Snow Monitoring with Sensor Networks

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***Abstract*— We are engaged in the construction of a smart sensor network to monitor snow conditions and help determine avalanche probability in back country ski areas in the Wasatch mountains. These sensor networks will be comprised of devices having the ability to communicate, compute and sense the environment temperature, light intensity, pressure, and other properties. We have developed several distributed algorithms for such networks and demonstrated them in simulation and small-scale experiments. Our goal is to build and test a 50-100 node network through Fall 2004, and to deploy it for experimental study this coming winter.**

I. Introduction

Many advances have been made in sensor network technology and algorithms in the last few years. See [1] for an overview of the state of the art. Work has been done on: architecture [2], systems and security [3], [4], [5], and applications [6]. Our own work has focused on the creation of an information field useful to mobile agents, human or machine, that accomplish tasks based on the information provided by the sensor network [7], [8], [9], [10], [11].

We are developing a 50 to 100 node sensor network testbed for the experimental study of our algorithms. Given our location in the Wasatch mountains in Utah, and the number of deaths each year from avalanche or snow-related conditions, we are developing a network for deployment in the mountains in popular cross-country skiing areas. Figure 1 shows a shaded relief image of the Dromedary Peak area in Big Cottonwood canyon just outside Salt Lake City. This image is derived from floating point elevation values in meters. The resolution is 10m in both directions.

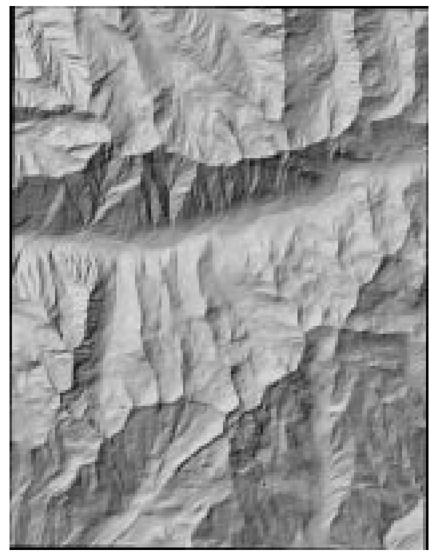

Fig. 1. Dromedary Peak Area in the Wasatch Mountains.

II. Sensor Nodes

The smart sensor network nodes will be based on the MSP430 family of processors from Texas Instruments [12]. The primary benefit of these processors is that they are extremely low power, operating off of 1.8-3.6V with an operating current of 330μA at 1MHz and several power saving modes. These processors are also rather versatile, available with a variety of options including analog to digital converters, digital to analog converters, and multiple memory configurations. For this particular application, the MSP430 can also be obtained with a built in temperature sensor which operates between $-40°$C and $85°$C. The MSP430 is available with 2 serial peripheral interface ports which allow communication with any number of SPI compatible devices. It also has a number of I/O ports which are usable for more traditional communication.

The nodes will communicate with each other by interfacing the MSP430 with the Chipcon CC1000 [13]. This RF transceiver will allow the nodes to communicate up to a few hundred yards depending on environmental constraints. The CC1000 is a low power device and has a programmable frequency of 300 – 1000MHz with a data rate of up to 76.8kbps.

We are developing sensors which will allow us to

Fig. 2. IR Snow Depth Sensor.

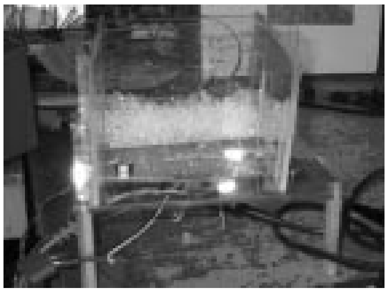

Fig. 3. Snow Depth Experimental Setup.

determine the sheer stress of the snow on a slope. This involves getting estimates of the snow density, height of snow, and slope of the hill. Slope can be determined by the use of an accelerometer. Height of snow and snow density, however, are more difficult to determine. It may be possible to use the weight of the snow (from a column above the sensor), the properties of light detection, or radio transmission variations due to snow conditions. It may also be possible to make a mobile device (e.g., a snow snake) which crawls to the surface and measures snow properties while moving.

In one approach to measure snow depth, a basic IR emitter/detector pair circuit was constructed and affixed to the bottom of a clear acrylic box. (Also, see [14].) Jewelry beads (4mm Rondells) were used to simulate snow. The Rondells are clear and multi-faceted such that in quantity they appear white, much like snow. These are much too large to accurately mimic snow but they avoid serious reflective aberrations noted with larger beads. Such effects are manifest as abnormally large readings when bead orientations provide greater reflectance towards the detector. The sensor is shown in Figure 2 and the experimental setup in Figure 3. Measuring the sensor output with various levels of this artificial snow shows that this system can determine depth. This particular system is limited however and can currently only differentiate in the first 2.5 centimeters.

We have begun to develop models for snow depth accumulation so as to have better simulation of the sensor network using the actual terrain data. We have also developed a model for wireless performance in mountainous terrain.

III. Conclusions

We are currently developing models of wireless operation in mountainous terrain and running simulations based on the terrain maps to determine optimal sensor node placement. In addition, we are exploring the use of such a network as an additional means to locate skiers who get caught in an avalanche; this requires the use of UHF receivers in order to triangulate the location of the skier's beacon. The parameters to be determined by the simulations include: node density, broadcast range profile, optimal node placement, best sensor suite, etc. Once the network is in place, we intend to develop distributed signal and data filtering, analysis and compression algorithms.

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