Possible Uses for Animal Tracking and Sensor Data

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Abstract: What other uses are there for animal tracking? We argue that the location data can be made more useful by analyzing it to determine the future position of animals and optimize farming. Other sensors such as temperature and RFID could be added to increase benefit for both farmers and scientists. Adding more sensors is not trivial and major challenges include energy consumption, cost, size and establishing a market. However these obstacles can be dealt with and the possibility of having mobile sensor platforms available to the public is intriguing.

1 INTRODUCTION

The invention of the GPS technology has revolutionized animal tracking. Animal tracking used to be reserved for scientists tracking radio tagged animals with big antennas. Now, with inventions such as Telespor (Thorstensen et al., 2004), farmers are tracking their animals and are able to easily locate them over the internet. This is of course a big improvement over the way it used to be, when the farmer could spend weeks walking in difficult terrain trying to retrieve his animals.

Large scale animal tracking generates vast amounts of data. A sheep flock can consist of several hundred animals that have their position logged multiple times each day for approximately three months. It is our opinion that using this data only to establish the location of animals is a terrible waste. Just by performing some simple analysis it could be possible to improve farming and create models of animal movement.

Adding different sensors to the animal is certainly possible if a modular platform such as Libelium's Waspmote is used. This will open up a range of new possibilities such as accurate local weather forecasting and predator detection. However it has far greater challenges and is therefore also more difficult to achieve than simply adding an analysis layer on top of the animal location data.

This article is focused on sheep and sheep farming, since that is what we have previous experience from. We feel however that many of the observations are true also for other types of animals such as cows, goats and horses.

This paper is structured as follows: Section 2 covers related work. In section 3 different uses for animal location data is described, including farming optimization and location extrapolation. Section 4 shows examples of what can be achieved by adding different types of sensors. The fifth section discusses difficulties concerned with adding more sensors. Section 6 concludes the paper.

2 RELATED WORK

The electronic shepherd research project (Thorstensen et al., 2004) culminated in the commercial Telespor product, which is the technology that Norwegian sheep farmers use to track their sheep. It has become quite popular and is also being used for cows. The technology is based on obtaining the position of the sheep via GPS and transmitting it via GSM to a central server. The farmer can then view the position of his sheep on a web site. This technology in itself already generates location data and can therefore be used for those things we suggest in the next section. It is not modular and therefore will need to be modified in order to support additional sensors.

In the survey on wireless sensor networks by (Akyildiz et al., 2002), they list a lot of the possible sensors that can be used in a wireless sensor network. These include temperature, humidity, movement, pressure and noise among others. This

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survey, although a bit old, is also a good introduction into many of the typical wireless sensor network problems such as energy consumption, cost and size issues.

Animal movement analysis is studied by (Jonsen et al., 2003) in an article concerned with how the data from GPS tracking can be used to create animal movement models. It uses state-space modeling to model animals' interaction with the environment while also dealing with measurement error. This method could be used if one would try to make a movement model for sheep based on the data from Telespor. State-space modeling for creating animal movement models has also been studied by (Patterson et al., 2008).

Finkenzeller and Müller has written a good introduction (Finkenzeller and Müller, 2010) into near-field communication (NFC) and RFID which is recommended for those interested in these emerging technologies.

There is a strong tradition for farming optimization. An example is the paper by (Mulder et al., 2006) which tries to optimize cattle breeding by testing out different breeding strategies and determine which strategy leads to the highest milk yield. In the article by (Zervas, 1998) he argues that there is a need for a collective optimizing strategy to best utilize the Greek pastures. A perfect mix of sheep and goats should be used to maximize the potential of the grazing areas.

3 USES FOR ANIMAL LOCATION DATA

An animal tracking system delivers a set of time stamped locations for each animal. This makes it possible to see the last known location of the animal and also create a trace of the animal's movement from the beginning of the tracking. But with some further analysis of the data, it is possible to increase the utility of such a system.

3.1 Location Extrapolation

Animals' movements are seldom completely random as they are conscious beings with certain needs. Examples of such needs are the need to sleep, eat and drink. This leads to patterns in their movement that can be used to extrapolate their current or future position based on the location data and a movement model. In its simplest form this location extrapolation can simply be to assume constant velocity and calculate a future location using the last known speed and direction.

Using knowledge of animal behavior it is possible to obtain far better predictions. Many animals sleep at night. Therefore their position at dawn will be close to where they ended up the previous evening. This can be used both in location extrapolation, by implementing a no movement at night rule, but also in duty cycling. Since the animals do not move at night, the tracking device can be switched off during this time and rather have more updates during the day.

To predict the future location of the animal weeks in advance, knowledge of animal behavior and tracking data from previous years becomes important. Their relative importance compared to last measured location and direction should increase the further into the future one tries to predict. Sheep can be used as a good example of how animal behavior can be used in far future prediction. Sheep prefer to eat the more nutritious early spring grass. To get to this grass, the sheep moves higher and higher up into the mountains as the summer progresses. This can be used to predict the altitude the sheep will most likely be at in a few weeks. Knowing the altitude it is possible to rule out areas that are either too high or too low. For such a system to work each animal type should have its own behavior model. Including previous year's location data to adjust the behavior model on an individual level would probably also be important. Animals are individuals and some prefer to stay with the flock while others are lone wolfs and do not come down from the mountains until the winter sets in.

To create a behavioral model it will be important to have one set of location data to use while developing it and another set of data to verify the validity of the model. It will also be important to test the accuracy of the predictions on an animal species basis. Some species have more regularity in their movement than others and can therefore be predicted further into the future. If it is even possible to give any meaningful predictions more than a few days in advance is an open question that requires further investigation.

3.2 Farming Optimization

Farmers have a strong tradition for optimizing the farms annual output. In case of sheep farms their output is measured in the amount of meat they produce. An example of such an optimization is the strategic breeding that has led to sheep that produce more meat and also meat of a more desirable quality in terms of fat percentage. We argue that the location data can be used to optimize farming in several ways.

Location data combined with knowledge of an animal's weight before and after the grazing season should be analyzed to establish the best grazing area. If one area over time sets itself apart from the rest, by providing a larger weight gain among the animals that have grazed there, measures should be taken to optimize the time the animals spend in that area. This optimization can be achieved in at least three ways. The animals can be released as close as possible to this area. This will lead to more animals discovering the good pastures and therefore graze there. Selective breeding is also an efficient way of controlling where the animals go to graze, since small animals learn from their mothers where to go. Therefore the grazing pattern of the animals should be taken into consideration as one of the parameters when deciding which animals should be allowed to breed. The grazing area can also be affected by the farmer by making it more desirable for the animals. This can be done by easing access via improved trails or by putting the salt stone in that area. The salt stone is a block of salt that the farmer place in the grazing area so that the animals have access to salt. The animals will go to lick the salt stone quite often. Therefore it is quite a popular spot for the animals and it makes sense to put it in the best grazing area.

When the grazing season ends it is time to collect the animals. Already this is greatly simplified by using an animal tracking system, but we think that there is still room for improvement. It should be possible for an animal tracking system to automatically find the shortest possible path to retrieve the animals. This is not as trivial as it might sound. To get a good solution it would have to take into account many factors: The start and end location, the presence and quality of trails in the area, the future position of the animals at the time of collection and the benefit of leading a smaller flock. There could probably be other factors as well. It would certainly be beneficial to the farmer to get a suggested path as the areas can be large and difficult to walk across and therefore choosing the wrong path can lead to many hours of extra work.

3.3 Other Applications

The location data collected from the sheep can also be used in non-farming related purposes. An example is automated collection of trails and paths. The sheep follows paths through the landscape and these can be mapped by a simple algorithm. The hypothesis is that the more the trail is used by the sheep, the better the trail. There are two reasons for this. First, the sheep is an animal that prefers comfort and will therefore choose the best trails from A to B. Secondly; the sheep creates their own trails through use alone. Therefore the more use the larger and better the trail. These trails should therefore be ranked based on their use and could then be presented to the public who wants to plan a hiking trip.

4 OTHER SENSORS

It is possible to attach sensors to an animal that can be used in combination with the location data to provide interesting information for the farmer as well as others. This section covers different sensor types and the benefit of adding them.

4.1 Temperature Sensor

The use of a temperature sensor can be divided into two categories depending on the sensors placement. The sensor could be placed as an external sensor that measures the ambient temperature. It is also possible to attach an internal sensor that monitors the animal's body temperature.

The external sensor is interesting as a tool in weather forecasting. The data collection is synchronized and performed multiple times in many locations. This gives a unique possibility to create accurate local weather models about how the temperature changes with the terrain. This kind of data collection would be almost impossible to achieve any other way. It is easy to get synchronized temperature readings from stationary weather stations and a scientist walking with a thermometer can add mobility. However, having 500 scientists walking around for 3 months, doing regular synchronized temperature readings, is impossible. The animals could easily have other weather related sensors attached as well. Examples include a barometer to measure atmospheric pressure and a moisture meter to detect rain.

An internal body temperature sensor could be a useful feature for farmers. A lot of animals die each year from diseases. By monitoring the animal's body temperature it could be possible to detect fever. The farmer could then take the appropriate action. This could mean seeing the animal to administer treatment or retrieving it back to the farm for observation. It could also be used to improve animal death detection. This can be achieved today by movement detectors, but they have a longer detection time. They require the animal to remain stationary for 24 hours. The long detection time is unavoidable since it needs to distinguish between sleeping and dead animals. A temperature sensor can alert the farmer the moment the internal temperature of the animal drop below normal values. This could save animals lives in a situation where they have been attacked by predators. If some dies, the farmer would be alerted much quicker. He can then tend to those that are wounded.

4.2 Gas Sensors

A gas sensor can measure the concentration of different gases in the air. Since some animals wander around in forests, it could be possible to attach a gas sensor to detect forest fires. Early detection is essential to minimize the damage caused by such fires. Therefore it would be very useful to protect the most fire prone forests by having animals walk around as mobile fire detectors. During a forest fire a nearby gas sensor would detect a sharp increase in carbon monoxide (CO) and carbon dioxide (CO^2) levels. This alone could be sufficient as a detection device. Combining it with an increase in temperature measured by a temperature sensor would further enhance the possible forest fire detection rate. Such a combination should be of the type where a fire is detected if the sum of gas concentration and temperature increase is higher than some defined threshold. This would make it possible to detect situations where there is a lot of smoke, and therefore a high CO concentration, but not yet a great increase in temperature. The temperature sensor can help in detecting fires when the wind is blowing the smoke away from the animal. An animal-based forest fire detection system would have to go through rigorous testing before being deployed. These tests would have to include the particular animal that the system is intended for. Without animal-specific tests it is impossible to tell how close the animal would go to a nearby fire. If the animals generally run away before the sensors can detect fires the system is of very little use as it could only detect fires that the animal could not escape from.

4.3 Microphone

A microphone can be used to listen for, and recognize, special noises in the environment. The question is what such a system should listen for. Since animals wander around in the forest or mountains an obvious choice is other animals or humans. The microphone could for instance try to detect the presence of predators such as wolves or foxes. This could be useful for public statistics. If an area has too many predators, maybe a choice has to be made between killing some of the predators or ban farmers from letting their animals graze in those areas. Birds are another thing that could be detected by a microphone. Since they often make very characteristic noises that are loud enough to be carried some distance, they are the perfect match for microphone-based detection. The information about the presence of birds in an area can be interesting for researchers as well as bird watchers. Also if it is a predator bird such as an eagle, it could be interesting for the farmer as well.

4.4 NFC or RFID

NFC and RFID are similar technologies since they both work over distances under a few meters and they only require one of the communicating parties to have power. Either of them can be used in an animal tracking network as proximity sensors. In the sheep tracking example it could be used to ensure that the lambs are still with their mother. It could also be used to check how frequently a particular spot is visited without continuous GPS tracking. In sheep farming this could be used to evaluate a salt stone placement. By placing a NFC or RFID reader next to the salt stone, the chip-equipped sheep could be counted. If few sheep use the salt stone, it can be moved to a new location. Similar applications are sure to exist in other types of animal monitoring as well. Animal proximity can also be used to trigger some event. In cattle farming it is already used to control that each cow gets the right amount food and do not steal food reserved for others. It could also trigger cameras so that it would be possible for the farmer to see images of their animals while they are grazing. This could be used to determine their current size which is an important economic factor as the income of the farmer is dependent on the total weight of the animals that are sold at the end of the season.

5 DISCUSSION

As have been documented in the previous chapter there are a lot of sensing tasks that can be performed by animals equipped with modular sensor boards. However there are four main obstacles: energy consumption, size, cost and establishing a marketplace.

Energy consumption is a major obstacle, especially if multiple sensors are added. Some sensing tasks also require the sensor device to be switched on all the time. This is not compatible with scenarios where animals are without supervision for several months. Having to change the battery on all the animals mid-season will in most cases be unacceptable. There are two solutions to this issue. The easiest is to fit a bigger battery. This solution is limited in two ways. The first is size. Big batteries are bulky and heavy. Forcing the animals to carry these for months on end could be considered as animal cruelty. The second problem is price as high capacity batteries are quite costly. The other solution is energy harvesting. As this study (Nadimi et al., 2011) shows, an animal, such as a sheep, generate a lot of energy while grazing. This could be used to power the sensors. This technology is relatively new and therefore it should be expected to become better, cheaper and smaller over the next years. This will most likely make energy harvesting a better solution than using big batteries.

A similar problem to energy consumption is the issue of size. If too many sensors are put on an animal it is not possible for it to comfortably carry the equipment. The size limit is of course animal-specific. A big cow can carry more than a small goat.

Cost is also a big factor. The cost of adding another sensor cannot exceed the perceived benefit of adding that sensor to the party responsible for paying for it. Adding a temperature sensor to measure the weather is not important to most farmers. Therefore the cost of adding a new sensor must be paid by those interested in using the data produced by that sensor. This would involve the weather service paying the farmer to be allowed to put temperature sensors on his animals. This leads to the last problem, the establishment of a common marketplace where farmers with free sensor capacity can offer that capacity to customers willing to pay the extra cost of adding more sensors. A web-based marketplace where customers can browse based on area and sensor type would seem like a good option for this kind of service. It should also be possible to discover already existing sensor deployments to allow new customers access to those data, for a price.

6 CONCLUSIONS

Animal tracking is already being used by both farmers and researchers to locate animals. By applying some logic, it is possible to add value to the location data. Location extrapolation to predict future locations and optimized farming is just a couple of examples. Since this can be done with the equipment being used today, this is merely a question of implementing the logic into the systems.

Adding more sensors could also be beneficial. The best candidates are those that can work well with discrete measurements, since they require less energy. Temperature sensors and RFID stands out as sensors that could be quite easily added and are very useful both to farmers and scientists. Generally adding more sensors are more complicated than doing more reasoning on the location data. Challenges such as energy consumption, cost and size are all serious concerns. The biggest challenge however is to establish a market for such a solution. To be successful it needs to be easy for farmers to offer sensor capacity to customers and for customers to find available sensors in an area. On top of all this it needs to be affordable. It is hard to tell if such a service is economically viable, as that depends on the application of the sensor data, but it would definitely be interesting to see it developed. Something so radically different could easily spawn new inventions only made possible by effortless access to mobile sensor data.

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