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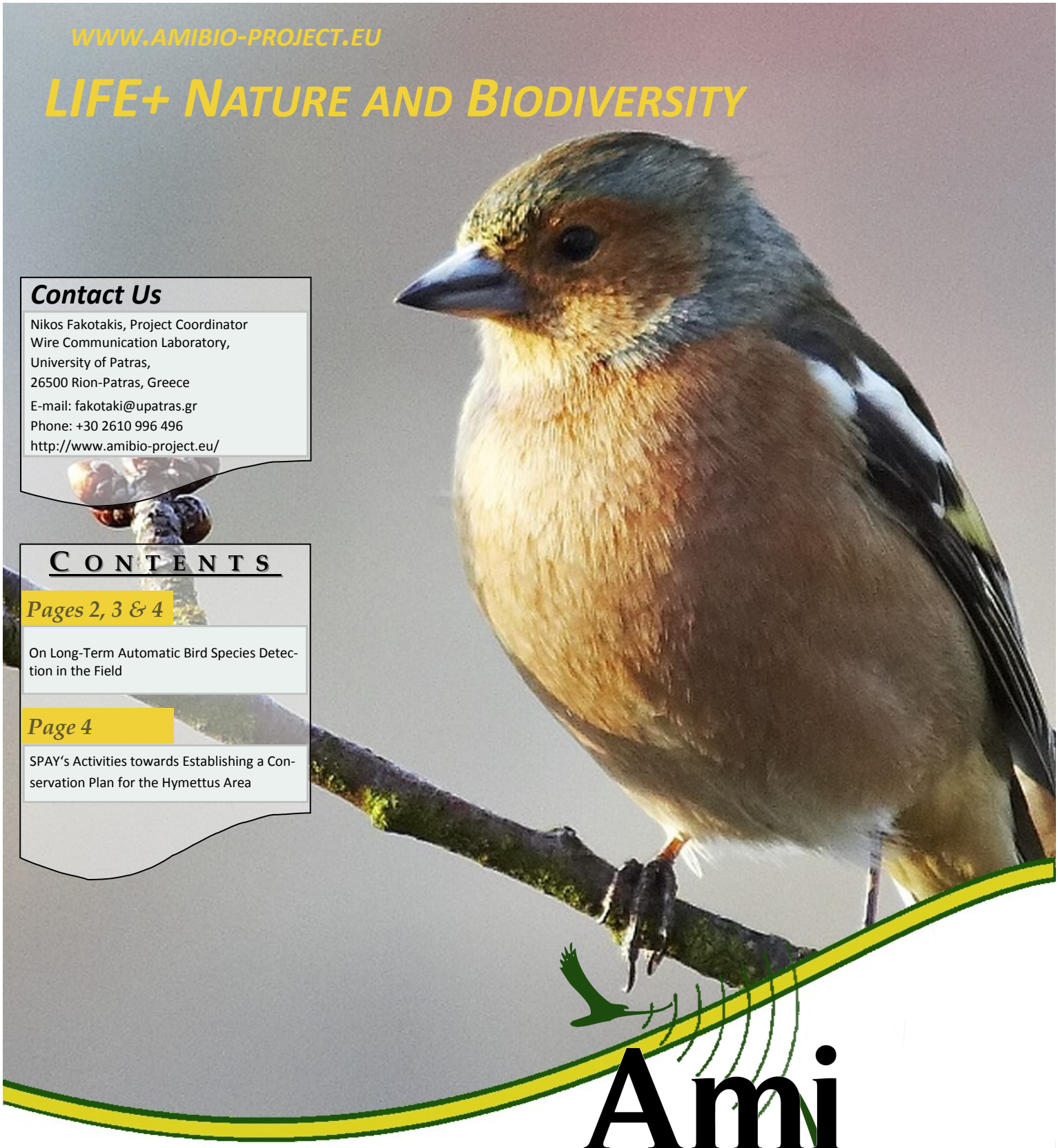

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On Long-Term Automatic Bird Species Detection in the Field

by Ilyas Potamitis and Petros Petrakis

In order to face the fact that many bird species are currently endangered or vulnerable we need to design conservation policies to correct population decline and reduce future risk of extinction. However, these policies rely on the understanding of birds' biology and interaction patterns which can be determined through the study of known individuals over time. Capturing and tagging of individuals in order to keep track of the birds' biodiversity can be very difficult, impractical and obtrusive.

It is now established that birds that produce sound as a means of communication can be categorized according to their sound emissions that are species-specific while species richness in a habitat can be assessed more rapidly than manual surveys. Therefore, long term acoustic monitoring of species and their population trend serves as indicator of environmental health, is non-intrusive and cost -effective compared to human expeditions.

The practical outcomes of developing autonomous remote recording stations and the analysis of their data are:

1) *Biodiversity assessment and inventorying of an area*: Visual surveys and human involvement typically give good spatial coverage, but they are very difficult to perform, have limited time-span and can be obtrusive. Acoustic monitoring can be set up for systematic seasonal and longitudinal long-term environmental monitoring that allows the automatic inventorying and examination of the biological diversity of a region as well as for long term monitoring of biodiversity activity trends of a region.

2) *Estimation of the density of species in the monitored areas*: Global environmental crisis is manifested in declining number of species and the status of population within a species. The species and their density can be used for drawing conclusions on the pollution levels, destruction of the habitat and migration of birds. Therefore, long term acoustic monitoring of certain species and their population trend serves as indicator of environmental health, human intervention and climate change.

3) *Draw a list of protected species under the Birds Directive, Habitats (FFH) Directive, and according to the global IUCN Red List*: Monitoring and alarming about the presence or absence of rare species or species under extinction in inaccessible areas or night-migrating birds and density populations can be inferred from of animal vocalizations which, subsequently can be related to species richness and diversity loss indices.

4) Alarming of specific atypical sound events such as these related to potentially hazardous human activities (e.g. gun shooting, tree cutting).

The progress of bioacoustic technology during the last years is evident especially in the field of hardware products that now offer Autonomous programmable Recording Units (ARUs) powered by solar energy with large storage capacity that can record for large periods of time, affordable weather proofed normal and ultrasound microphones, wireless sensors for data transmission, microphone arrays for location and population estimations and GPS tagging of recordings. In parallel to hardware progress, large amount of bird recordings are becoming available (e.g. McAulay and DORSA) and acoustic signal processing and pattern recognition in bioacoustics signals for the purpose of detecting or identifying bird species is currently a very active research area.

Pattern recognition of bird sound has a long history and many signal transformation, feature extraction techniques as well as pattern recognition approaches have been applied to the problem of automatic bird detection and identification. To our point of view, reported bird recognition approaches follow the evolution steps of speech recognition starting from employing limited, species-specific recordings, heuristic feature extraction, template matching techniques and multivariate statistics and are now moving progressively to more advanced pattern recognition techniques such as neural networks, SVMs and HMMs as well as species independent acoustic features.

Most previous studies typically make use of recordings either from databases or –fewer– make use of real field recordings. However, in either case these recordings are manually selected, evaluated and annotated by experts and are of high quality. Moreover, the operational settings of the recognizers are laboratory based in the sense that vocalizations are manually cut and annotated before presented to the recognition engine in order to test the efficiency of the recognition process.

The approach followed in this work is based on the observation that bird songs bear strong similarities to spoken human language (see Fig. 1). As speech processing has been a major research area through several decades it has currently reached the maturity of launching commercial products. The experience accumulated in this area to our point of view, can provide ground for boost in the related area of bird detection-recognition.

The following sections provide the insight of AmiBio species detection system and the pattern recognition techniques used.

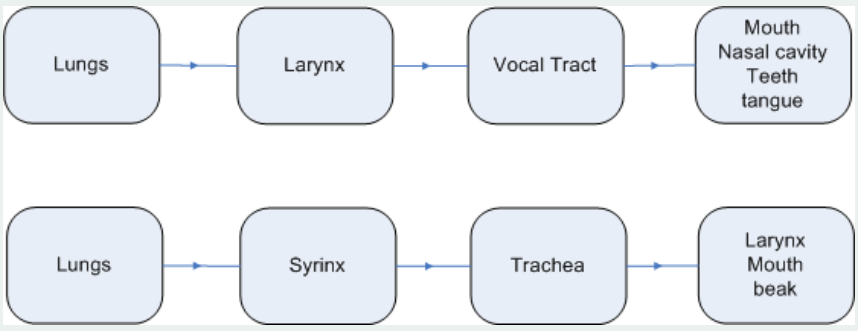

Fig. 1. *Sound production in humans (top) and avian (bottom)*

Detecting Fringilla Coelebs

Birds produce a variety of sounds to communicate, that can be separated into two large categories: Calls and Songs. Calls usually refer to simple frequency patterns of short, monosyllabic sounds that correspond to food or offender messages. While all birds produce calls only a subcategory of birds produces songs as well as calls (the so called songbirds, order passerineform, suborder passeri). Songs are longer, acoustically more complex, modular structures. Their basic elementary unit are simple non-separable segment of the spectrum (also called elements, pulses, or notes). Different elements make larger units called syllables. Syllables, in turn make phrases. Syllables in the same phrase form a statistically repetitive sequence. The various hierarchies of phrases and its subunits make the songs. The number of different syllables, phrases constitutes its syllabic-phrases repertoire while the recombination of phrases makes the song repertoires (see Fig.2)

As our aim in AmiBio is the long-term automatic monitoring and alarming about the presence or absence of bird species in the Hymettus mountain, we propose a novel species-independent detection-recognition framework that,

a) Detects and extracts the species of interest (in our case the Chaffinch -*Fringilla Coelebs*) from very long real-field recordings. Due to their enormous size (of the order of Terabytes for a single station of annual recordings) these data cannot not be manually processed or examined or annotated by human observers, thus the AmiBio system is designed to face the practical limitations of handling enormous amounts of data and the unknown boundaries of vocalizations.

b) The operational ground is strictly the real-field and the recordings are not selected to be of high quality. Therefore they include all kinds of acoustic degradations encountered in nature such as wind, rain, interfering audio sources, frequency selective attenuation due to distance and acoustic reflections.

Our approach to detect a specific species applies two passes on the original data of the ARUs. First, a statistical sound activity detector is used to reduce the original training data (first pass) and to annotate automatically all available data. Following, a global bird detector is applied on the data to reduce the search space to a pool of audio data that is composed only of bird vocalizations. At this stage the bird vocalizations detected are manually verified and further used in the adaptation phase of the global bird recorder. The adapted global bird detector is re-applied to the search space after the first pass. Finally a more sophisticated decoder that is tailored to the specific species is applied to the detected results of the first pass. While the first is fast and designed to screen out most of the irrelevant audio events, allowing many false alarms, the second pass is designed to be elaborate and exact and therefore computationally intensive.

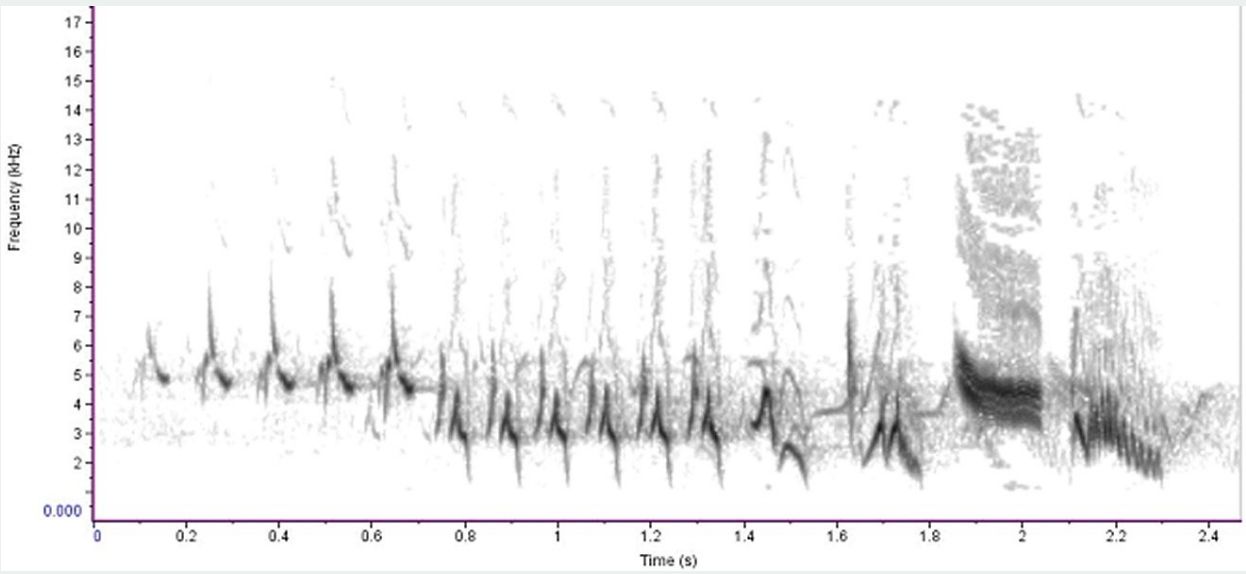

Fig. 2. *Song of Fringilla Coelebs*

Pattern Recognition Techniques for Birds Vocalizations

The bird verification process based on its vocalization is a typical two-class decision problem ending with a binary decision of existence about the species that vocalized a specific utterance. The bird detection task in very long recordings has to detect the portions of the vocalization, where a specific species vocalizes. It also has to determine the boundaries of the audio parts uttered by the enrolled bird-species. The bird detection task normally consists of three stages: a) segmentation of the audio into regions with birds' presence; b) clustering in one cluster per bird species; c) labelling with provisional labels each cluster with a species identifier (in our case the Chaffinch). This task often serves in various content extraction schemes. The clustering collects the vocalizations belonging to an individual or (individuals of the same species) into a repository. Subsequently, this repository is used for species-dependent adaptation of species-independent vocalizations' recognition engines. We apply the framework of hidden Markov models (HMMs) as it is able to deal with patterns that vary both in time and frequency and is able to incorporate a language model into the decoding procedure that we intend to use in order to incorporate context information. We employed the Hidden Markov model Toolkit (HTK) which has been deeply explored by the speech processing community mainly for speech and speaker recognition.

In focus

SPAY's Activities towards Establishing a Conservation Plan for the Hymettus Area

by Vassilis Nomikos and Vassiliki Dimitriou

SPAY, according to its objectives and legal status, is acting as an adviser for the state authorities on matters concerning the protection of the Hymettus area. This status was gained through a lot of sustained effort to protect the mountain from the various threatening dangers (of which fire is first on the list), to maintain and develop its biodiversity through reforestation activities, to educate and aware the citizens of the area on environment protection issues and to provide non-formal environmental education for school children.

Acting as such we are entering in consultations with state officials in order to conclude the legal infrastructure necessary and to proceed with the materialization of the Hymettus Conservation Plan and then to proceed in becoming this plan a legal document and not bits and pieces on various legislation.

Our consultation included meetings with: Ministry Of Environment, Ministry of Public Order, Headquarters of Fire Brigade (Chief), Ornithology Society, Head of Athens District, University of Athens Geology and Geoenviroment Dpt. (Chief), Head Of Attica Eastern District, Local Union of Attica Municipalities, Nuclear Science Laboratories (Demokritos) President (State Controlled Organization), Head of Environmental Committee of the Greek Parliament, Mediterranean SOS (nongovernmental organization), Students of Technical High School of Ilioupolis, Students of Deree College of Agia Paraskevi, Fire Brigade Training Academy (Chief), Fire Brigade Operations Center (Chief), Military Command of Eastern Mediterranean, Municipalities SPAY's members.

The consultations resulted to :
- The establishing of independent Hymettus Forest Authority (Dec 2010) Not in full operation as yet.
- The new Law for Preservation of Biodiversity (Law 3937/31 March 2011)
- The Presidential Decree for the determination of measures in protecting Hymettus Mountain (Government Gazette No 187/16 June 2011).

We are still expecting Ministerial Explanatory Circulars from the Ministry of Environment and consultations with Ministry officials in order to finalize the contents of the Conservation Plan, the supervising Government Body and the financing of the project.

Project progress

Pattern Recognition Techniques for Birds Vocalizations

(continuation from Page 3)

Training Data. For the global bird model we used 20 recording for each of the 127 species of Hymettus (~2540 recordings pooled together). These recordings contained little background noise and were of high quality. Furthermore we employed 234 recordings of the Eurasian Chaffinch with a mean of 10 syllables per recording for the detector of the Eurasian Chaffinch. The training data used to train the global bird detector model as well as the recording of the Eurasian Chaffinch were extracted from the DORSA database.

Model Adaptation. The baseline system (global bird model) is trained using high quality data. The individuals that the system will face in the operational conditions of Hymettus will not match the training data as the background noise, reverberation and frequency selective attenuation due to the distance of the bird and possible obstacles will be local characteristics. To better account for the acoustic variability of the operational condition we use bird calls and songs from the Hymettus mountain to form a corpus of acoustic data that will be used for adapting the initial models of the baseline system. The adaptation data are found by applying the global bird model on the Hymettus data and by manually screening out false detections of bird vocalizations. The advantage of the adaptation process is that it is fast and requires moderate amount of data in order to achieve performance approaching this of matched data.

State modeling. Detection of a specific species must be carried out regardless of any changes to its song repertoire. Moreover its repertoire characteristics may change over time, using different call categories. In order to assist the matching procedure of the HMM based on feature extraction form the spectrogram we incorporate an additional source of information coming from the observations of the recordings of the European Chaffinch. By annotating manually the syllables of songs and calls we produce a pattern of transitions from syllable to syllable (i.e. a language model). Males of this species have a small repertoire of one to six song types and 8 calls.

First Author's Profile: *Ilyas Potamitis is Assistant Professor at the Department of Music Technology & Acoustics at TEIC. He holds a PhD from UOP, in the area of "Speech enhancement techniques in the context of automatic speech recognition". His scientific interests are in the following fields: speech signal processing, recognition and enhancement, Hidden Markov Models, Bayesian statistics, Independent Component Analysis, microphone array techniques for DOA estimation and localization, multi-sensor multi-target tracking techniques. In AmiBio he is working on the automatic bird species detection.*

Cover photo: **Male chaffinch—*Fringilla coelebs***. Photo taken by Michael Apel (en.wikipedia.org/wiki/File:Fringilla_coelebs_male1.jpg).