.