Automatically Updated Soundmaps as a tool for environmental monitoring: Research in progress

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The research work presented here is focused on the development of a method for the formation of Automatically Updated Soundmaps (AUSs) aiming to utilize them as a tool for environmental monitoring, regional planning and decision making. The proposed method consists of three steps: Development and deployment of a Wireless Sensor (Microphone) Network – WSN (Step 1), Pattern Recognition of the Environmental Sounds recorded and transmitted by the network (Step 2) and automated Soundmap creation, publishing and update (Step 3). Ongoing research based on encouraging preliminary results obtained within the scope of Steps 2 and 3, (Paraskevas et al., 2009; Rangoussi et al., 2010), currently focuses on Step 1 issues (electronics design, energy awareness and communications aspects of the WSN) as well as on the integration of all three steps into an interoperable application. The novelty of this research, compared to other relevant works (Aspuru et al., 2011), (Lavia et al., 2011), lies in the engineering approach taken towards the development and automated updates of the AUSs, inspired by the similar yet distinct notion of noise maps.

Automatically Updated Soundmaps: Method Outline

Research related to the environmental or ecological assessment of landscapes was originally focused on their visual content, e.g., the morphological characteristics of a biotope. However, acoustic ecology has shown that the sound content of a site can be employed as a valuable additional information stream in order to characterize or monitor areas of ecological interest (Mazaris et al. 2009). Indeed, sound can provide an additional ecological indicator for areas of environmental interest, for purposes that include monitoring of the wildlife or the various human activities and their evolution with time. After appropriate signal processing, the large amounts of information required to this end, originally in the raw form of sound recordings, can be presented in the concise yet meaningful form of a soundmap.

Soundmaps are useful tools for the conservation of nature, because periodic assessment of soundmaps from a certain area can lead to significant ecological observations. They extend the mature concept of noise mapping to cover the whole sound / acoustic content of a site of interest, signals and noises all considered as useful information. In contrast to the geographic maps that are rarely changed, soundmaps require regular updates because they vary with time (Paraskevas et al. 2010).

In the following part, a three-step method is proposed for the development of an AUS:

Step 1: Wireless Microphones Network

The first step for the development of an AUS is the collection of sound recordings by microphones that are placed at selected locations over the whole area of interest. Sound is recorded locally but is processed centrally. Specifically, a wireless sensors (microphones) network is designed, developed and deployed so as to communicate the locally pre-processed sound information from the sensors to the central processing node, where the pattern recognition and the soundmap formation steps take place (Step 2 and Step 3), (Raghavendra et al., 2005).

Step 2: Pattern Recognition of Environmental Sounds

In the second step, sound/audio recordings are searched for 'events'; events detected are classified into a hierarchy of target classes. In order to 'feed' the classifier selected for this step, sets of features are extracted by signal processing of the sound recordings.

The pattern recognition step includes: (i) the feature extraction stage and (ii) the classification stage. In feature extraction, class discriminating features are extracted in order to classify each sound recording (Duda et al. 2000). Efficient feature extraction requires that the signals be transformed either to the frequency domain e.g., via the Fourier transform, or to the time-frequency domain, through a time-frequency signal representation, e.g., the spectrogram, according to their (non-) stationary character.

The classification of the environmental sounds is addressed hierarchically in levels that proceed from 'coarse' to 'fine' classification. Specifically, at the first level of the hierarchy, the aim is to group sounds into three major sound classes, namely: anthropogenic, geophysical and biophysical (other than anthropogenic) (Mazaris et al. 2009). At the second level, the aim is to further classify sounds into subclasses that belong to the same major class, e.g., to identify different species of animals within the major class of biophysical sounds. At the third level, sounds within the same subclass are further classified e.g., sounds produced by different kinds of birds (biophysical) are classified into the existing families of this species within the area of interest.

For the classification stage, different kinds of classifiers, e.g., distance metric classifiers, Artificial Neural Networks (ANNs) etc., can be employed. The final selection of a feature extraction and a classification method pair is typically driven by the spectral characteristics of the signals at hand; recognition performance can be critically influenced by a judicious choice, (see (Paraskevas et al. 2009), (Rangoussi et al., 2010) for a discussion on choices appropriate for the aims of soundmapping).

Step 3: Soundmap Formation

In the final step, each classified acoustic / sound 'event' (Step 2) is placed as a tag on a geographical map of the area of interest. The soundmap thus formed expands into various levels of detail, depending on the 'depth' of levels in the associated hierarchical classification scheme employed; it may therefore cover a wide range of environmental interests, visualizing the results of the sound classification (Rangoussi et al., 2010; Paraskevas et al., 2011).

At this point, the relevant research carried out in Greece by the 'Reconstruction Community' Group is worth referencing. A sample of this work (t-echos) can be found in (Reconstruction Community, 2011). The methods and tools employed therein differ from the ones employed here, however, because the main purpose of that work is the development of soundmaps for the monitoring of noise pollution within urban surroundings, while here the purpose is to monitor the whole sound / acoustic content of a natural environment of interest, mainly for nature preservation, ecology and regional planning purposes.

Applications

Web publishing and periodic update is designed to be the typical function of the AUS of an area of environmental interest (e.g. a NATURA 2000 protected area). Hence, governmental / non-governmental agencies will be able to monitor and compare these AUSs in order to draw conclusions that will assist the decision making process regarding the area of interest. Moreover, the audio related information (AUSs) can be combined with visual information from cameras, in order to protect certain areas more efficiently. Thus, the proposed method aims to contribute to the multidisciplinary research related to acoustic ecology from the aspects of a wireless sensor system for automated environmental monitoring, the pattern recognition of environmental sounds, and the soundmap formation.

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