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WORK APPAREL FOR URBAN SEARCH AND RESCUE DOGS

Abstract: While there are many working dogs, few face the challenges experienced by Urban Search and Rescue (USAR) canines. Humans have the benefit of protective clothing, whereas USAR canines have none. Canine handlers rightly believe that the risk of canines becoming trapped by worn items, such as a collar or harness, is too great and searches are almost universally conducted without any functional apparel being worn by the dog. As an adjunct to the Canine Augmentation Technology (CAT) project a number of canine garments have been created which address the safety and well being of the dog and the need to protect the components of the CAT system.

1. INTRODUCTION

Often working in extremely rugged and dangerous conditions, USAR dogs are confronted with unsafe situations on a regular basis. These dogs are trained to find live people who are trapped in the aftermath of an urban disaster. These disasters are commonly associated with the structural collapse of an occupied building. Trained dogs are used because they are the fastest and most reliable means of finding people in rubble. However, the search for people is not without risk. Rubble often contains dangerous artifacts, such as reinforcing rods, that can cause serious injury to both human and canine.

Whereas humans have the benefit of protective clothing, USAR canines have none. Canine handlers rightly believe that the risk of canines becoming trapped by worn items, such as a collar or harness, is too great and searches are almost universally conducted without any functional apparel being worn by the dog. While this approach to the problem has worked well and has become institutionalized in emergency response organizations such as the

Federal Emergency Management Agency (FEMA), the status quo fails to address emerging technology that will rely on canine apparel that can be worn into a disaster site.

Over the past three years the Canine Augmentation Technology (CAT) project has been evolving ever more complex video and sensing equipment that is intended to be worn by USAR canines to help first responders determine what is happening around the dog while it conducts a search, even when the dog cannot be directly seen. The goal of the project is to allow first responders to see what the dog sees, hear what the dog hears, know where the dog is, and provide immediate assistance to trapped people who have been found by the dog (Ferworn, et al. 2006, Ferworn, et al. 2007).

For this equipment to be useful, the hurdle of canine safety must be addressed. As an adjunct to the CAT project a number of canine garments have been created which consider both the safety and the well being of the dog and the need to protect the components of the CAT system. We have devised canine garments that provide exceptional protection for the dog while providing remarkable stability and durability for the sensing components that form the basis of CAT.

In its current form, the canine body harness consists of a vest-like garment that contains mount points and pockets for the various electronic components, cable harnesses and sensors that comprise the CAT system. In addition, heat shielding and padding is provided for the safety, well being and comfort of the dog. A mechanism to allow the dog to rescue itself by shedding the garment, should it become entangled in rubble, is incorporated into the design.

The system has gone through several prototypes and was recently tested at a joint Ontario Provincial Police (OPP)/Federal Emergency Management Agency (FEMA) training exercise in Florida, USA. This paper discusses the design of our garments, how they relate to the work environment of the dogs and what we have observed concerning their performance.

Figure 1 USAR Canine Dare wearing CAT before a work garment was designed

Figure 2 Canine Darby wearing USAR CAT work apparel

2. CANINE APPAREL CATEGORIZATION

Prior to the design of the prototype garment to accommodate the CAT system, a thorough search was conducted to assess the state of the art. Many canine apparel garments and accessories were identified, and placed into five general categories: traditional, sport and recreational, designer, USAR and wearable computing. The traditional group comprises items commonly worn by dogs when walking or traveling, such as leashes, walking harnesses, training harnesses, vehicle restraint harnesses, collars, all-weather coats/back covers and footwear. These items can be purchased at pet stores and even most grocery stores.

The sport and recreational grouping includes hunting vests, padded vests, reflective vests, dog sledding harnesses, skijoring harnesses, weight pulling harnesses, freight harnesses, carting harnesses and dog backpacks. These items can be purchased at specialty sporting outlets.

By far the most popular and lucrative category in canine wear today is the designer group, which consists of vests, dresses, jackets, coats, hats, jewel-encrusted collars and footwear of all types. Often frivolous and restrictive, these items are not designed to perform a function but rather they are designed to adorn the dog. They are designed by humans for human enjoyment and are available at specialty pet stores.

Garments designed for USAR dogs are mostly in the genre of vests and body coverings. They provide safety features (life support in the water, warmth in cold temperatures, reflective tape) and allow free movement. Fairly simple in design, they strap onto the dog using adjustable buckles or clips. Functional and protective, these garments generally cover the back and sides of the dog where a logo or identifiable feature is located. These items are available through specialty manufacturers—often created specifically for an individual dog--and are generally purchased by law enforcement, fire and volunteer organizations engaged in canine USAR tasks.

The category of wearable computing is the newest, least known and represents the next frontier in canine USAR apparel. Two examples, both developed in Britain, require the dog to wear a camera on its head. Wireless Operationally Linked Electronic and Video Exploration System (WOLVES) transmits images and sounds to rescuers (WOLVES, 1995). The Firearms Intervention and Dangerous Operations (FIDO) camera also sends video signals back to a handheld monitor for police officers to see (FIDO, 2005).

With the development of the CAT system, it became necessary to design a garment to fit the dog's body that would allow technology and canine to successfully interface. While there has been considerable development in the area of wearable computing for human purposes, extensive searches have not yielded any documented research being carried out in wearable computing for this type of canine USAR apparel.

3. DESIGN AND PROTOTYPE DEVELOPMENT

The apparel design process, used in the development of functional apparel for humans, has been modified to accommodate working canines, as we believe the creative problem-solving process for apparel design should not be reserved only for humans. A thorough understanding of the end user is critical to executing successful design. Identifying user needs and wants provides a means for establishing design criteria (Lamb and Kallal, 1992, Parsons and Campbell, 2004). Much of what is documented with regards to design development, as a creative problem-solving process, has focused on apparel for humans (Watkins, 1995, LaBat and Sokolowski, 1999). Common steps in the problem-solving models

reviewed, by and large follow this order: identification of the problem through observation and consultation, establishment and ranking of critical and secondary design aspects, investigation of preliminary design ideas, design refinement through prototype development, and evaluation through implementation.

The development of the prototypes, began with the identification of critical primary aspects that would form the foundation from which the design would emerge. A demonstration of the CAT system and its capacities allowed the designer to fully understand the potential and scope of this product. All previous harness attempts, designed by the technical team, had resulted in CAT prototypes being destroyed or rejected by the dogs during field tests. Upon examining the photos and video footage, it was clear that the sensitive components needed to be protected and needed to be closer to the dog's body. Certain parts of the technology were required to be in proximity to other components, for the computing and communication systems to be effective. It was imperative for recording devices, wires, flat cables, batteries and photosensitive lights to, not only be located and secured strategically, but to also be easily replaced when damaged. In order for the design to fulfill the required needs of CAT, measurements of all component parts were recorded.

A simulated disaster exercise provided the designer an opportunity to observe a typical disaster scenario unfolding--complete with collapsed buildings, rubble and USAR handlers and their canines. The dangerous and hazardous nature of the environment was clearly evident and became an important factor to consider when designing the garment for the dogs. This excursion into the field also enabled the designer to discuss with the handlers, their needs and concerns as they pertain to canine work apparel and to observe the relationship between handler and dog. The safety of their dogs was very important and it was clear that the handlers would not allow the dog into a site if there were a perceived risk of injury or entrapment. The garment would need to have a safety mechanism allowing the dog to disengage itself from the debris and the garment, should the garment become tangled or otherwise restrict the movement of the dog.

Through consultations with the technical team, and the handlers and through observations it was determined that there were two critical aspects of the canine work apparel to consider.

First, the garment had to be safe and comfortable for the dog, and second, the garment had to protect the CAT equipment.

Important secondary aspects to consider, in the prototype development, also became evident at this time, specifically: fabric selection, adjustability features and safety devices. To allow maximum comfort for the dog, the ideal fabric should be durable and lightweight. The fabric utilization should be minimal, allowing optimal body movement, covering as little of the canine body as possible, but large enough to secure and protect the CAT equipment. Minimal covering would also help to address the concern many handlers have that their dogs might overheat from both their own exertion and the heat burden the CAT equipment generates. A fabric heat shield was also incorporated into the design to provide a protective layer between the dog's body and the technology.

In terms of adjustability, it was observed that USAR canines, as a whole, are comprised of many different dog breeds: German Shepherd, Collie, Border Collie, and Retrievers to name a few. The work apparel designed would need to be adjustable for all medium to large dog body types used in canine USAR. Documentation regarding standard canine body measurements was found to be incomplete and inconsistent. In addition, seasonal changes in the thickness of the dog's coat could change the body dimension considerably. Good fit would need to be attained easily and quickly. A garment that would adhere closely to the body would also be less likely to get caught on protruding debris. Lastly, and most importantly, in order for the handler to allow the dog to enter a dangerous area, a safety device to allow the dog to disengage itself if caught on debris would need to be incorporated into the design. This mechanism would have to be strong enough to withstand the dog passing through narrow spaces, but disengage if the apparel were to become hung up on debris within the search area.

Figure 3 CAT Prototype on Canine Dare

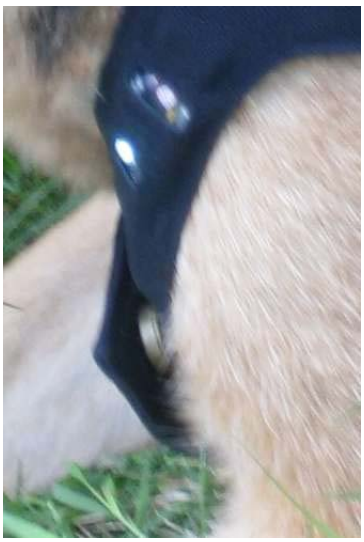

Figure 4 Magnetic closure detail on CAT USAR canine apparel

Considerable research resulted in the preliminary prototypes. The first two samples were void of any design detail and were focused entirely on developing and refining the body shape to house the technology. These were fitted on a stationary model form that had been created to resemble a “medium” sized dog. The third sample tested the functionality and locations of the adjustability feature and the safety device. It was during the development of

the fourth sample, fitted on a real dog, that the following were finalized: the placement of the critical components: the safety features and the adjustability features. The fabric utilization was also reduced in the fourth sample to allow for greater movement and comfort. The fifth prototype was completed, incorporating all of the above, and successfully tested in the field on several canines of various sizes.

Four different fabrics were sampled over the development of the five prototypes: 100% waterproof medium weight nylon, 100% nylon micro-porous laminate, 100% rip-stop nylon and 100% medium weight canvas-type nylon with a slightly rubberized backing. The last and most successful prototype was made of a combination of 100% medium weight canvas-type nylon (for the exterior) and 100% rip-stop nylon (for small interior areas). The canvas-type nylon provided durability, strength and some flexibility when cut on the bias grain. The rip-stop nylon offered superior strength without bulk for the internal pockets and cable carriers.

The adjustability features that were considered for sampling were Velcro and zippers. While Velcro was the easiest to apply and offered the greatest amount of flexibility, it was felt that for this prototype, zippers would be tested. The fifth prototype incorporated a series of tactically positioned plastic separating zippers that could inter-zip with each other providing adjustability in fit, security and lasting performance.

The safety device selected for all prototype testing were magnetic closures. These magnetic closures were strategically placed to allow the dog to release parts of the garment if caught – in other words, the closures would disengage and allow whatever was hindering the dog's motion to be released while keeping the garment on the dog. Easy to operate and very sturdy once closed, the magnetic closures did not interfere with the technology and enabled the dog to independently free itself without struggling.

4. CAT PROTOTYPE TESTING AND EVALUATION

The fifth prototype, or final garment, was completed and evaluated in the field over a period of three days. Its design and execution addressed the two primary critical aspects that were

identified at the beginning of the design process. The canine handlers required that the garment be safe and address the well-being of the dog and the technical team required that the garment protect the CAT equipment. The important secondary aspects were also addressed in the design of the final prototype, those being: suitable fabric selection and utilization, sufficient adjustability within the garment, and self-shedding abilities. The end-users conducting the field tests overwhelmingly and unanimously indicated that all aspects were attained with considerable success.

Across all categories, the final CAT prototype, resulted in an USAR garment that performed beyond expectation. This was achieved through the accurate identification of the design problem, an appreciation of the bond between canine and handler and a thorough understanding of the critical aspects and how they related to the design problem.

5. ADDITIONAL GARMENTS – CRDS: DESIGN AND EVALUATION

One of the subcomponents of CAT is the Canine Remote Deployment System (CRDS). This technology allows an USAR dog to directly benefit trapped people it finds by delivering emergency supplies that can be dropped at the press of a button by the handler. An interesting new requirement, it changes the design space of the garment from one of passive sensor support to one of active remote manipulation through the handler to the dog.

With the critical and secondary aspects of the design problem firmly established and with the invaluable experience of the previous CAT III prototypes, designing a harness to accommodate the deployment system began. The design problem was to create a two part harness: one part which was worn by the dog at all times; and a second part, the “under-dog”, which would be detached or deployed to land next to a survivor.

Figure 5 CRDS and under-dog on Canine Cy

The purpose of the harness was to securely hold the CRDS mount and mechanism in place. As the CRDS technology could only exist on the outside of the body and as there were no wires or cables to contain, minimal fabric utilization was obtained, resulting in optimum free movement and comfort for the dog. To incorporate as much flexibility as possible, the fabric was cut on the bias grain. Similarly, as with the CAT harness, fitting of various dog breeds was a consideration. For this sample, Velcro was chosen as the adjustability feature. Several Velcro strips, 2" wide, were positioned, adjacent to the CRDS mount. In addition, as Velcro is often used for closures, it was decided that for this prototype, magnetic closures would not be used and that the Velcro would be tested for its self-releasing abilities.

For the second part, the "under-dog", it was essential that it be attached in such a manner to not hinder the dog from movement and yet, upon command, be easily dropped. The purpose of the under-dog was to hold emergency supplies, i.e. radio transmitter, water, nutrition bar, etc. Three large openings placed along the outer edge of the bag, closed with Velcro tabs, were incorporated into the design. Long adjustable loops were attached to large hook-n-claw closures which were latched onto the CRDS mechanism. Also, as the under-dog would be placed next to the dog's lower body, it was necessary for it to be contoured not only to fit this part of the anatomy but also large enough to hold life saving supplies.

The CRDS prototype was completed and tested in the field. Overall, considerable success was attained. The fit of the harness was superior and it held the CRDS mount securely in place and delivered supplies to the intended target. While the Velcro was successful in being adjustable to various canine body sizes, it performed poorly as a self-releasing feature, remaining completely closed while the main vertical seam in the harness ruptured. The recommendation was that magnetic closures be incorporated in future prototypes.

6. ADDITIONAL GARMENTS – HYBRID CAT and CRDS: DESIGN AND EVALUATION

The third and latest in the development of the CAT series of garments is a hybrid harness, combining key features of both the CAT and the CRDS harnesses. This prototype considers all the critical and secondary aspects established: the safety and well being of the dog and the protection of the CAT equipment; and secondary aspects: fabric selection and utilization, adjustability features and safety devices.

For the purpose of this prototype, the zippered panel on the CAT garment has been replaced by the CRDS mount and mechanism. Wide Velcro strips have been strategically located under the CRDS mount to provide adjustability and to accommodate the various canine body sizes. The original CAT design has been fitted with the CRDS in its entirety, and it is hoped that it will be able to deliver emergency supplies as intended.

It is hoped that this new hybrid prototype will perform successfully. It is currently being evaluated as part of the Response Robot Evaluation, in co-operation with Texas Engineering Extension (TEEX) Exercise, Texas A&M University, in Disaster City, College Station, Texas, USA. Preliminary testing is inconclusive and further investigation is necessary.

7. CONCLUSIONS AND FUTURE WORK

We have used a collaborative approach to designing canine work apparel for USAR dogs. Our designs fulfill the needs of dogs by providing comfortable and protective garments that can be shed if the dogs wearing them become entangled. The designs also satisfy the needs

of the canine handlers who have a garment that is easy to place on the dog and assuages their fears that their dogs might become entrapped. In addition, our garments provide protection for the delicate electronic components of the CAT system it houses and allows emergency supplies to be delivered to trapped survivors.

CAT is a work in progress and as the system becomes more capable there will be additional requirements placed on the designers of all its components. Two areas are currently under investigation. Canine Brain Function will examine the physiology of the dog during the activity. Headgear will be designed to fit the head of the dog, and will accommodate a sensor measuring the blood oxygenation level in the canine brain. It is believed that it is possible to examine their thoughts and experiences while searching for survivors. Another garment, intended for Canine Pose, will be designed to hold a set of accelerometers and a wireless signaling system to allow the position of the dog to be indicated to the handler. This is important as the dog's body position often indicates many things including camera angles for images received from CAT and the presence of survivors. We are working to integrate these new requirements into the apparel designs.

As previously discussed, the apparel design process used in the development of functional apparel for humans was modified to accommodate working canines. Adopting this process has achieved great success, and has allowed the research to move forward. It is apparent that, regardless of the "bodyform" involved in the design of functional apparel, following the general steps in the creative problem-solving process can lead to ground-breaking and purposeful solutions. It is further apparent that applications suitable for wearable technology, need not be reserved for USAR canines and that humans also could benefit from these innovations. It is foreseeable that in the future, similar technology could be adopted in functional apparel to benefit the broader community, such as the sick, the infirm, the disabled and the elderly.

It is clear that with the development of canine wearable computing, there are challenges with every prototype, and as technology advances so must the critical thinking behind it change. The success of this project is a representation of the merging of non-traditional fields of

study. It is with the development of such interdisciplinary relationships between designers, textile specialists, computer scientists and engineers that this new frontier of wearable computing will be explored (Smith, 2007).

8. REFERENCES

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