Identification of nesting phase in tortoise populations by neural networks.
Extended Abstract

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Abstract. The extinction of the tortoises is a critical problem on global scale. The most useful technique to assist their population growth was identified in the rescue of the eggs in order to protect the hatchlings during their first year of life. We propose an autonomous system based on input delay neural network that can automatically recognize the activity of the tortoise by analyzing signals recorded with a 2-axis accelerometer. Particularly the model is able to recognize the excavation of a nest. This research represents a good initial point to create an autonomous and complete system to localize nests in order to rescue eggs.

1 Introduction

In the last decade the environmental awareness among the public is increased. This concern includes the interest in the ecological state of reptile populations, especially those species that are declining on a global scale. Although the decline of population due to the natural causes is a normal process (and in general this is not a cause of alarm), often these declines are not natural. Non-natural causes are mainly due to human interference on reptiles habitat and on their daily life. In [7] the main causes associated to the reptiles decline are identified by six categories:

1. Habitat loss and degradation.
2. Introduced invasive species.
3. Environmental pollution.
4. Disease and parasitism.
5. Unsustainable use.
6. Global climate change.

For example, the loss of suitable habitat is the largest single factor contributing to the declines of reptiles ([1],[3] and [5]).
In particular, turtles and tortoises are among endangered reptiles populations and they are defenseless against the habitat degradation: deforestation, draining of wetlands and pollution from agricultural runoff. In addition to the habitat degradation, tortoise and turtle species are endangered by the harvest of their shells, eggs, oil, and meat. The introduction of new predators or new poisonous plants in their natural habitat is also an important cause of decline. One of the famous examples is the introduction of feral pigs in the Galapagos Islands ([17]). An analysis on the impact of habitat variation in the tortoise's life is presented in [21]. Especially environment pollution affects the habitat of turtles and tortoises, either directly or indirectly. For example, environment contaminants can have direct influence on the eggs, while indirect effects can be climate changes that alter the habitat. At the population level, the pollution effects may also occur through changes to patterns of individual energy allocation, which may result in less energy being devoted to reproduction or growth.
During the last few years, many organizations took part in defense projects of tortoises and turtles for restoring their welfare and supporting the population growth. A notable example is the protection program of giant tortoises (*Chelonoidis nigra*) that started in the last years at Galapagos Islands by the Darwin Scientific Foundation and the Charles Darwin Foundation. Its purpose is to restore the giant tortoise population in the islands. The Galapagos giant tortoises are not the only ones endangered, many species are in the same situation. In Jumby bay, the population of hawksbill tortoise (*Eretmochelis imbricata*) that is threated by the harvest, is monitored by the Jumpy Bay Hawksbill Project [13] run by the Jumby Bay Company. Other projects monitor the turtles and tortoises nests to improve the surviving of the hatchlings. For example, this is done in Southern California to protect the population of gopher tortoises (*Gopherus polyphemus*) [4] and in Madagascar and Mexico for different species of turtle and tortoises [18].
It is important to point out in these contexts that the identification and localization of nests is critical to assist population growth and to protect hatchlings. Usually herpetologists study the nesting phase in tortoises through observation and they identify the nests using their professional knowledge. The process conducted by herpetologists is very tedious and time consuming (see [13] section 2.1), which makes the operation impracticable on a large scale. Furthermore, each year the herpetologists have to operate on the field during the months of reproduction, whose duration depends on the species considered. Only during these periods it is possible to identify the nests or the females during the digging phases. To simplify this process and make it possible on large scale, it is necessary to use an automatic system to assist the herpetologists during the eggs rescue by identifying the animal behavior.
The automatic system needed to use both miniaturized tags attached on free-ranging animals and an intelligent system for localization of nest and performs the identification of animal behavior. This automatic system fits into the research field of biologging, introduced in [16] and described by Bograd in [2]. In next sections it is described the structure of the system, the data collecting and the neural network models used.

2 Automatic system to rescue eggs

One of the challenges in the defense of tortoise population is to develop an automatic system that is able to localize the nests through

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the identification of animals activities. This automation could support projects for increasing tortoise populations through eggs rescue in order to assist hatching during their first year of life. To this purpose, we design the biologging system Tortoise@. This system allow us a timely and easy localization of nesting side. Tortoise@ is sensor-based and it is capable both of localizing tortoises during the phase of nesting and of transmitting the geographical coordinates of the nest to a remote control center.

2.1 Material

The current prototype of our system exploits a number of sensors embedded on a programmable board. Specifically, it is based on an 8 bit, 8 MHz microcontroller, equipped with a 8 Kbyte RAM memory and 256 Kbyte of flash memory. It is powered by two AA batteries. The microsystem also embeds a light sensor, a temperature sensor and a 2-axis accelerometer. We are now extending this prototype by including GPS and GSM modules. The device is not water-proof in it self but the final prototype will be encapsulated with a protective cover that makes the device usable also for turtles (aquatic turtles).

The device is attached on the carapace of the tortoise in a way that does not impair their movements. Figure 1 shows a prototype attached on the carapace of a *Testudo hermanni*.

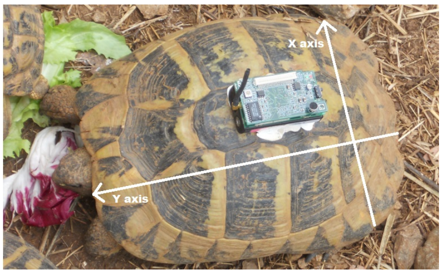

Figure 1. The prototype of Tortoise@ attached to the carapace of a tortoise. The two white axis are related to the accelerometer.

2.2 Structure of the system

It is well known that eggs deposition can occur only with certain environmental conditions. The system leverages several sensors to monitor the environment conditions and the movements of tortoise. The Tortoise@ system follows a sequence of stages to monitor the tortoises (shown in figure 2), which are:

1. Environment monitoring (EM).
2. Movement monitoring (MM).
3. Extended movement monitoring (EMM).
4. Data communication (DC).

In the stage of environment monitoring, the system monitors the environment parameters in order to identify the suitable conditions for the deposition. The stage of EM avoids the use of the accelerometer and GPS modules if the current habitat conditions are not suitable for deposition. This strategy enables saving the energy of the system. In this research, the suitable conditions for deposition are based on the habits of *T. hermanni* during their deposition period. This species digs nests during spring season with high temperature and in sunny locations; therefore the system monitors the brightness and the temperature of the environment. When the environment parameters are suitable for deposition, the system switches to the stage of movement

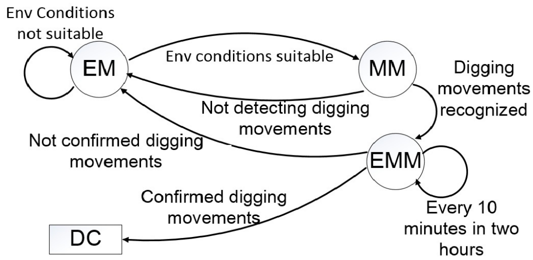

Figure 2. Stages of Tortoise@

monitoring. In the stage of MM, the system exploits the accelerometer to detect the digging activity of the tortoise, by analyzing its movements. When the response of this analysis is negative, then the system switches back to the stage of EM. Otherwise it switches to the stage of environment movement monitoring where it repeats the same activity monitoring used in the stage of MM. However, in the stage of EMM the activity monitoring is repeated along a longer period of time, with a frequency of about ten minutes. This is because the digging activity of the *T. hermanni* may last up to two hours, and in some cases the tortoise may stop this activity and leave the nest without deposing the eggs. The stage of data communication is activated only when the response of the stage of EMM is positive. The stage of DC consists in communicating the position data of the nest to a human station for the eggs rescue.

2.3 Data Collecting

The Tortoise@ prototype has been used at the “Centro di protezione delle tartarughe mediterranee” (CTM, Protection center for Mediterranean tortoises) in Massa Marittima. It is used to conduct data collection for several common species of terrestrial tortoises presented in Italy and hosted by CTM: *Testudo hermanni hermanni, Testudo hermanni boettgeri, Testudo graeca* and *Testudo marginata*. The data collection experiments have been conducted in June and July 2012. During this period we observed the behavior of tortoises in the breeds at CTM and we have registered the data by attaching the device to the carapace whenever main activities were recognized.

During that period we collected two-axis accelerometer data of about one hundred different activities in the daily life of around one hundred tortoises with different size and age. It has been possible to note that the main activities of tortoises are the eating activity, the walking activity, and the digging activity. The digging activity is reserved to the female tortoises. Among these activities, around 53 refer to nest excavations, while the others refer to walking and eating.

These data have been labeled and organized into a dataset of sequences of accelerometer signals that have been used to devise a methodology for the recognition of the main activities of the tortoises. This methodology builds over the observation that different activities are characterized by different patterns of the accelerometer signals. Specifically, we consider that the X-axis and the Y-axis accelerometer signals provide different information: the X axis indicates the movements of the carapace of the tortoise on the short side, the Y axis indicates the inclination on the long side of the carapace (the two axis are shown in Figure 1).

During the excavation the tortoise alternates the back paws to excavate a homogeneously shaped nest. As shown in figure 3 this signal of excavation is similar to a square wave, due to the alternated movement of the carapace along the two axis. In particular, the motion

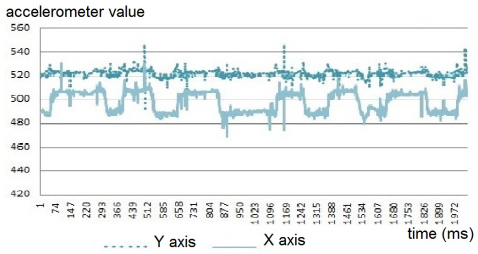

Figure 3. Signal recorded during the nesting phase

along the X axis represents the oscillation of the legs that move alternately the left and the right side of carapace. The oscillation on the Y axis is due to the depth of the nest and indicates the inclination of the carapace needed to reach the bottom of the nest. The eating

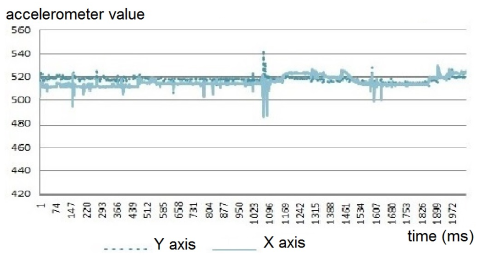

Figure 4. Signal recorded during the eating phase

activity is identified by a long period of semi-immobility with brief movements due to the interaction with the other tortoises or to the attempt to reach the food. A sample of this signal is shown in figure 4. Finally, unlike the two signals described above, the walking

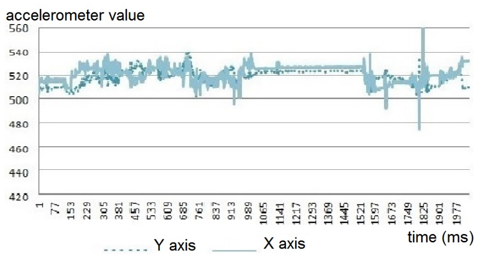

Figure 5. Signal recorded during the walking phase

activity is not identified by specific features of the signal, as shown in figure 5. In fact, the tortoise moves the carapace along the X axis and along the Y axis without any periodicity. This particularity of the signal is due to the fact that the movements of the tortoise follow the terrain typology and the obstacles on the path. For this reason, the movements are characterized by a variety of different patterns. Among these patterns, short patterns of alternated signals as occurring in excavation movements can also be occasionally observed (for example to climb an obstacle).

2.4 Artificial neural network models

An artificial neural network [8] is a machine learning model to approximate complex relationship between input and output data. Specifically artificial neural network can be used to classify the inputs as for signals of accelerometer in our work. An artificial neural network can be defined as a collection of formal neurons interconnected by having the output of each neuron function as input to a subcollection of neurons. A designated set of neurons receive external inputs, while another designated set of neurons is identified as a set of output elements. The fundamental aspect for learning is the presence of connections weighted by free parameters between neurons. The training algorithm allows to tune the weights of the neural network adapting the input-output mapping to the task at hand. Thanks to the flexibility of artificial neural networks we were able also to cope with the constrains of a real deployment on sensor board device. These conditions concern the small memory, the low complexity and the power available limited to batteries. Considering these conditions, the design of neural network configuration will result in a trade off between the ability to predict tortoise activities and the possibility to be implemented on a device.

Considering the data analysis described in section 2.3, our problem can thus be reduced to the recognition of the accelerometer patterns similar to the square waves. To this purpose the artificial neural network models is particularly suited to classify the patterns of interest in a context of noisy data. Given the dataset, it is necessary to provide a training set allowing the neural network to learn the recognition of the nesting phase. The training set is composed by positive and negative samples. The positive samples have been composed using a characteristic pattern. In figure 6 it is shown a sample from the set of positive case signals used for training the model. The window temporal amplitude is chosen in order to recognize the square wave form. For negative specimens, we use the samples of data taken from the phases of eating and walking.

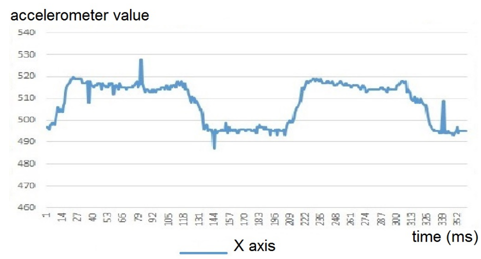

Figure 6. Characteristic pattern for activity recognition

The artificial neural network has to analyze in real-time the accelerometer signals, therefore creating a neural network that is pure reactive can't capture the real situation of the tortoise. To this aim we investigated the use dynamical network with memory elements as Time Delay Neural Networks (TDNNs). These neural networks have many application fields that range from vocal recognition [19],[9] to gesture recognition [14]. The memory elements gives to network the capability to handle the time depending problem in order to deal directly with temporal and sequential type of data. For this work we consider a subclass of TDNNs with delays limited to the inputs, this subclass is called input delay neural networks (IDNNs). The memory in this case is made by an input window on a temporal signal. IDNNs exploit a memory buffer allowing us to make decisions based

not only on the present input but also on previous ones. The memory buffer is an input window shifted on the temporal input signal of the movement. The size of window depends on the period that is necessary for classification for our purpose the window size of 90 seconds. This size was chosen based on the characteristic patterns. The IDNNs are composed with a hidden levels. Specifically to analyze the signal of tortoises' movements we choose to use one hidden level with a limited number of neurons founding a trade off between results of classification and a limited use of memory. The output level of IDNNs is used to classify the input window, in this case we use a sigmoidal classification with value between $[-1, 1]$. The output level classifies patterns with value close to 1 as movements of digging phase, and with valued close to -1, as movements of eating or walking phase. The artificial neural network generates its outputs value on the basis of its knowledge of the environment. The knowledge of the artificial neural network is obtained by the training of the model by the learning algorithm of backpropagation. The IDNNs model with standard structure is able to extract and classify the movements but it can lead to use an excessive amount of memory with respect to the capacity provided of the device. Hence, in addition to the use of IDNNs, we developed a model inspired by the Convolutional Neural Networks (CNN) ([11], [8] chapter 4) because it demands less memory space.
The CNN is introduced by LeCun and Bengio to find the locally sensitive and orientative nerve cells in the visual cortex of cat. CNN are usually applied for images and speech recognition, as described in [12] and in [10]. This network structure implicitly extracts relevant features by restricting neural weights of one layer to a local receptive field in the previous layer. This structure encourages the neural network to focus on the local features of the signal of digging phase. With this model we exploit the repetitive structure of the signal present in the pattern of excavation, as we can notice in figure 6. As shown in [11], the use of CNN reduces the number of free parameters through the parameters sharing technique thereby further reducing the memory occupation of the machine.

3 Conclusion

Our work presents the usage of artificial neural networks to implement an automatic identification of specific activity through the analysis of the signals of accelerometer. This automatic identification of signals is part of the Tortoise@ system focused on to the environmental monitoring and animal health care. The total amount of data for the analysis were one hundred signals. Each signal is about two hours. From these signals, we extracted patterns of 90 seconds and signals of 300 seconds, all data were supervised. We have trained and validated the artificial neural network that receives as input a pattern. Then we have tested the artificial neural network on the signals. The classification of the signals is made by considering the results of neural network on each window that composes the signal. The developed method achieves 96% of movements correctly classified distinguishing between the movements of excavation and other activities. The method can be employed for reliable recognition of the nesting phase signals movements. The 4% of misclassification is a reasonable accuracy considering the high noisy signals of analyzed context. Although the implemented method is at its initial stages, the results are promising and they seem to be already effective for providing a complete system for the localization of tortoises nesting sites.

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