The Challenges of Wearable Computing for Working Dogs

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Abstract
We present two case studies on creating wearables for dogs and discuss them in terms of challenges of safety, space, weight and comfort, that motivated them. You can use these case studies and our design process as a practical primer for designing wearables for working dogs.

Author Keywords
animal-computer interaction; wearable computing; prototyping

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H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction
Despite the increased emphasis the wearable computing community has placed on supporting working dogs [2], few descriptions exist detailing how to achieve designs that are functional, robust, and comfortable for the dogs to use.

Our goal is to help others meet these design challenges head-on, by sharing our experience with two wearable devices we created.

Designing for the Collar
When we think about where to place wearable technology on dogs, the first place that comes to mind is the collar. But

the collar is not always the best place for wearable technology because it's one of the most restrictive in terms of safety, space, weight, and comfort. As we break down each of these aspects we will share how we have tackled them in our previous work.

Figure 1: The Voyce^{TM} is a complete collar replacement. Reprinted with permission from i4C Innovations.

Safety

"Safety first". While we should follow this guideline with any wearable, it becomes even more important when the target user can't tell you if something is painful. One of the biggest concerns around dog safety are strangulation hazards. It's crucial to think of the impact your technology will have on the likelihood of the collar getting caught. Items like dog tags protruding from the collar can be strangulation hazards. This is why the form factor of most commercial products like the Voyce (Figure 1) focus on trying to keep protrusions to a minimum. Many dog owners switch to a style of collar that alleviates strangulation concerns. These so-called break-away collars, are designed to literally break away from the dog's neck should the collar get caught on something.

Adding mass to a dog's body can also affect how they move and navigate through obstacles. This is similar to what happens in humans, where the study of proxemics, as used by Francine Gemperle [1], addresses how wearables impact someone's perception of the size of their own body:

> Forms should stay within the wearers intimate space, so that perceptually they become a part of the body. Compromises are often necessary but a general rule of thumb is to minimize thickness as much as possible. This increases safety and comfort, both physical and perceptual. A good example to observe is when a young American football player first dons shoulder pads, and immediately starts bumping into people and door ways because of the extra bulk.

Because we are talking about technology that could be added to the collar, thinking through the implications to the dog's movement and safety are all that more vital. With a collar-based wearable it's unlikely that the dog would see if the device was caught on something dangerous.

Space

When we talk about space, we are basically talking about how much real estate is available for the wearable technology. How big of a footprint does your device have and how does this affect where it can safely fit? With a collar-based device you have the circumference of the dog's neck and the width of the collar, however, if all of this space is used, how safe will it be and how is that going to feel?

Weight and Comfort

The weight of any device attached should lie below the guideline of 4-5 % of body weight established by Yonezawa et al. [4]. This rule was established for the sake of the comfort of the animal, but we have found in our experiments, that even this percentage is a bit too high and we strive for our technology taking far less than 2% of the body weight.

To increase comfort it is important to strive to keep the device as small as possible and to avoid using the full circumference of the collar. Doing so will enable the dog to to lie down without being inhibited by pressure from the wearable on their neck. In addition to the weight of the device, another component to consider is the collar itself. How does the collar lie on the dog's neck? Does the collar have multiple moving parts that might pull on strands of the dog's hair leading to their discomfort? Designing for comfort means

Figure 2: A commercially available flat collar. Reprinted with permission from Therapy Dogs International.

not only minimizing the weight, but also keeping the surface against the neck as soft and seamless as possible.

For prototyping purposes, flat buckle collars (Figure 2) offer greater versatility because new components can be slid on and off as needed, unlike flat snap collars whose buckles only allow items to be attached with rubber bands and not slid onto the collar itself. Unfortunately, most commercially available break-away collars are the snap buckle variety so the same limitations apply to them.

Ideally, we want the collar to comfortably fit the size of the intended dog without being too snug or too loose. Prototyping with off-the-shelf collars tends to restrict the design choices to only a few sizes. For example, a given flat buckle collar, of an acceptable width (relative to the wearable to be added) might only be available in one size.

If all the requirements above limit your possible options or you want to maximize safety through the use of a break-away but still have versatility, we recommend creating a custom collar.

Case Study: Collar for Inertial Sensor

We put the lessons above to use in the design of a collar for the Shimmer 3 inertial sensor. Because we needed a consistent placement, we settled on plastic clips to secure the sensor rather than attaching it with rubber bands. To remove strangulation concerns, we designed our collar to have the break-away feature that would detach from the dog's neck should it get caught. We created our collars in three adjustable lengths to fit dogs of almost any size.

Figure 3: Julius K9 vest with instrumentation on the sides.

Figure 4: One of our recent collars breaks away as a safety feature. Nonetheless it includes all the features needed to withstand the wear and tear.

We used nylon straps of 3/4 inches (1.9 cm) in width along with two plastic 'quick snaps' for each collar. The interior of the collar was lined with un-coated natural rubber (from rubber bands) to minimize the amount of slip. All of these materials can be purchased at a hardware store such as The Home Depot for a fraction of the price of a commercial collar.

Designing for the harness

Although we defined the four challenges using collar-based wearables specifically, these considerations are also suitable when working with a harness.

Working dogs have different types of harnesses, or none at all, depending on their occupation. We can generally divide them into two types: those worn by service dogs and those worn by dogs in field occupations. Our example of a service harness is the Julius-K9 Power harness (Figure 3, 5). These comprise some of the most versatile commercially available harnesses. The VELCRO® hook material on the sides is ideal for attaching new components.

Figure 5: Julius K9 vest with custom tug-interface on the left side

Safety
The main safety consideration when using a harness is keeping the components securely in place to avoid them falling off or having loose wires exposed. This is most important when securing the heavier components such as the battery. Because of the experimental nature of some of our earlier prototypes, we relied heavily on VELCRO® hook and loop fasteners to secure such components to the side of the vest (for reasons detailed below).

Despite using heavy-grade VELCRO® material, vigorous movement over long periods of time made these components fall off. To fix this, we used metal snaps to attach the components because they provide sufficient design flexibility yet enough strength to stay attached.

Space
Unlike the collar placement, the harness provides much more space. Having more space, though, does not mean that all of that space should be used because that would likely impact the weight and comfort.

Figure 6: Adding VELCRO® hook and loop material to the strap allows it to fold into itself to fit smaller-sized dogs

Weight and Comfort
Although the first inclination might be to place components on the top of the harness (particularly for service harnesses), this is rarely something we recommend. The top of the harness usually contains a handle that must be accessible in both field and service scenarios. In addition, significant weight (0.91 kg or 2 lbs) along the spine can affect the posture of medium-sized breeds and decreases their comfort. We suggest placing the components on each side of the harness, balancing them as much as possible to prevent it from slipping.

Fit can be much more challenging with a harness than it is for a collar. Not only must the harness body fit the dog well, the straps must fit too. When working with different dogs, we saw cases where the best-fitting harness came with straps that were too long for a given dog. In these situations, we found that adding VELCRO® hook and loop material to the strap allowed it to fold into itself to fit smaller-sized dogs (Figure 6) [3]. This solution was easy to put in place and worked well for several dog sizes thanks to the adjustable nature of the VELCRO® material.

Figure 7: A 10.16 cm stretch resistor. We ultimately used a 20.32 cm version. Reprinted with permission from Images Scientific.

Figure 8: We used 2.54 mm pitch terminals due to their breadboard compatibility. Reprinted with permission from Altech Coporation.

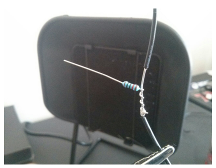

Figure 9: Soldering of a voltage divider for analog sensing.

Figure 10: A LightBlue Bean. Reprinted with permission from Punch Through Design.

Case Study: Respiration Monitor

The goal of this project was to create a wearable respiration monitor for explosive-detection dogs using an analog stretch resistor (Figure 7). Because police K9s already use vests like the Ray Allen Renegade Harness, we have focused on instrumenting this harness rather than designing a custom vest (Figure 11).

Wires and Connectors

Point-to-point soldering provides ideal strength compared to female headers or breadboards. Initially, we used larger platforms (e.g. Arduino UNO) due to the flexibility provided by general purpose female-header pins. Unfortunately, not only did this choice increase our weight and power consumption (due to the 5V UNO), it also led to wires coming out of their headers. The intermediate solution, for prototyping flexibility and connection strength, were screw terminals (Figure 8).

Analog sensors, like the stretch resistor, that require a voltage divider configuration, can be created by pealing off a small, non-contiguous segment of the wire insulation and making the necessary connection there (Figure 9).

Unlike the solid-core wire in Figure 9, the use of stranded wire might provide increased flexibility. In any case, we typically begin with .22 gauge variant of either stranded or solid core and change according to the need of a particular task.

Platforms

Beyond the issues of flexibility mentioned above, considerations of power had limited our platform choices in the past. Unlike the UNO, which has an easy-to-access barrel connector for power, smaller, more novel platforms required devising a new connection scheme that was just as robust. Failure to find both suitable power and programming ports led us back to larger platforms.

Figure 11: A new vest strap contained the stretch resistor to detect changes in respiration. This strap was attached to the vest using metal snaps.

Figure 12: An example of a harness used in field occupations, such as police and military working dogs, is the Ray Allen Renegade harness. This one is instrumented with a resistor-based respiration monitor.

Fortunately, newer platforms like the Punchthrough Light-Blue Bean address this issue (Figure 10). They afford enough flexibility in terms of size (dimensions), holes for prototyping, integrated coin-cell power (no need for a connector), and Bluetooth programmability (no need for a programming header). This last feature is particularly attractive for systems with constant 'tweaking', even while being worn.

Design

By using the Bean and the analog stretch sensor, we were able to keep the footprint of our components small and encase them in an elastic strap measuring 1.905 cm (3/4 inch) wide. This enabled us to keep the device design to the strap form factor and attach it to the interior of the vest with metal snaps. The new strap was placed under the existing chest strap that was built into the harness. When worn, the built-in strap helps to keep the new one from sliding. The snaps allow the strap to be easily removed for further prototyping as well as to quickly return the vest to its original state.

Final Result

By embedding the sensor as a new strap into the existing vest we achieved many purposes. The proxemic considerations do not change because there are no devices protruding from the vest and the weight is virtually unchanged. Finally, the elastic material is even softer than the original straps and hence, we can guarantee maximum comfort over long term use.

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