SMASH

machine learning for science and humanities postdoctoral program

This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 101081355.

Co-funded by
The European Union

ML and animal communication

Prof. Todor GANCHEV, Technical University of Varna, Bulgaria

UNIVERZA V LJUBLJANI

Jožef Stefan Institute

IZUM
Institute of Information Science Maribor

REPUBLIC OF SLOVENIA
MINISTRY OF THE ENVIRONMENT, CLIMATE AND ENERGY
SLOVENIAN ENVIRONMENT AGENCY

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Bio-Sketch

Prof. Todor Ganchev

Dept. of Computer Science and Engineering
Technical University of Varna, Bulgaria
University Federal Mato Grosso, Brazil (2011-)
University of Patras, Greece (2000-2012)

Artificial Intelligence Laboratory

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Prof. Todor Ganchev
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Technical University of Varna, Bulgaria
University Federal Mato Grosso, Brazil (2011-)
University of Patras, Greece (2000-2012)

Leadership

Head of the Artificial Intelligence Lab (2019-now)
Vice-Rector of Research at TU-Varna (mandate 2019-2023)
Vice-Chair of IEEE Bulgaria Section (mandate 2023-2025)

Research

200+ research papers (2 books, 60+ journal articles)
3300+ citations (H-index = 29)
30+ projects (FP5, FP6, FP7, H2020, COST, LIFE+, InterREG, etc.)

Membership

IEEE Senior Member (2010-)
Confederation of Laboratories for AI Research in Europe (CLAIRE) (2018-)
The AI Cluster Bulgaria (2022-)

Awards

"2013 Joachim Adis Prize for Interdisciplinary Tropical Ecology"
"2023 Varna Prize for Individual Achievements in Technical Science"

OUTLINE

- Animal Communication
- Information Extraction
- Computational Bioacoustics
- Success Stories

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DALL·E 2024-10-05 10.27.49

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Hypothesis test:

H1: Animal communication is a fascinating field – observations reveal the complexity and diversity of the natural world.

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OUTLINE

- Animal Communication
- Information Extraction
- Computational Bioacoustics
- Success Stories

Hypothesis test:

H1: Animal communication is a fascinating field – observations reveal the complexity and diversity of the natural world.

H0: Well …, the available data do not support H1.

DALL·E 2024-10-05 10.27.49

Animal Communication

1. Diverse Methods

Animals employ a wide range of methods to communicate:

- *Acoustic Emissions:* Sounds like *Vocalizations* (barks, howls, chirps, and songs), *Stridulations*, *Drumming*, etc.
- *Body Language:* Postures, gestures, facial expressions, and movements.
- *Chemical Signals:* Pheromones and scents.
- *Visual Signals:* Colors, patterns, and displays.
- *Tactile Signals:* Touch, grooming, and vibrations.

Animal Communication

2. Purposeful

Communication serves various purposes:

- *Social Bonding*: Maintaining group cohesion and cooperation.
- *Reproduction*: Attracting mates and defending territories.
- *Food Acquisition*: Finding and sharing food resources.
- *Avoiding Predators*: Warning others of danger.
- *Navigation*: Providing directions and guiding group movement.

Animal Communication

3. Species-Specific: Communication methods are often unique to specific species, reflecting their evolutionary history and ecological needs.

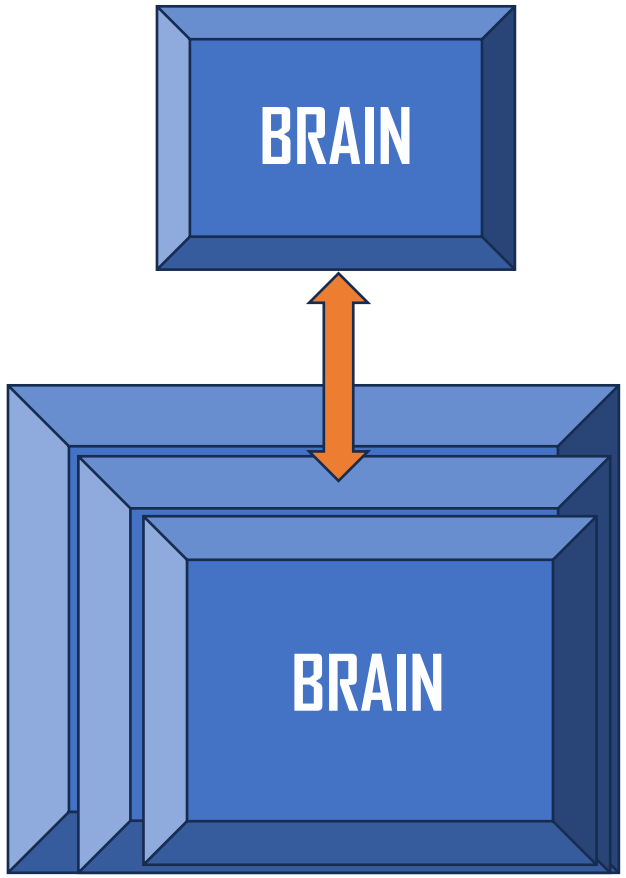
4. Context-Dependent: The meaning of a signal can vary depending on the context, such as the social hierarchy, environmental conditions, or the relationship between the sender and receiver.

5. Evolving: Animal communication is not static; it can evolve in response to changing environmental pressures and social dynamics.

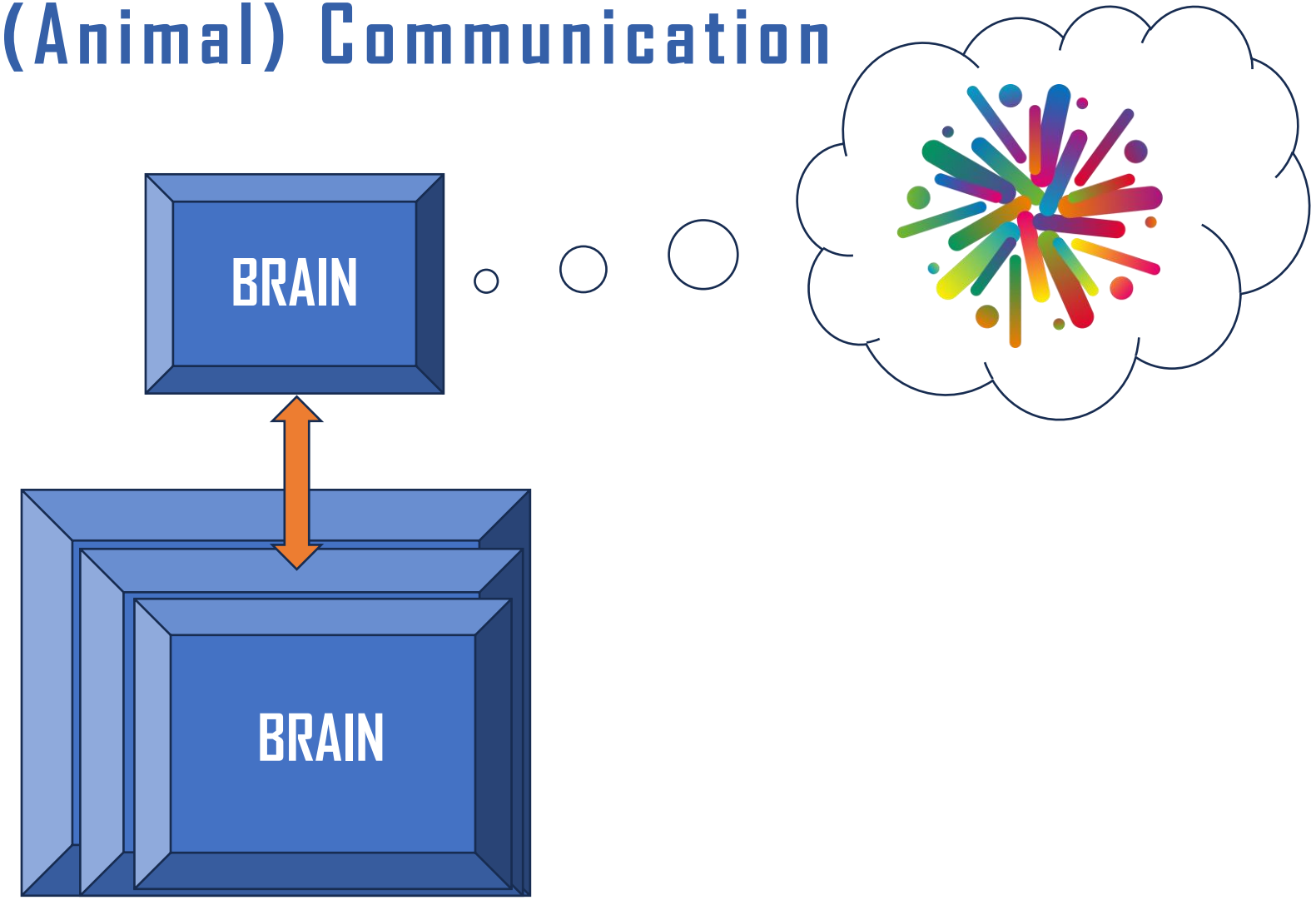
6. Complex: While some forms of animal communication may seem simple, they can involve intricate systems of signals and interpretations.

7. Inter-Species Communication: While most communication occurs within a species, there are examples of inter-species communication, such as symbiotic relationships or predator-prey interactions.

(Animal) Communication



(Animal) Communication



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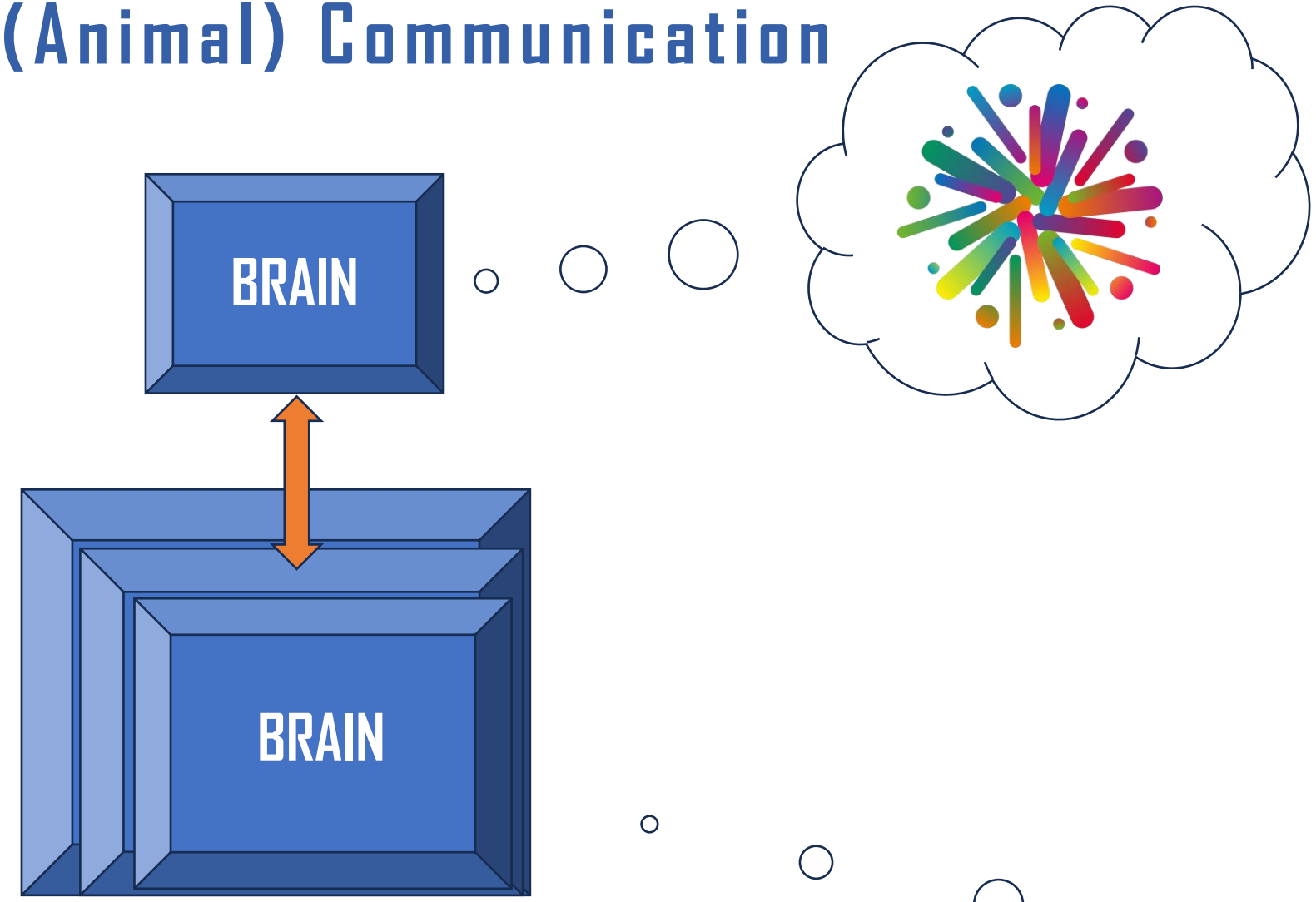

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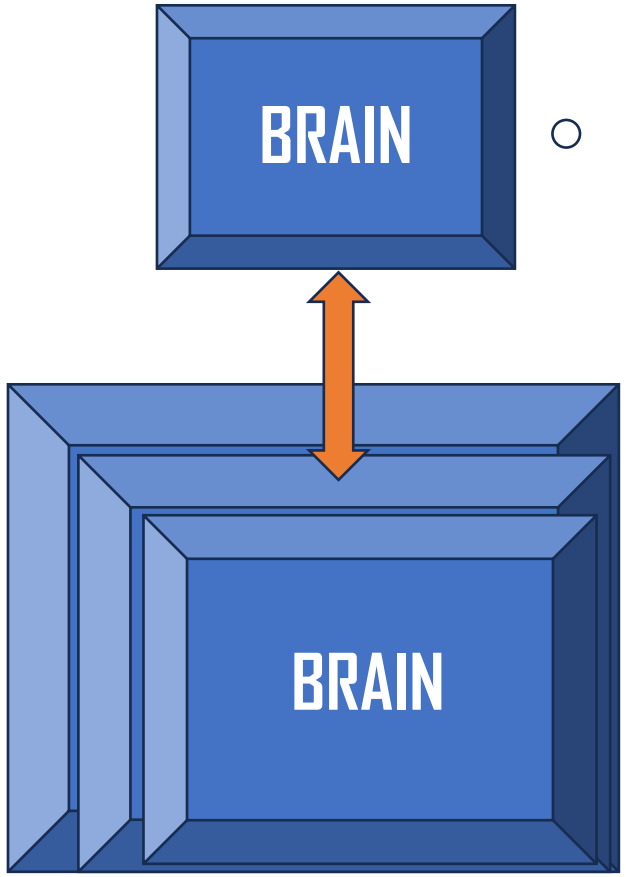

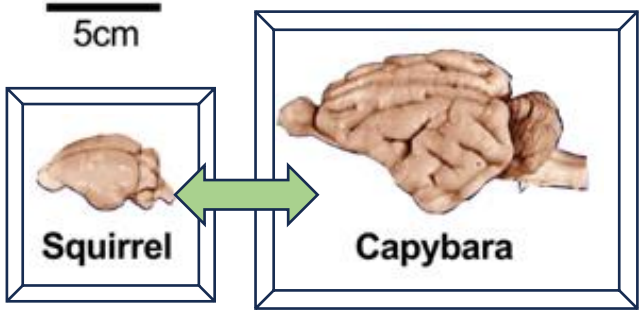

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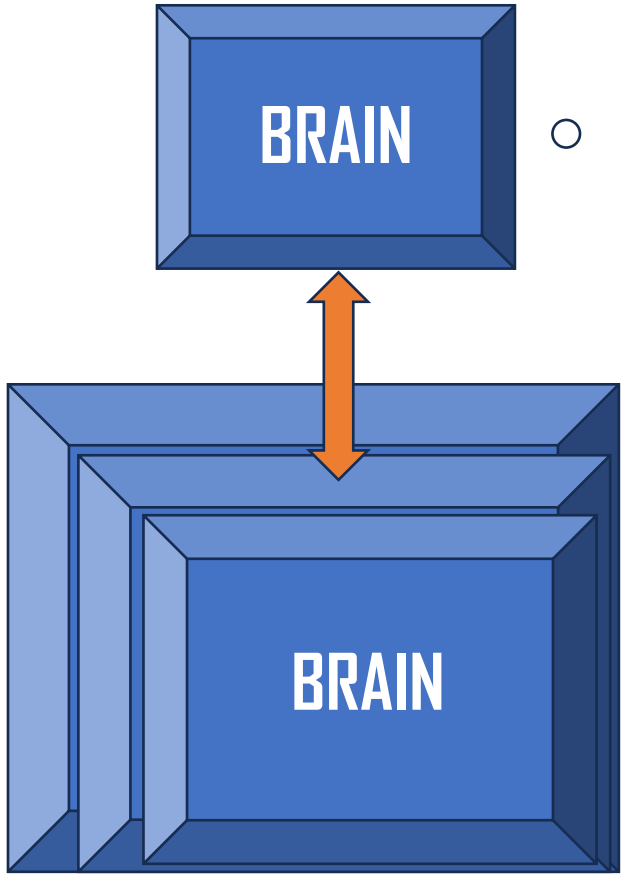

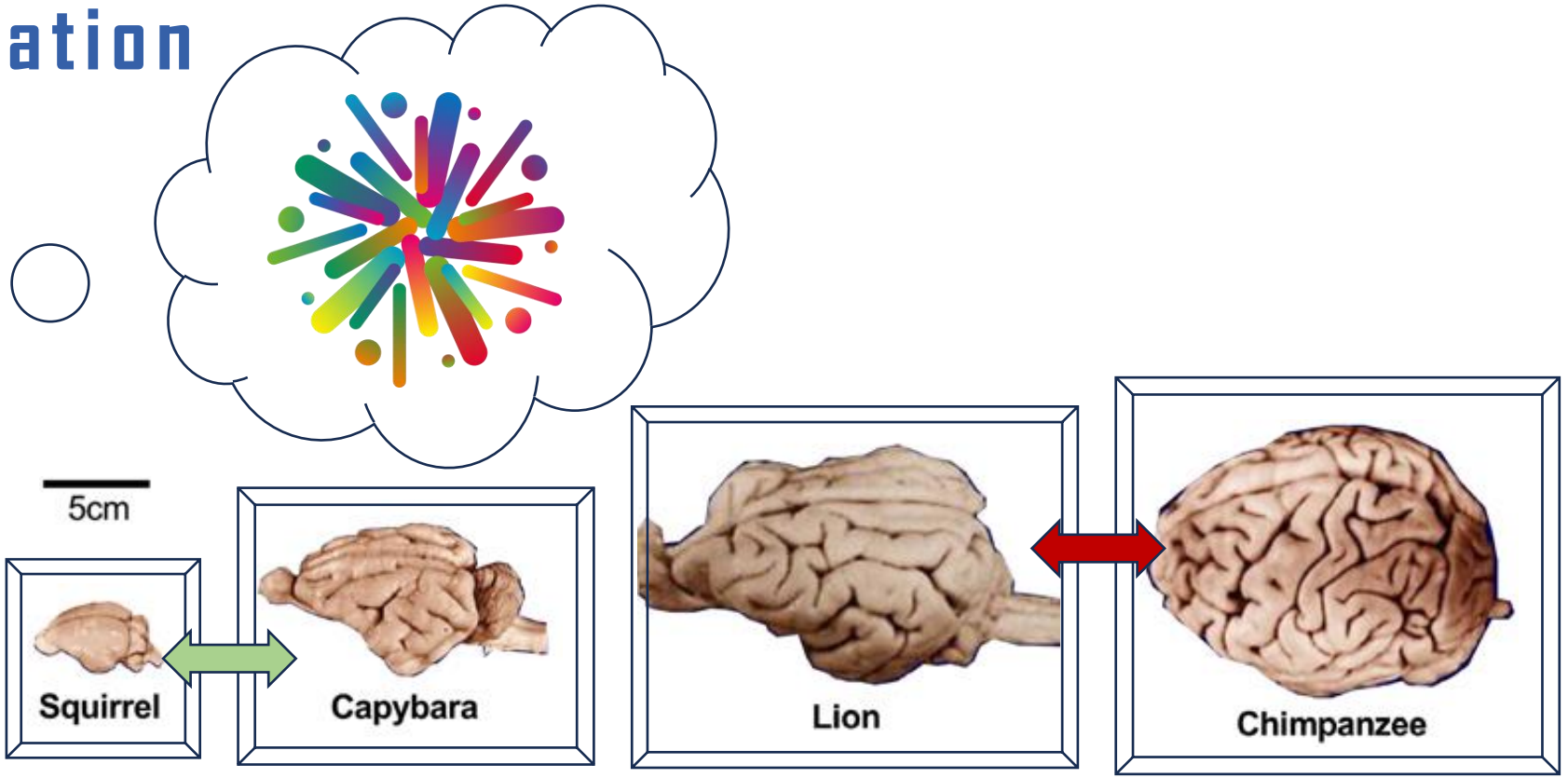

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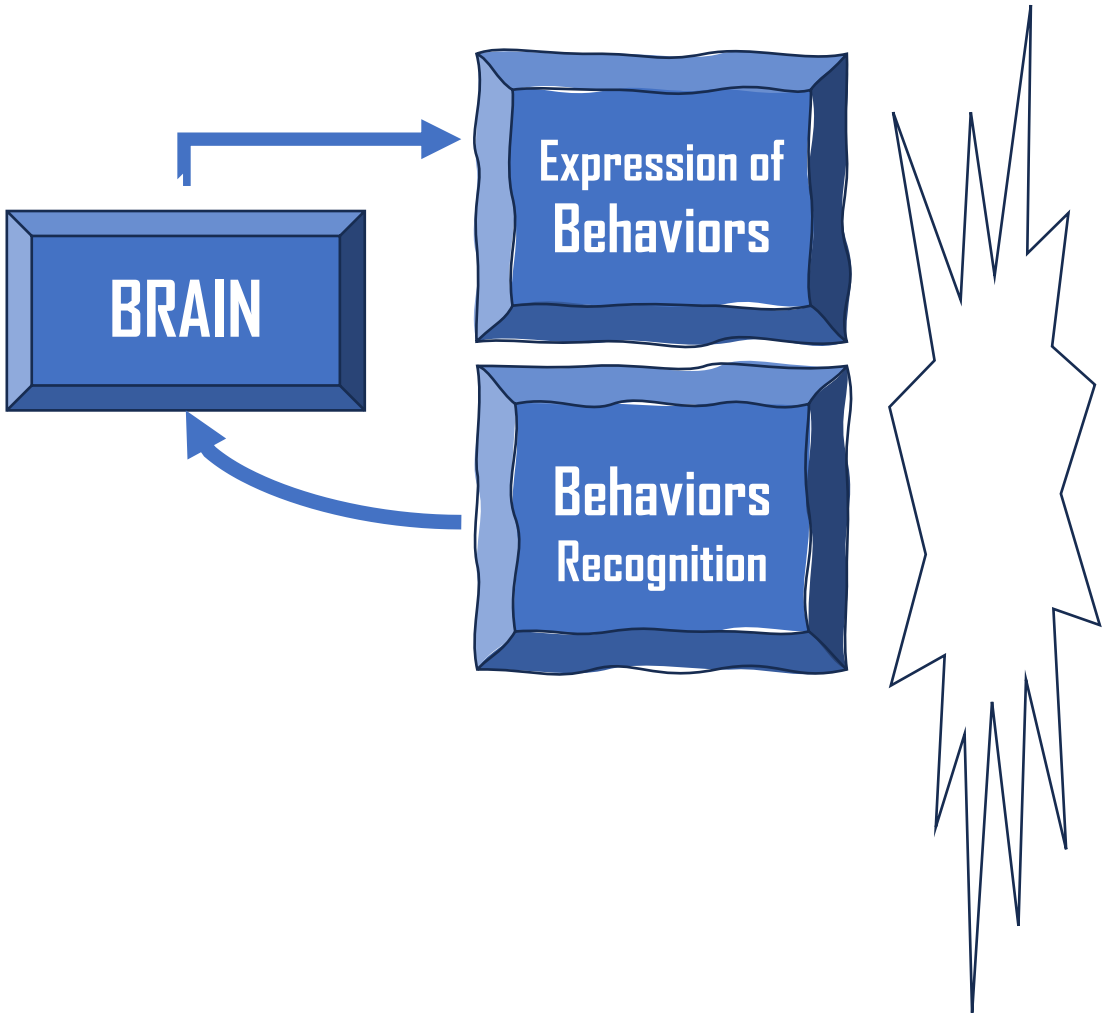

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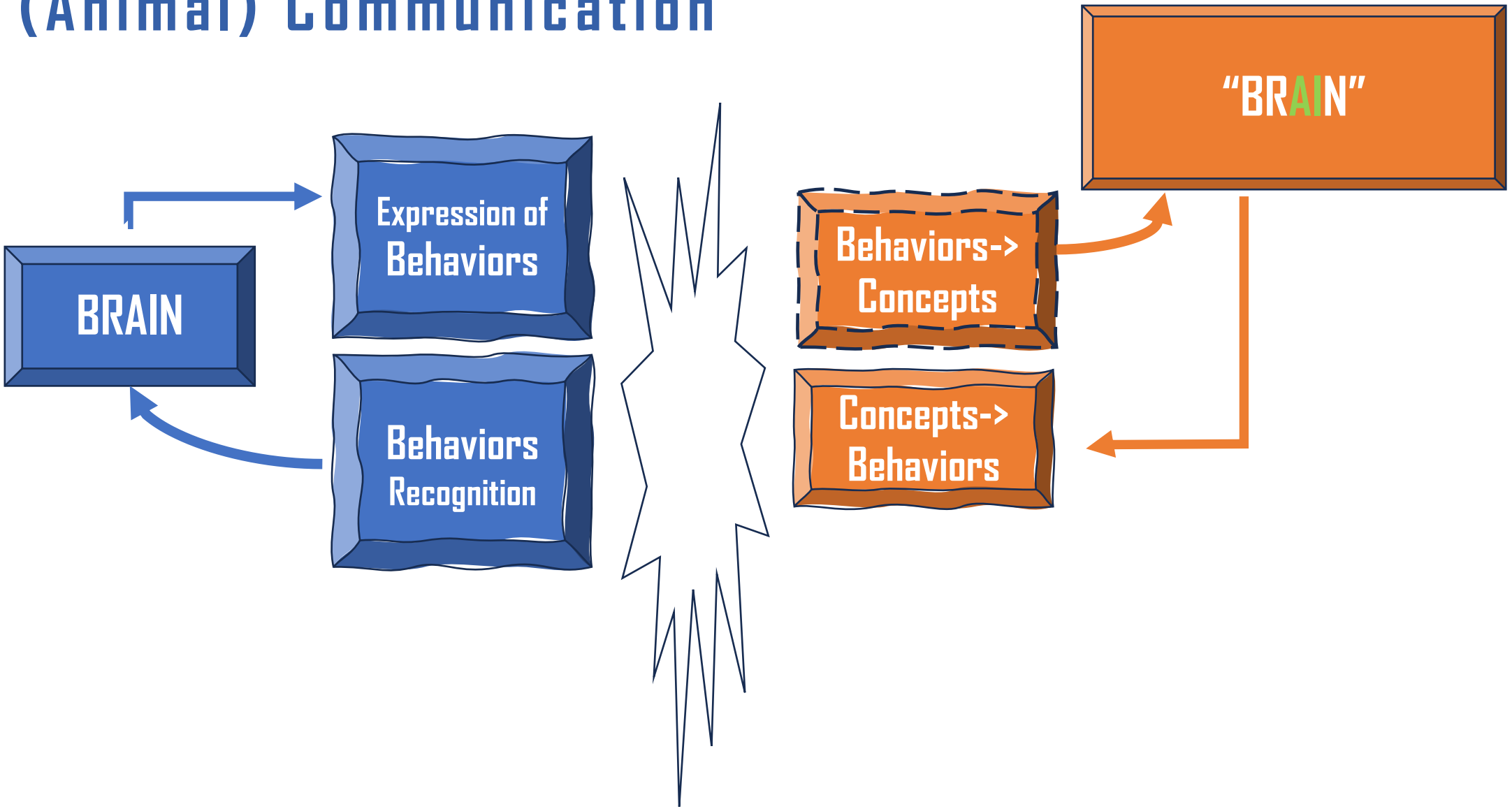

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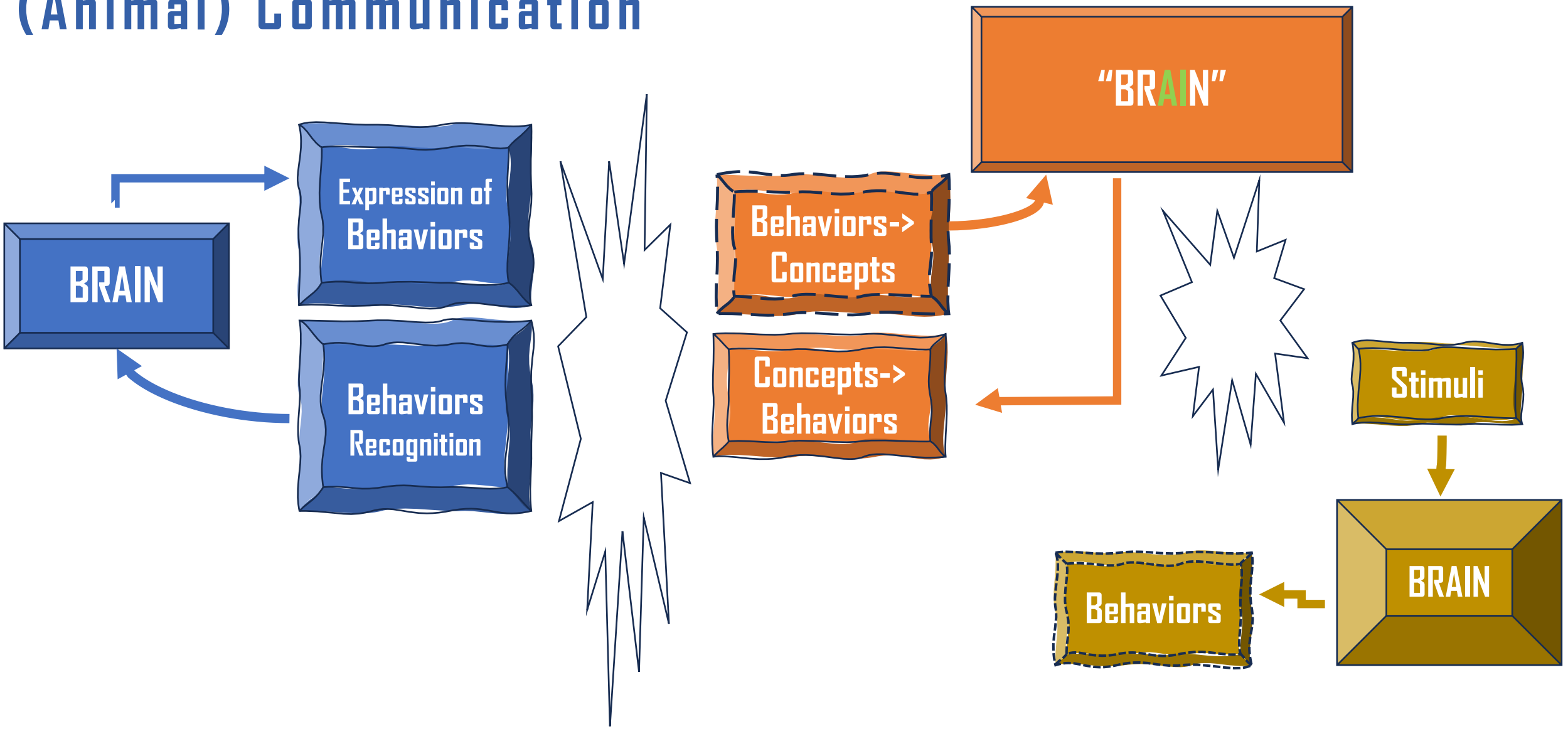

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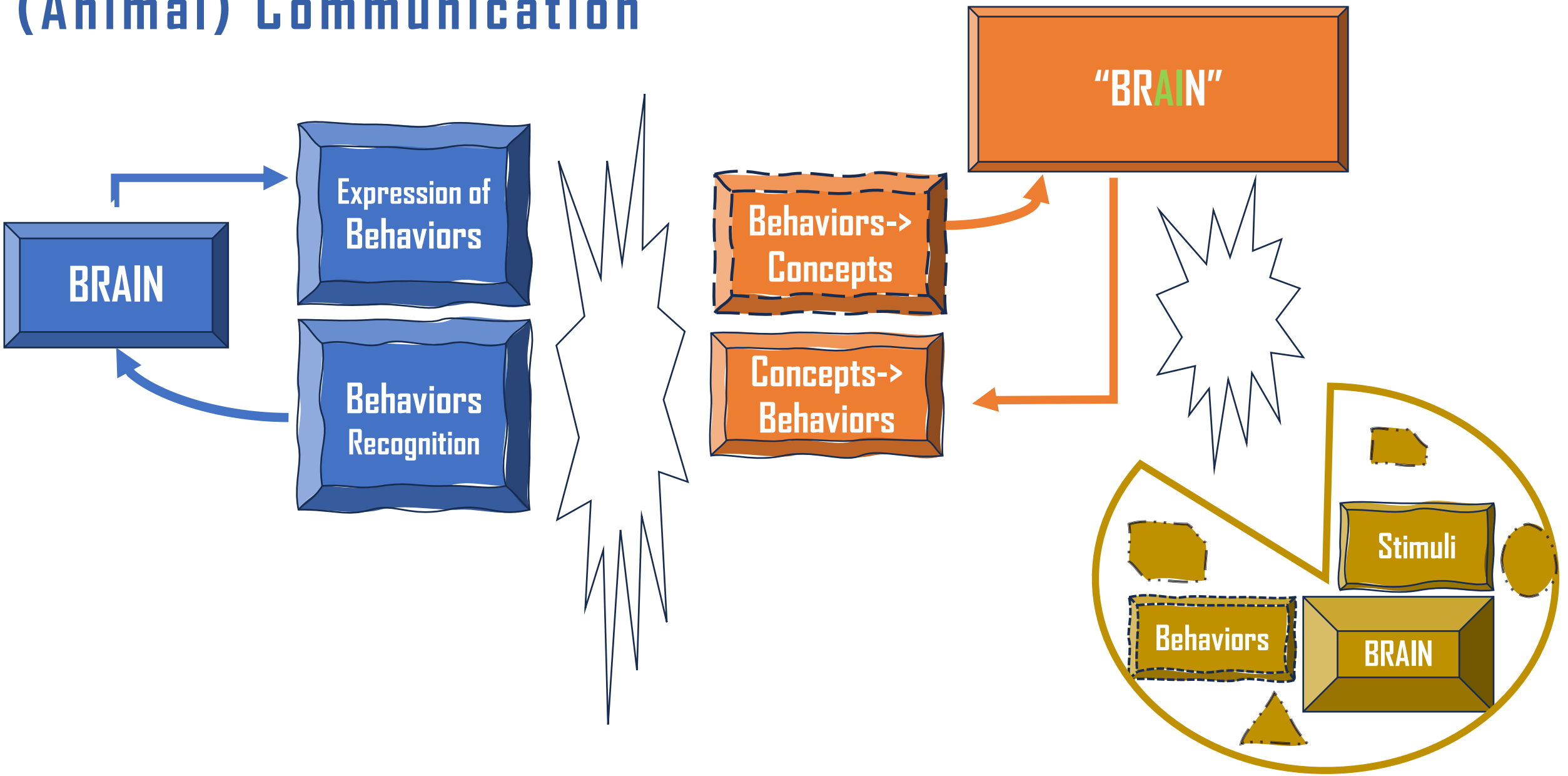

Information Extraction

- **Behaviour-to-Concepts Translation**

  => interpretation (understanding) of multiple sets of (subjective) observations of behaviours in a certain context

Information Extraction

❖ **Behaviour-to-Concepts Translation**

=> interpretation (understanding) of multiple sets of (subjective) observations of behaviours in a certain context

❖ **The ML perspective**

=> **resources** (datasets), i.e. comprehensive sets of representative observations

=> **references** (tags, values), i.e. an agreement that specific sets of observations relate to certain intentions or actions

=> **predictions** (best guess or multiple guesses) based on pre-trained models (or distances), i.e. plausible predictions of categories or values

Information Extraction

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Information Extraction

Animal Communication is Multimodal

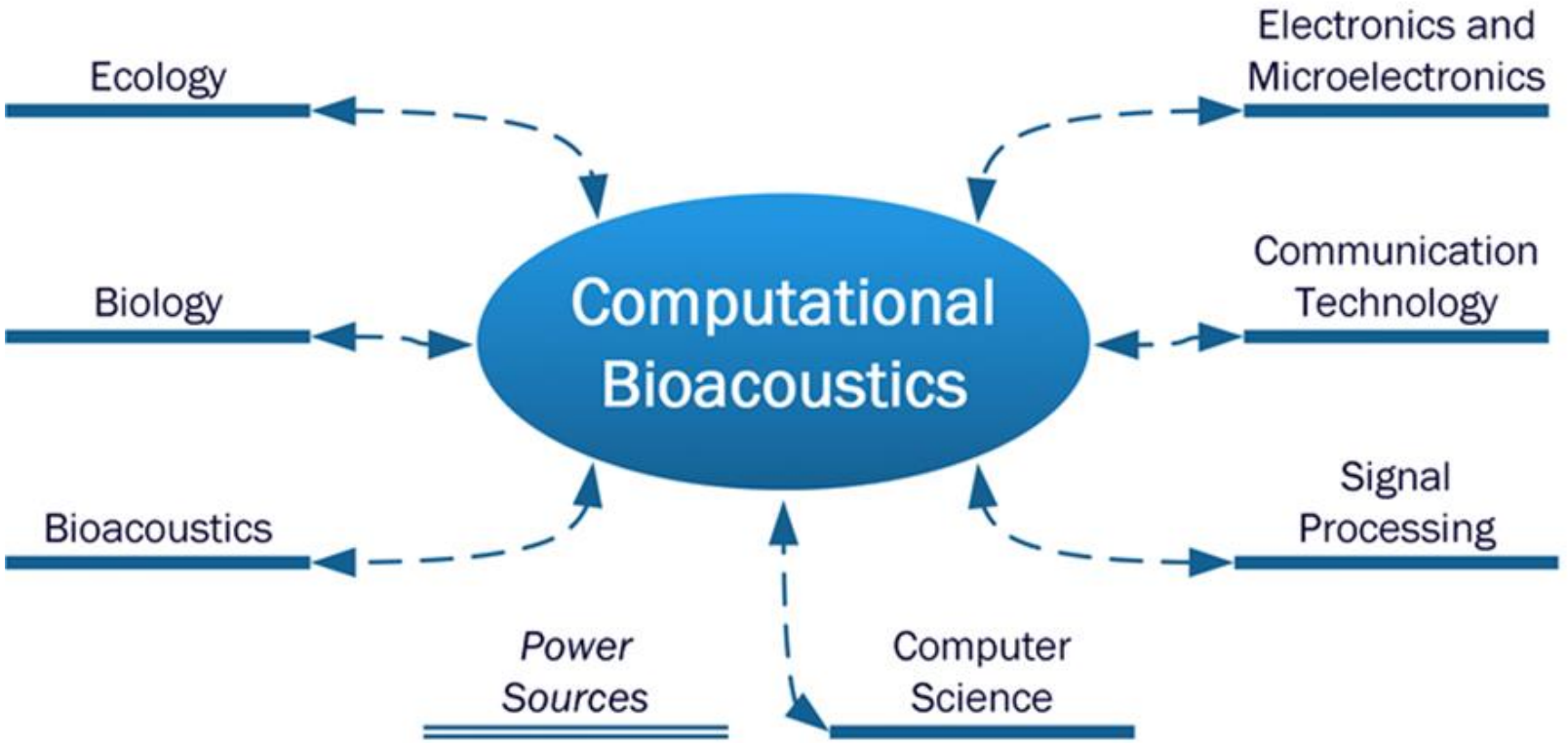
Audio Emissions

+ Line-of-sight is not mandatory
+ Not dependent on day-night luminosity
+ Produced in various ways
+ Flexible information encoding
+ Universal (sensitivity to acoustic vibrations)
+ Doesn't require collaboration,
+ PAM is OK for now!

Audio vs. Vision, Tactile, Chemical…

– Partial information
– Lower communication range
– Less reliable

Computational Bioacoustics



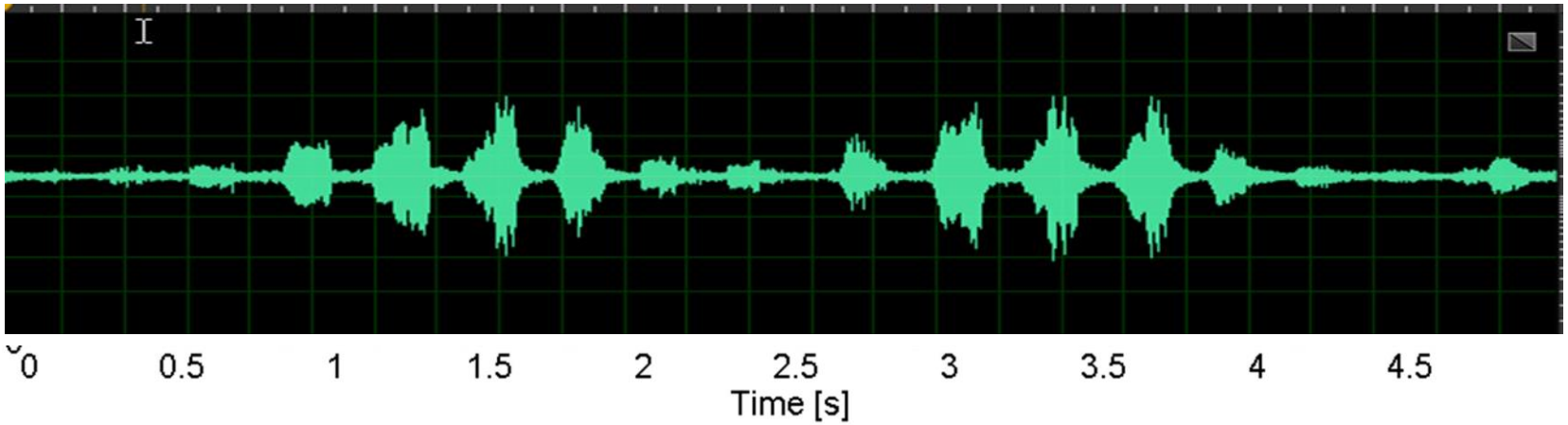
Computational Bioacoustics

- ✓ Observation data are recorded and can be verified after many years.
- ✓ Reduces subjectivity, i.e. allows independence of the qualification and skills of the observer.
- ✓ Automated tools can help improve taxonomic efficiency – and could be used to aid taxonomists and para-taxonomists in identifying species during large-scale surveys.
- ✓ Automation of species identification can speed up the biodiversity assessment process and improve the efficiency of expert labour.
- ✓ Allow long-term monitoring without a human observer, i.e. continuous observation of remote habitats.
- ✓ Automated technology can be used in difficult-to-access or dangerous areas.

https://wallpapers.com/

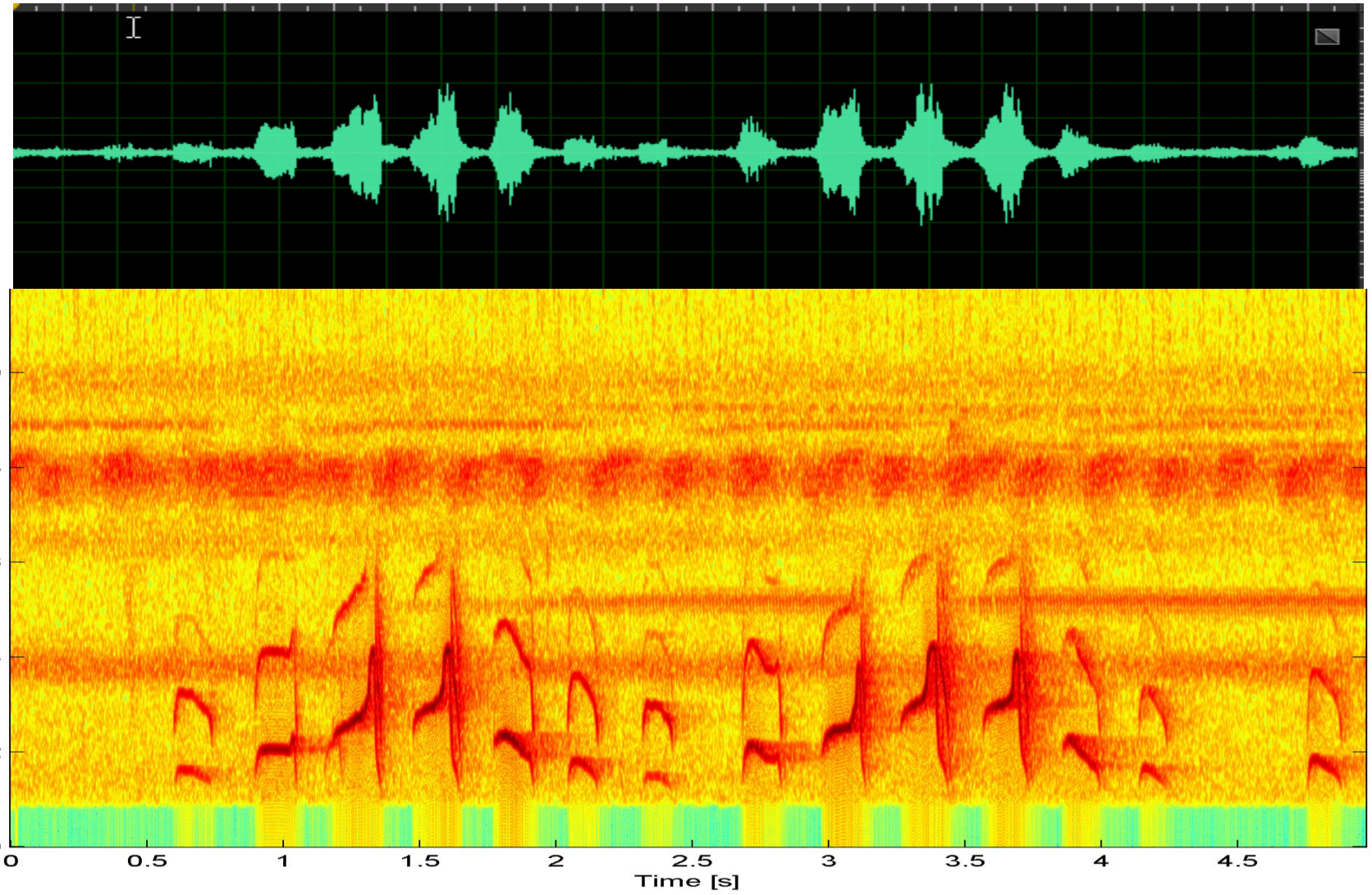
Soundscapes

Observations

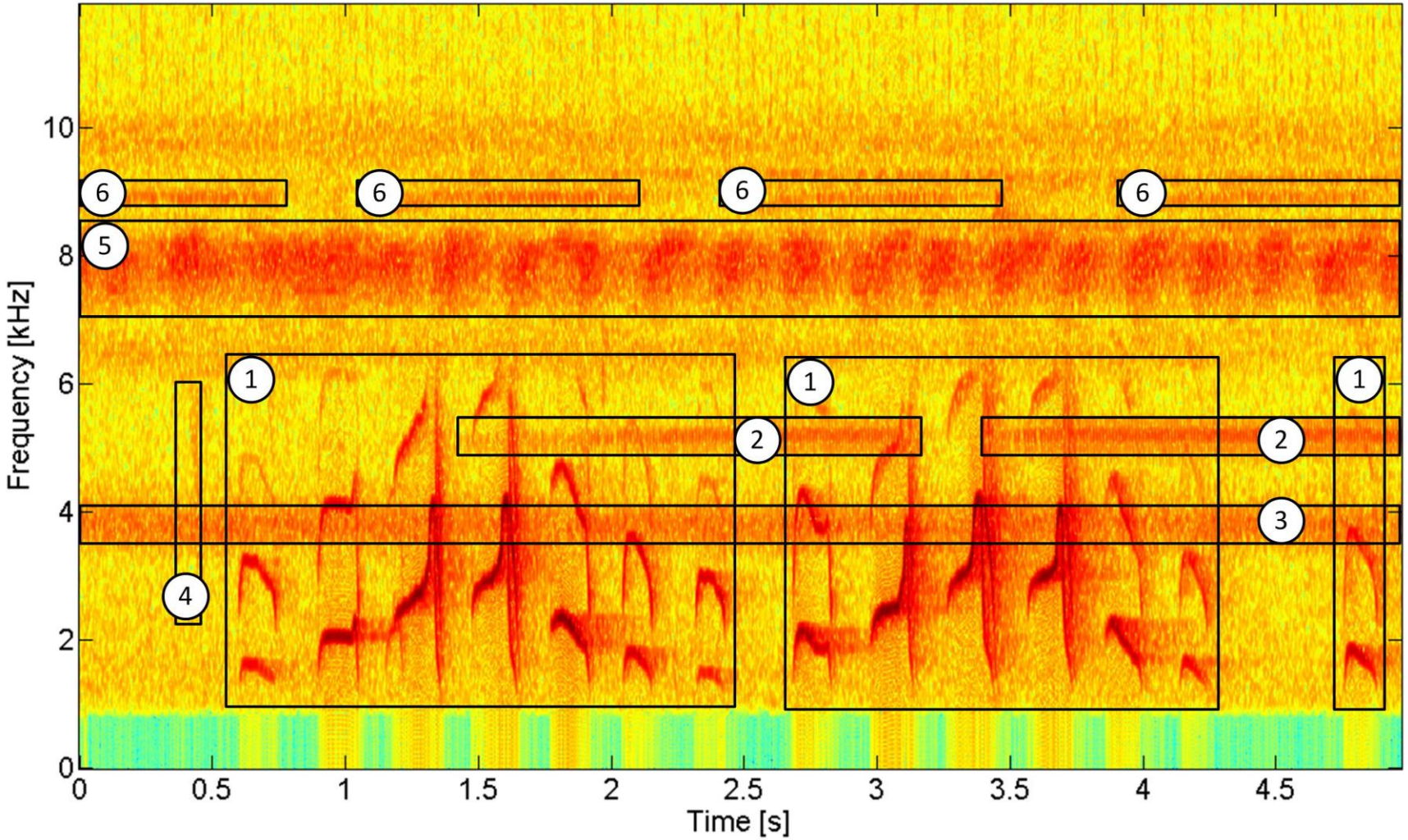


We can apply the Time-frequency decomposition (STDFT) on a 5-sec excerpt

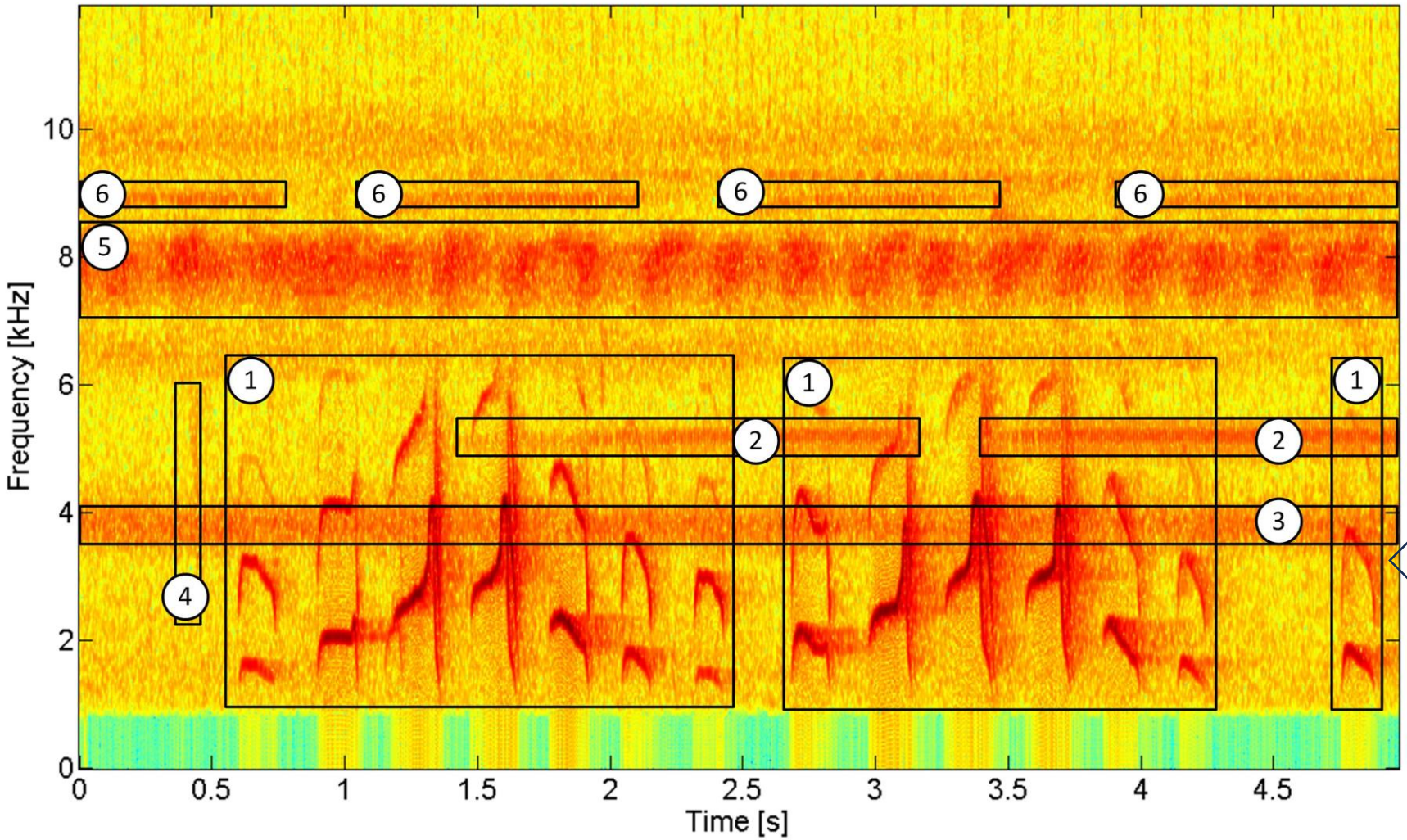
Observations



Annotated Spectrogram



Annotated Spectrogram



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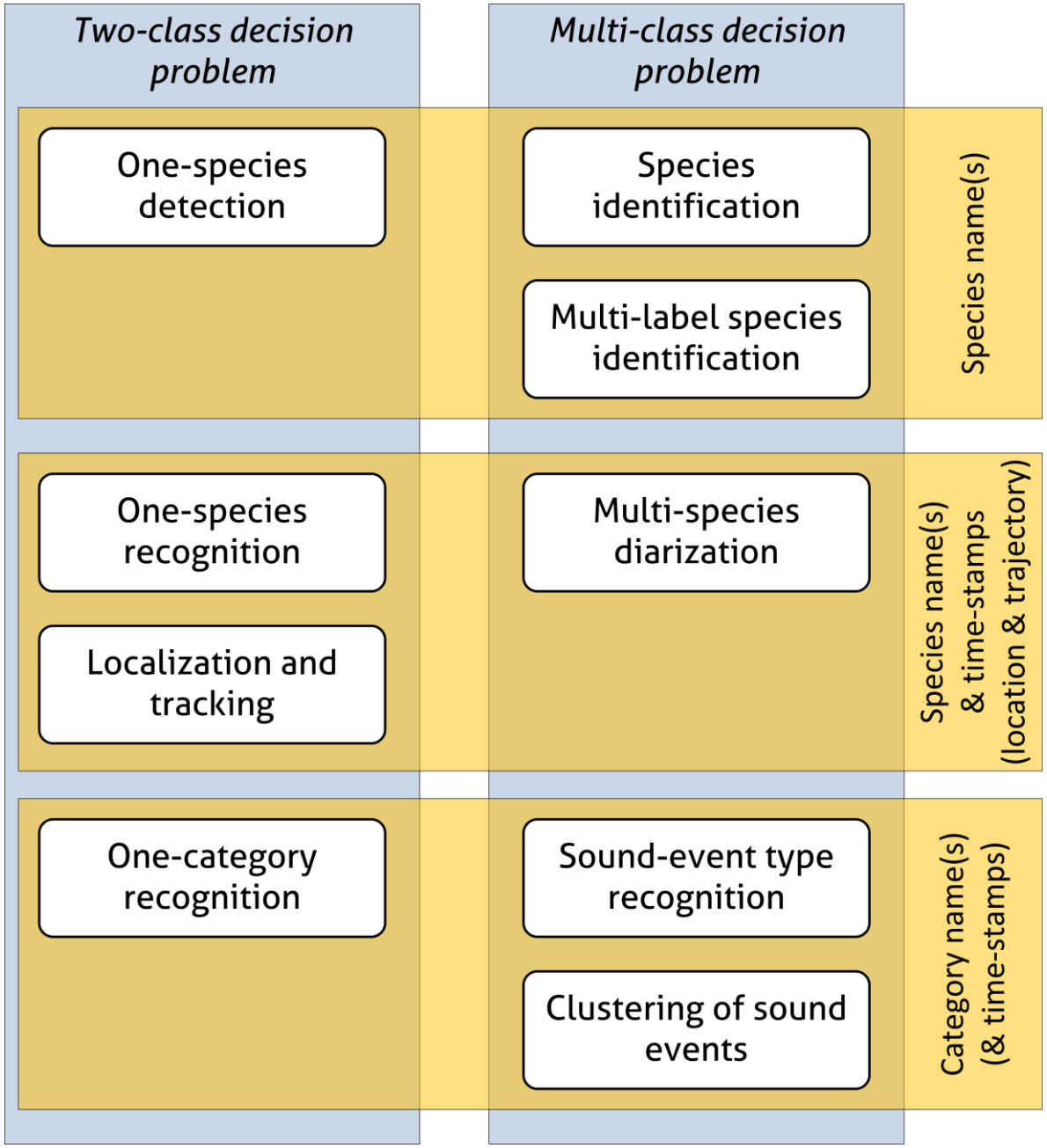
wallpaper.mob.org/image/humor-

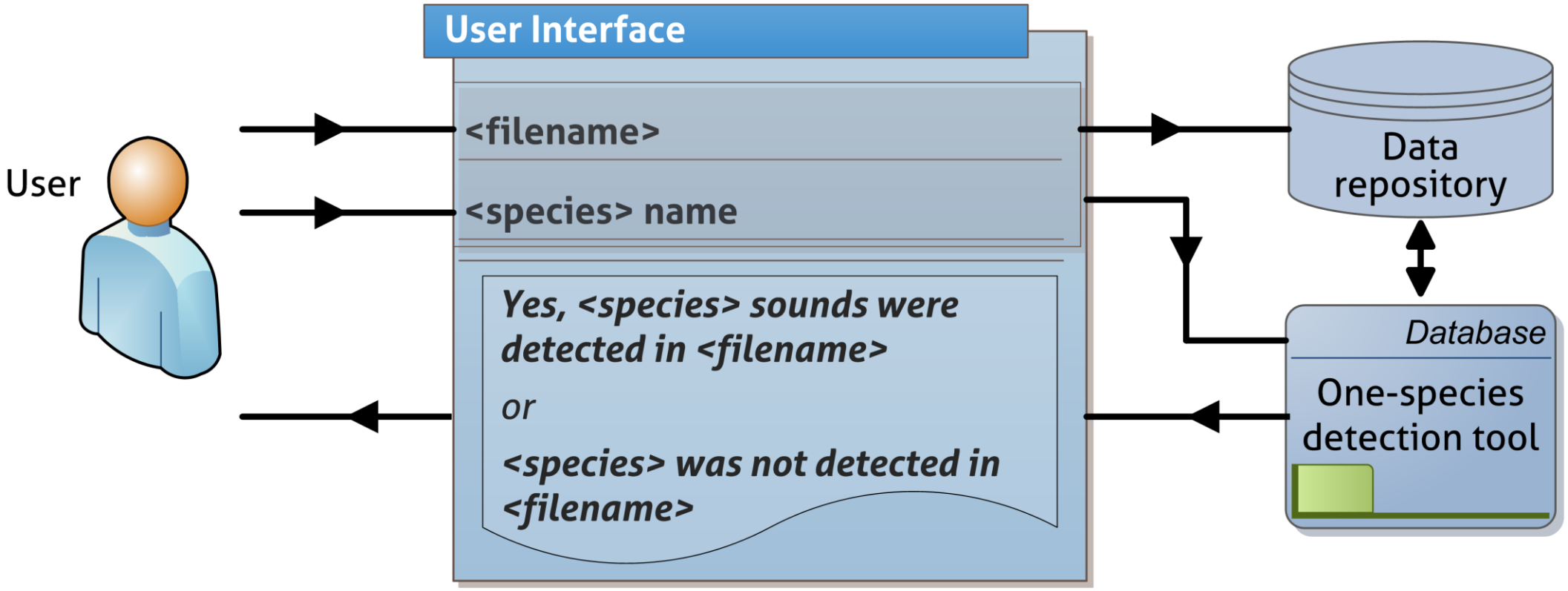
Question(s) ?!

Well, this wasn't the correct answer but what is the question?

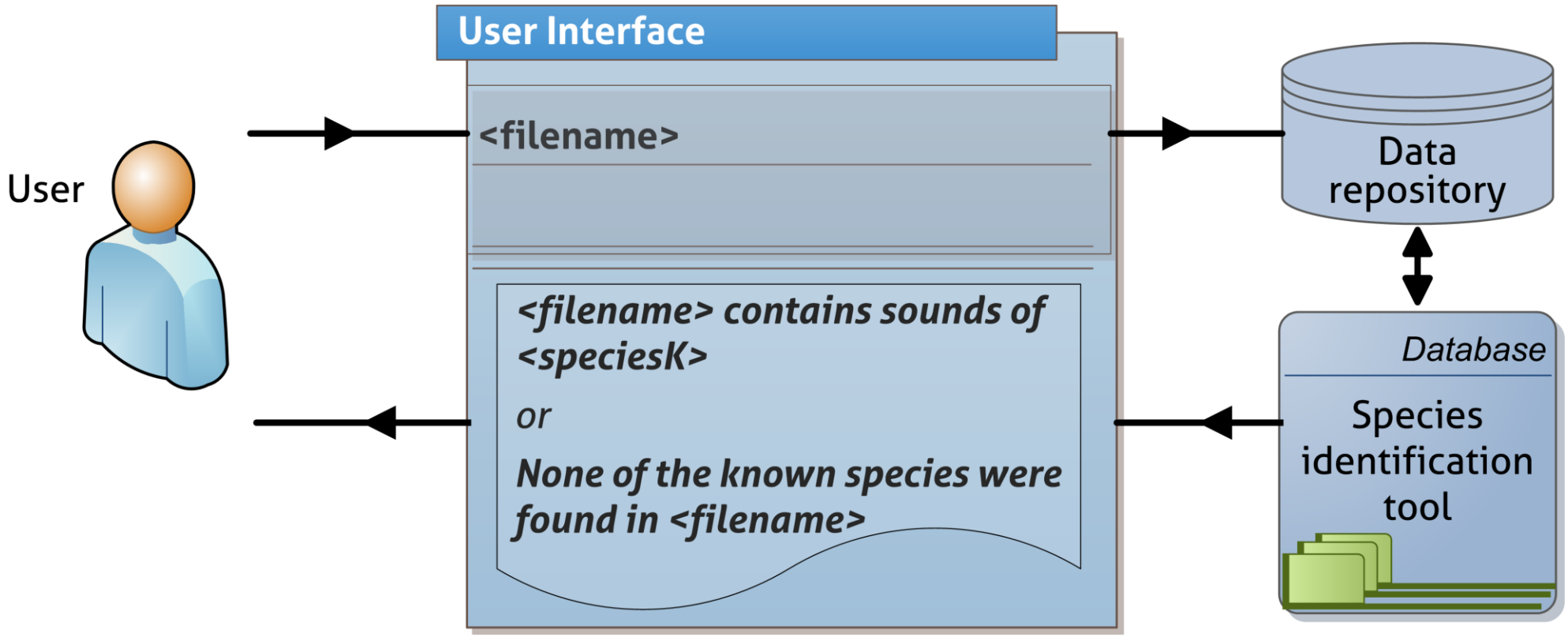
Problems


Two-class decision problem
Multi-class decision problem
One-species detection
Species identification
Multi-label species identification
Species name(s)
One-species recognition
Localization and tracking
Multi-species diarization
Species name(s) & time-stamps (location & trajectory)
One-category recognition
Sound-event type recognition
Clustering of sound events
Category name(s) (& time-stamps)

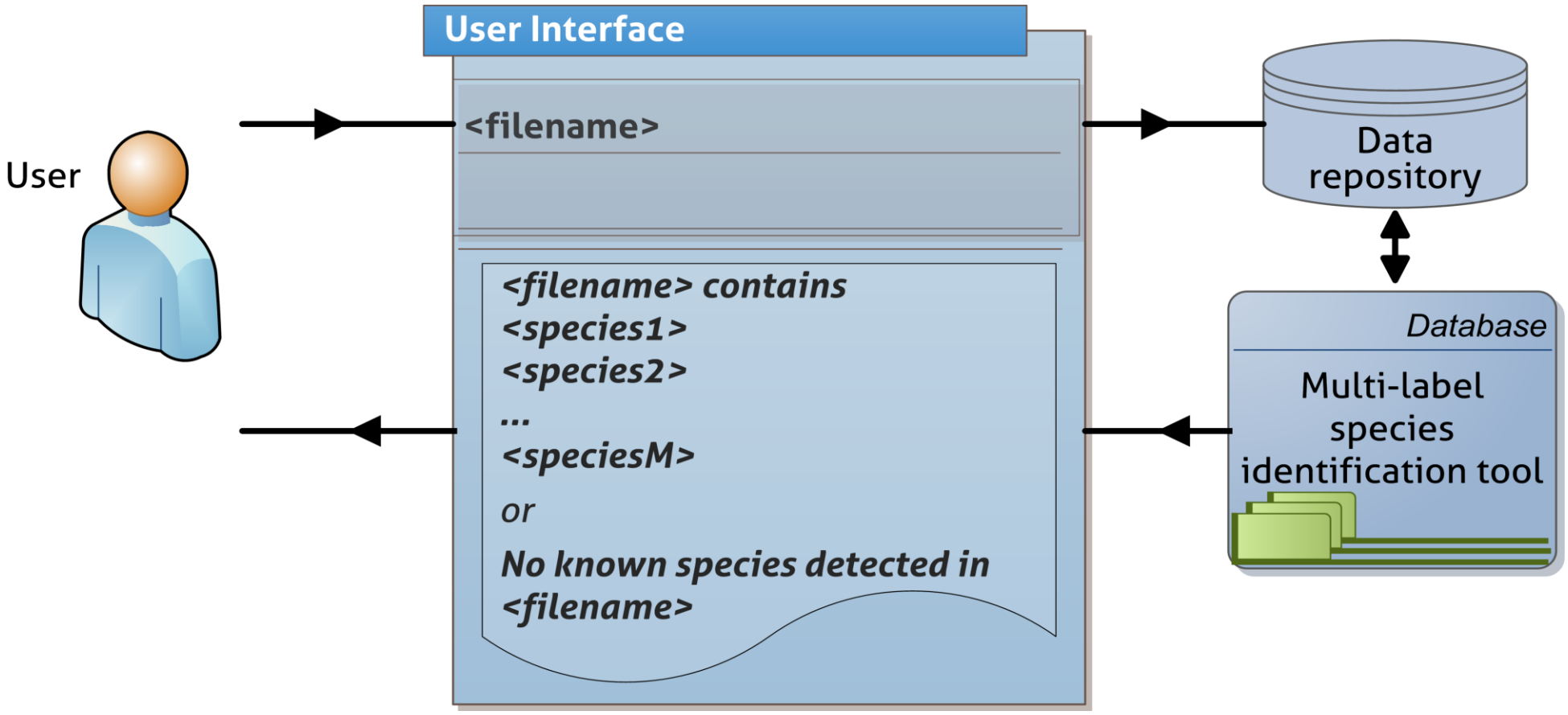
One-species detection



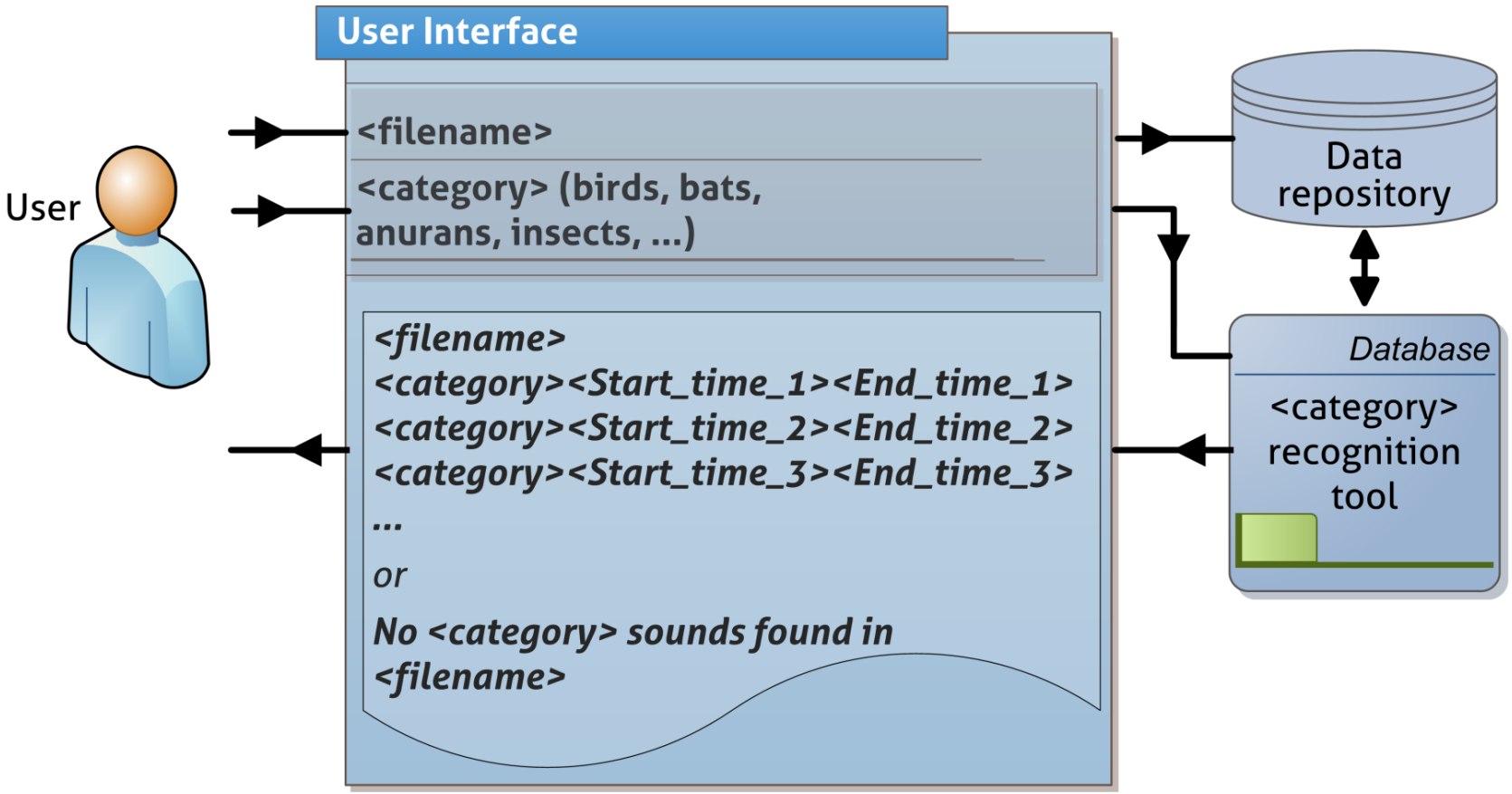
Species identification



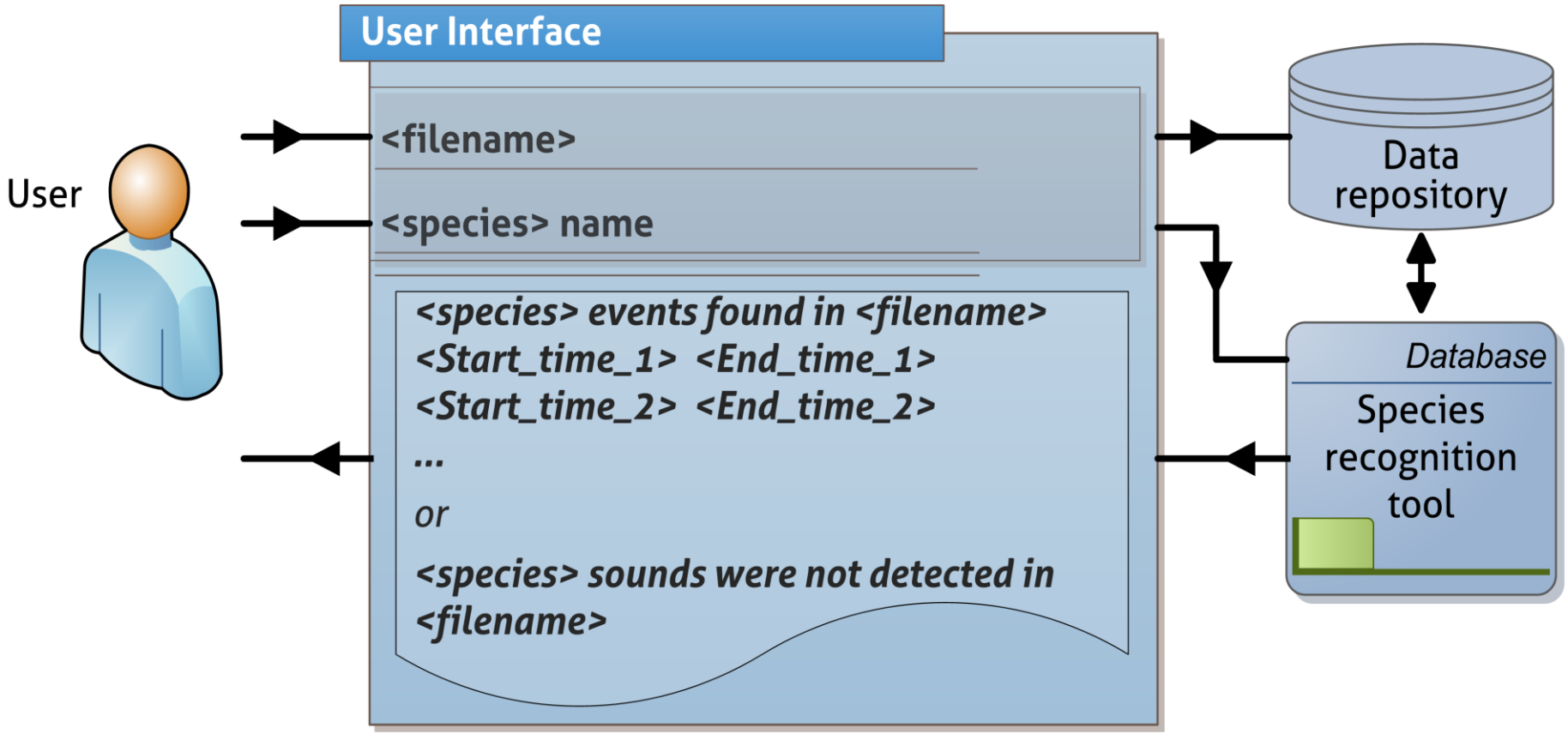
Multi-label species identification



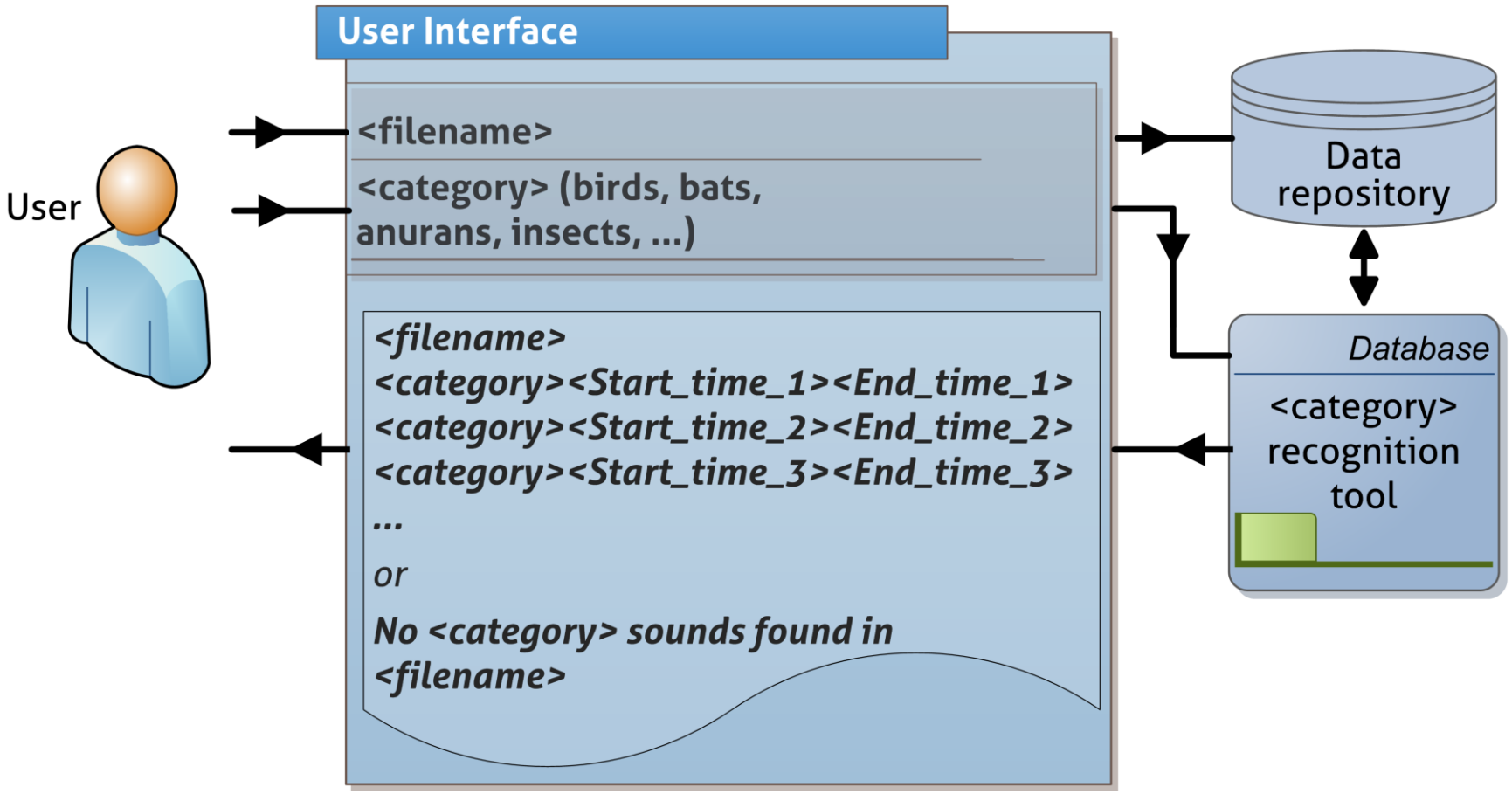
One-category recognition



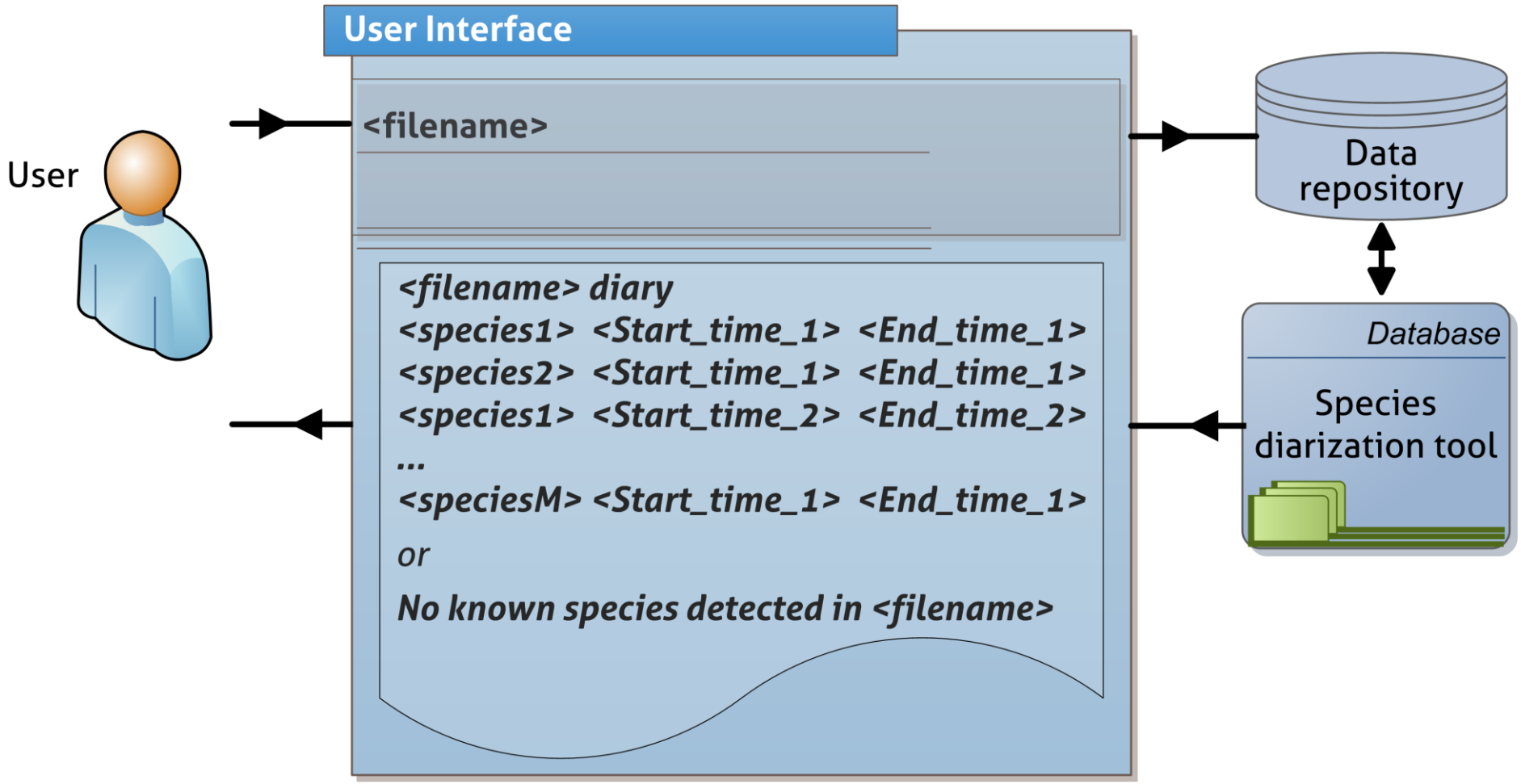
One-species recognition



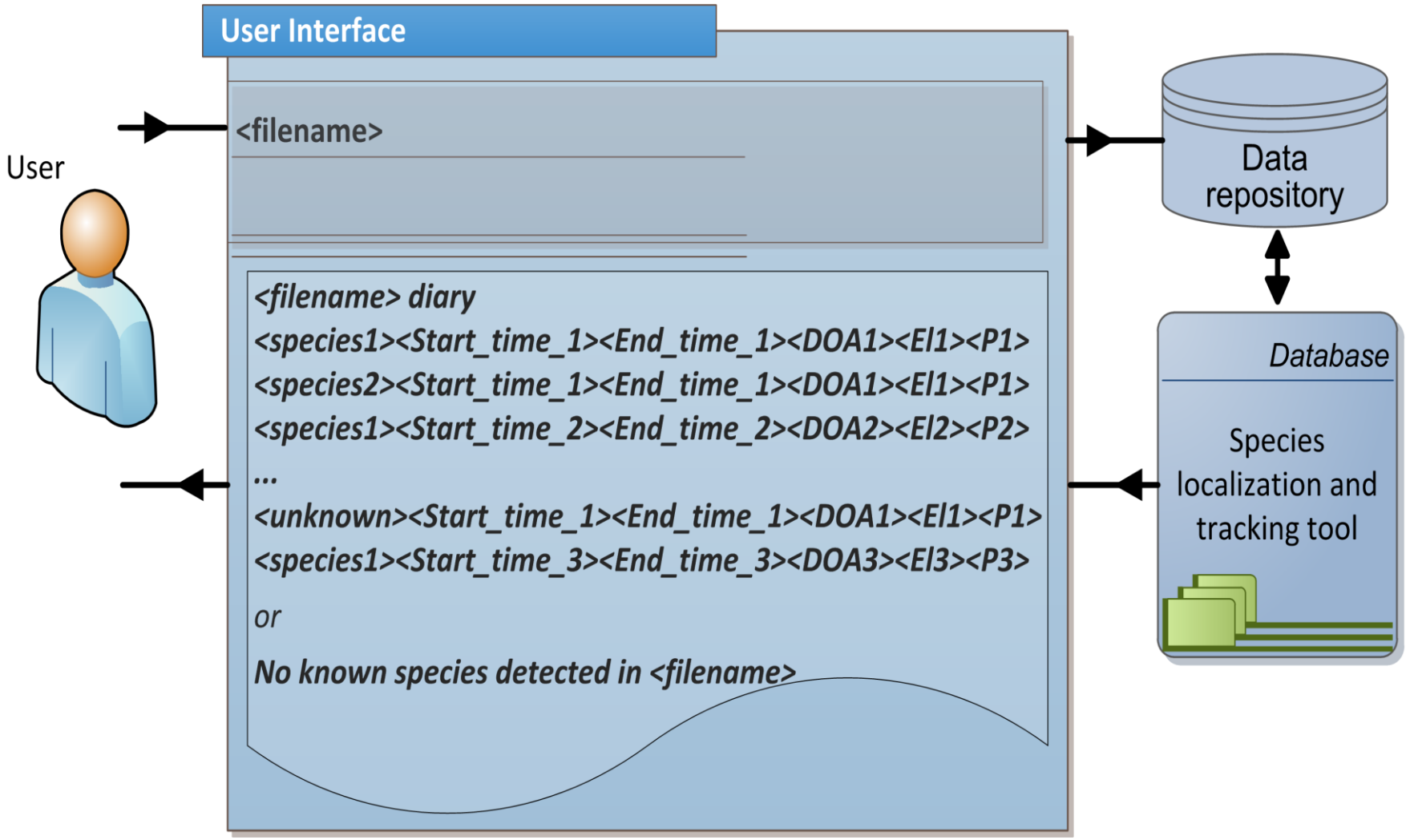
One-category recognition



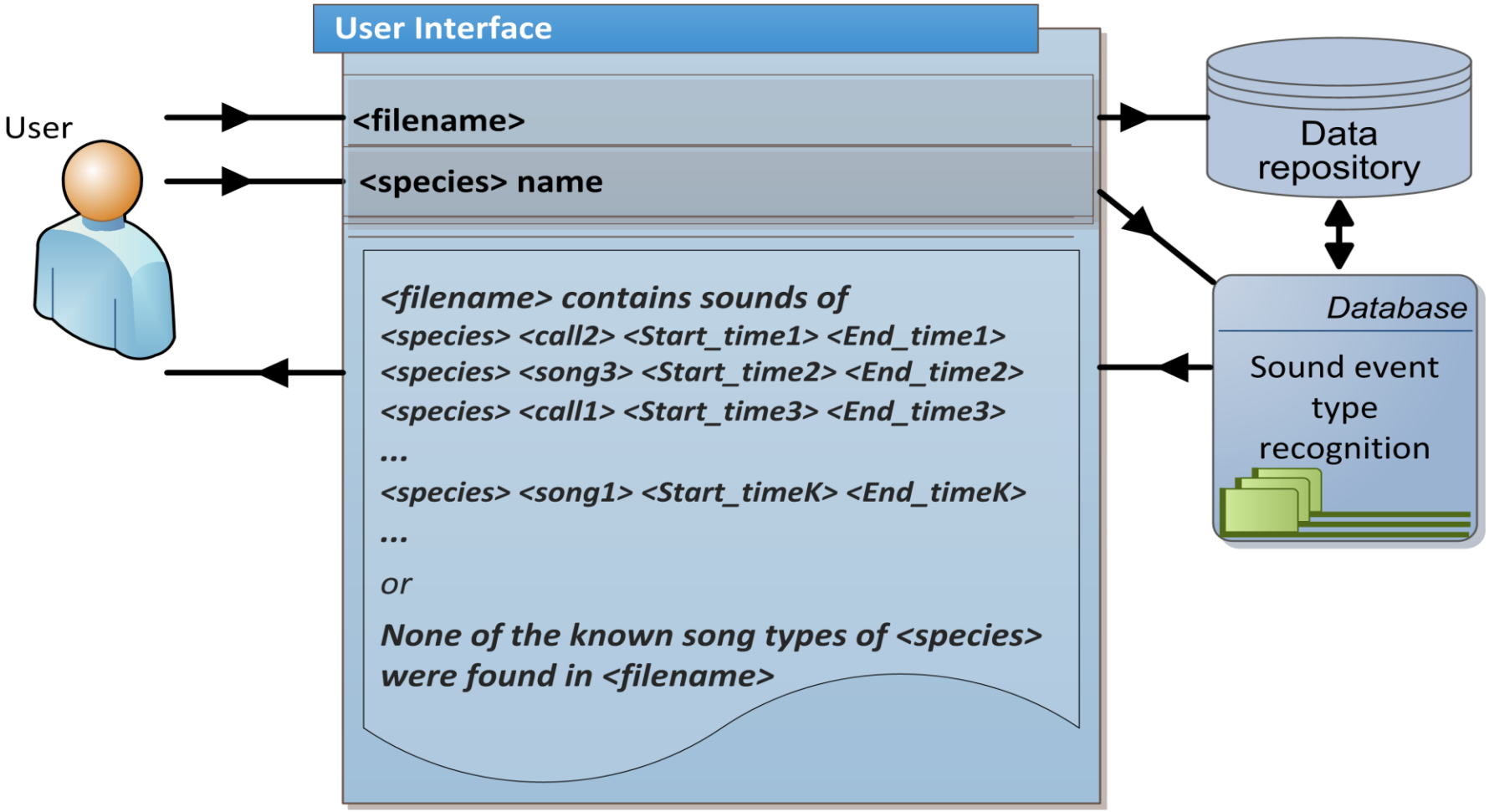
Multi-species diarization



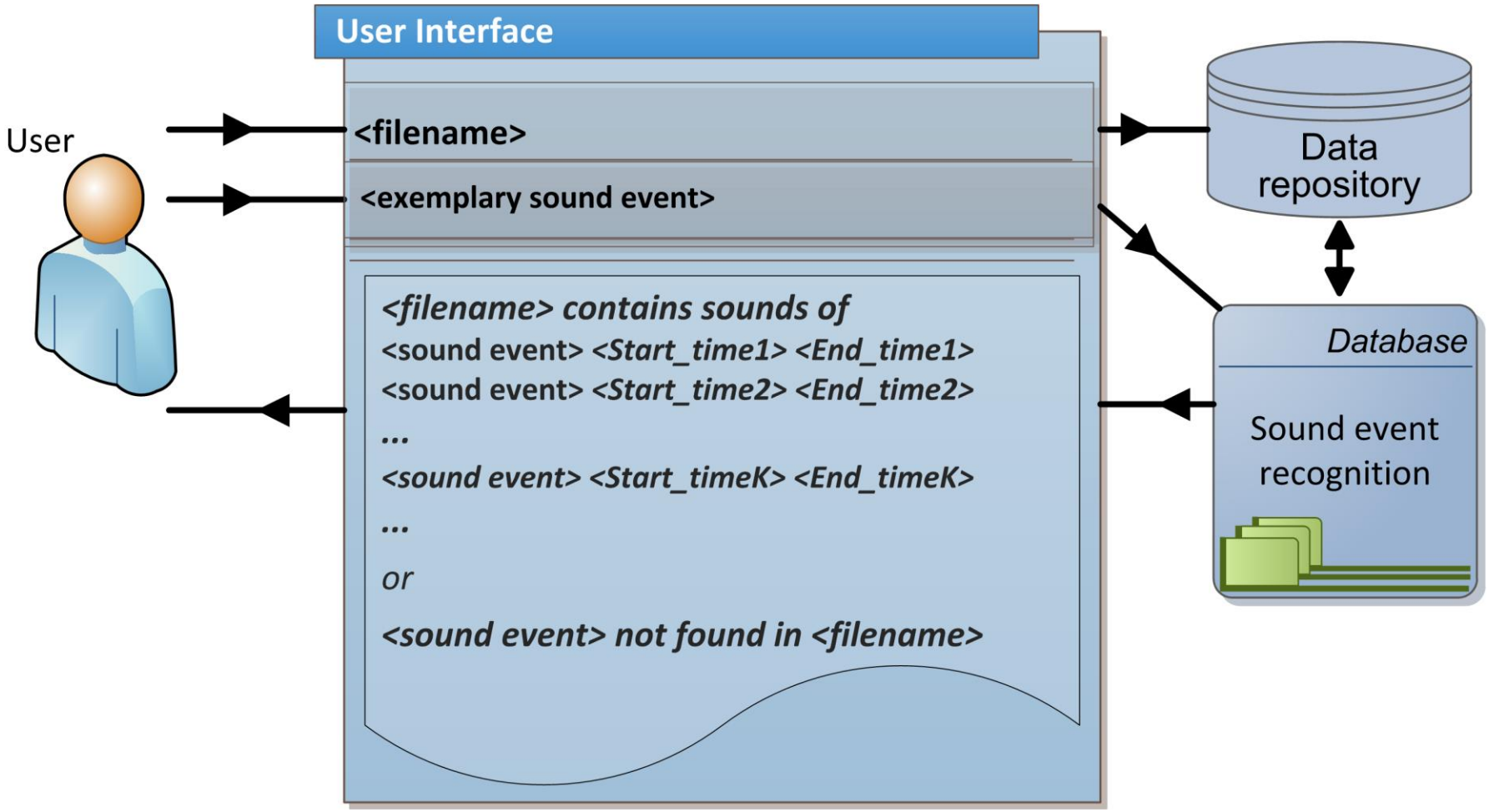
Localization and tracking of individuals



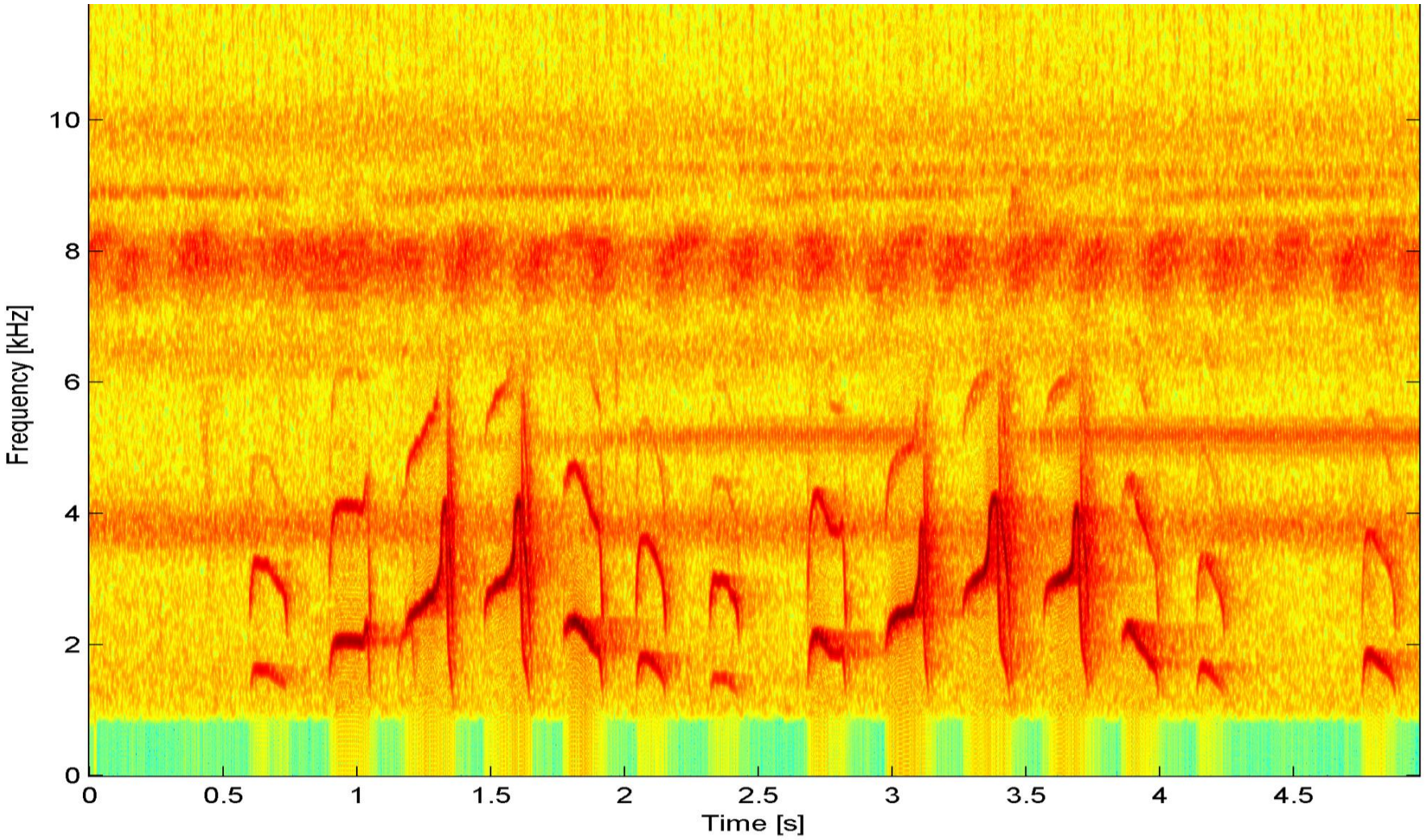
Sound event type recognition



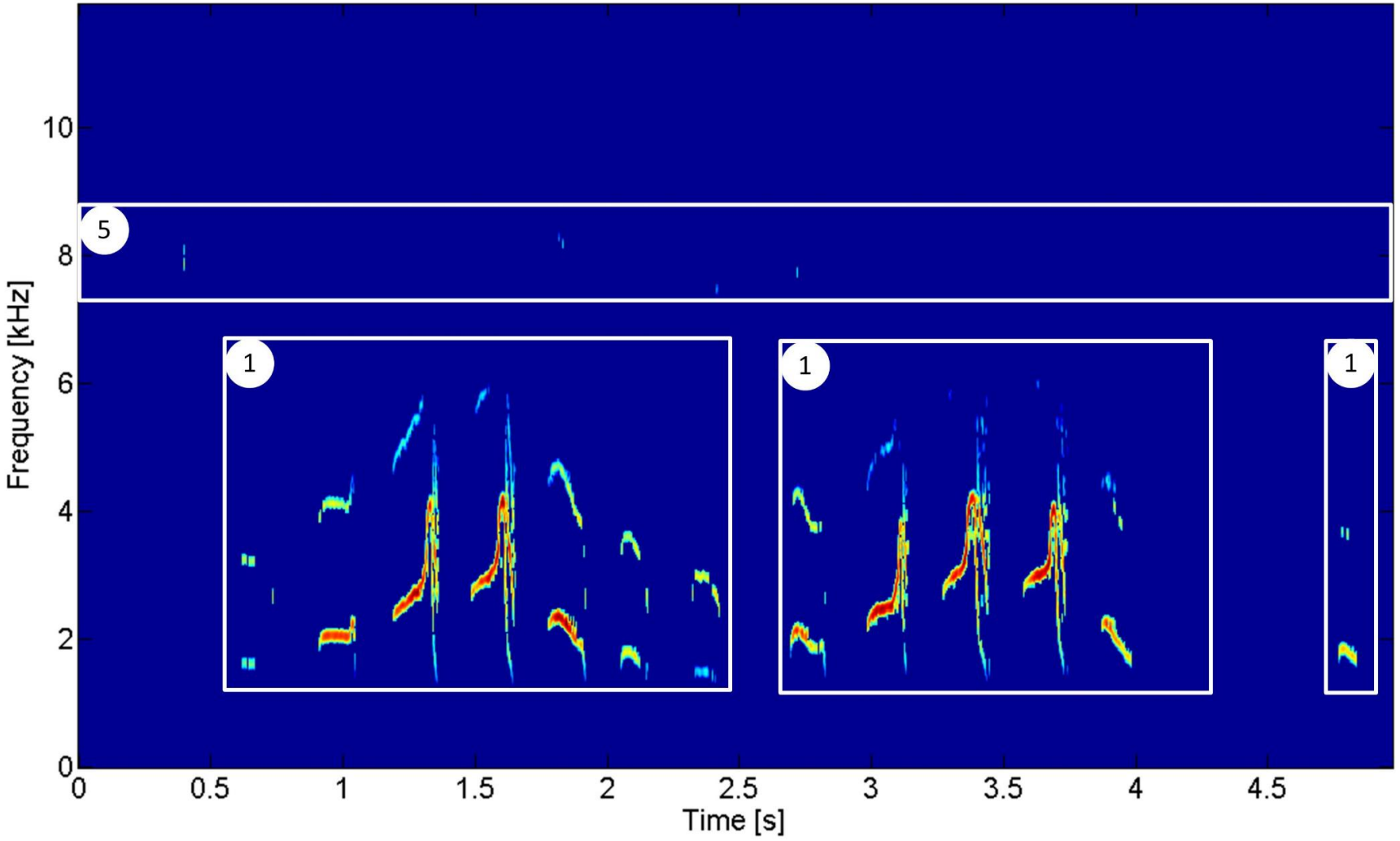
Query-by-example search

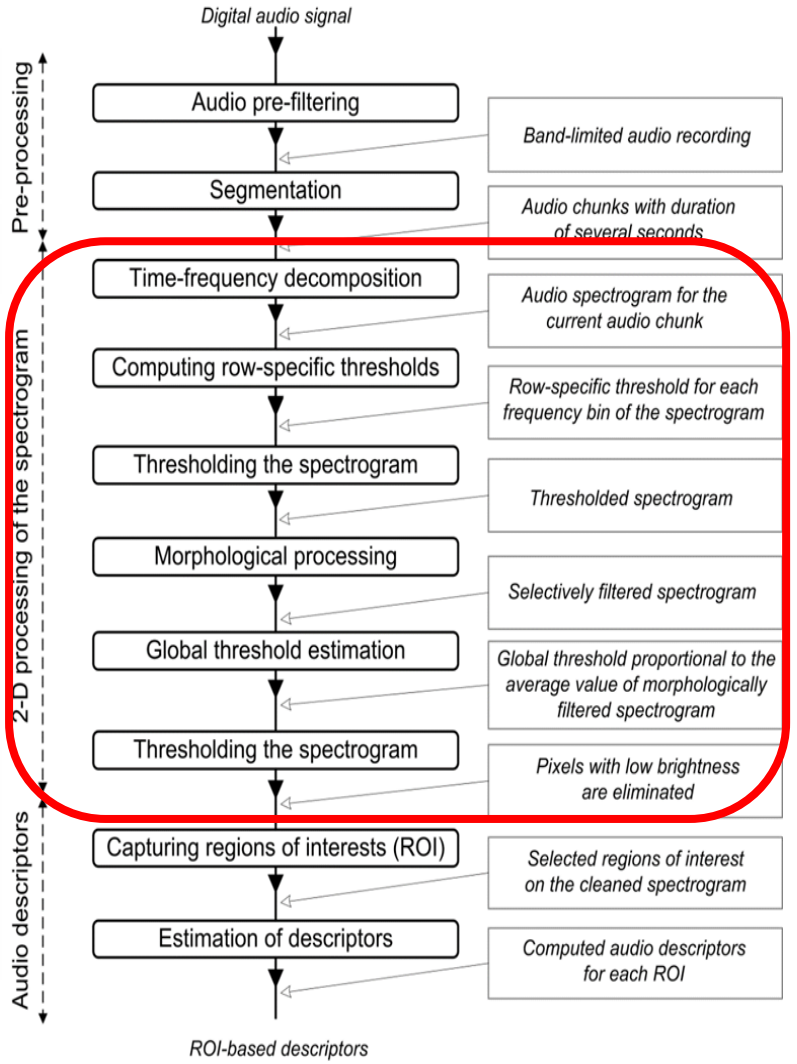


Spectrogram

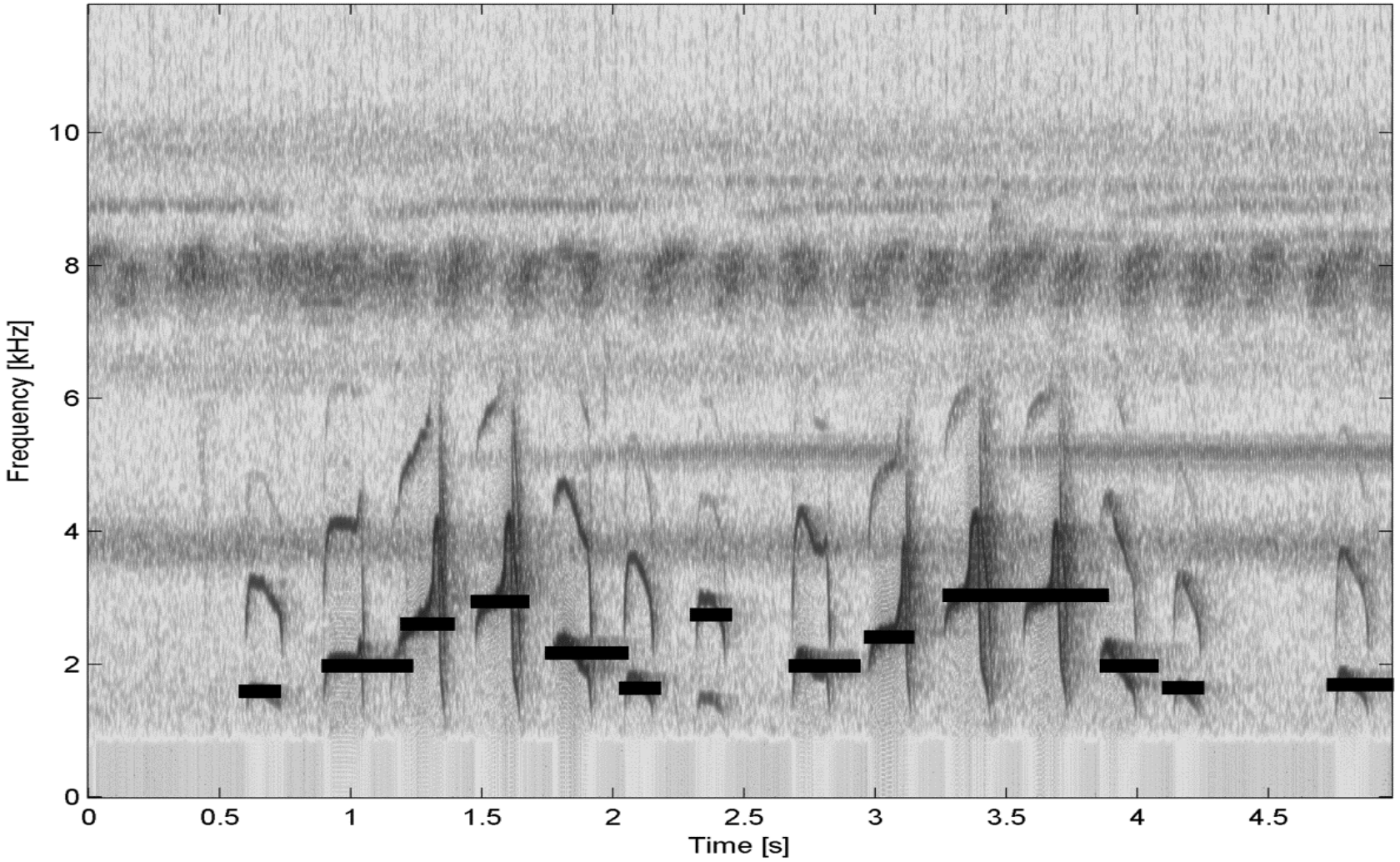


Regions of Interest

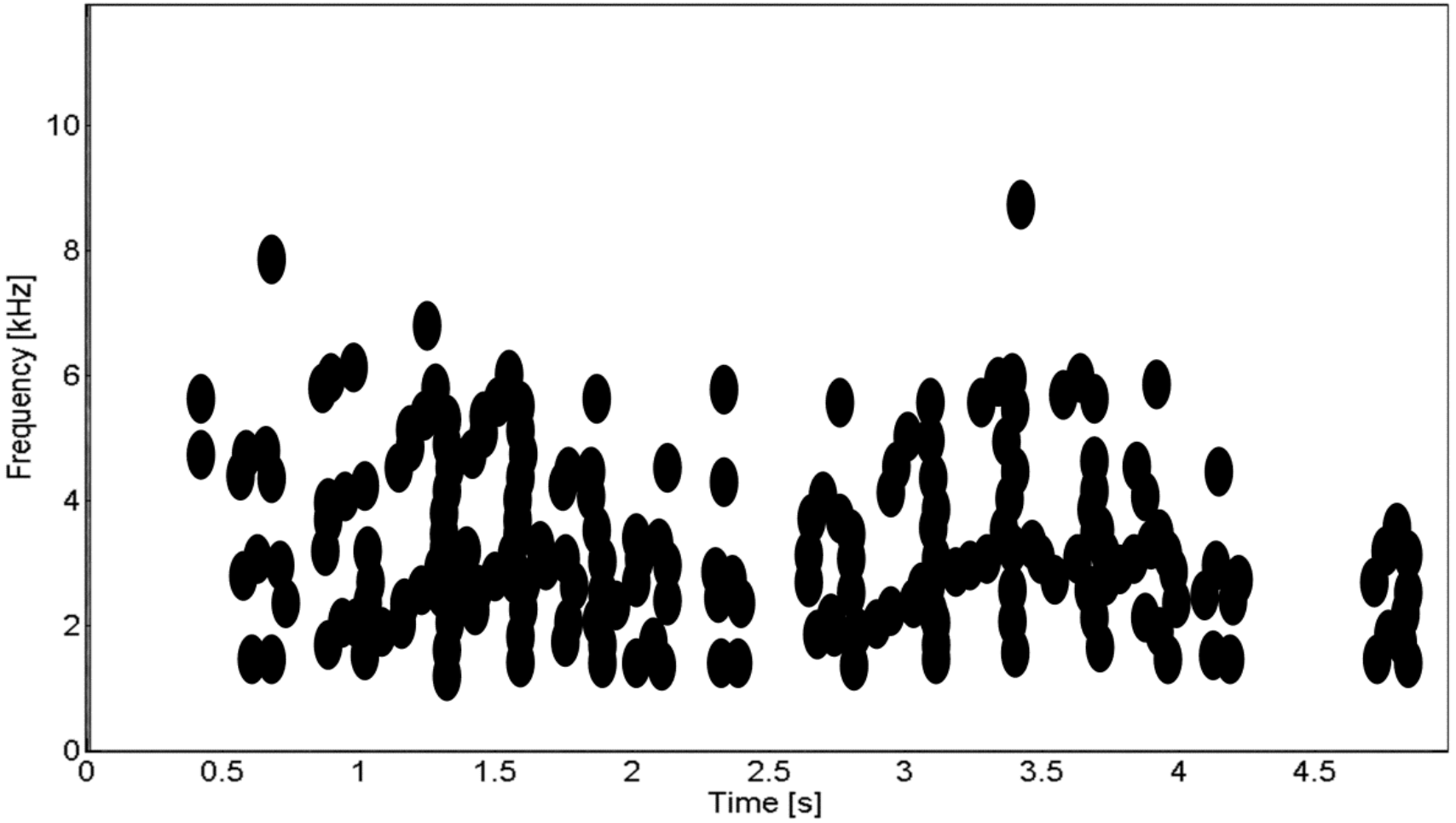


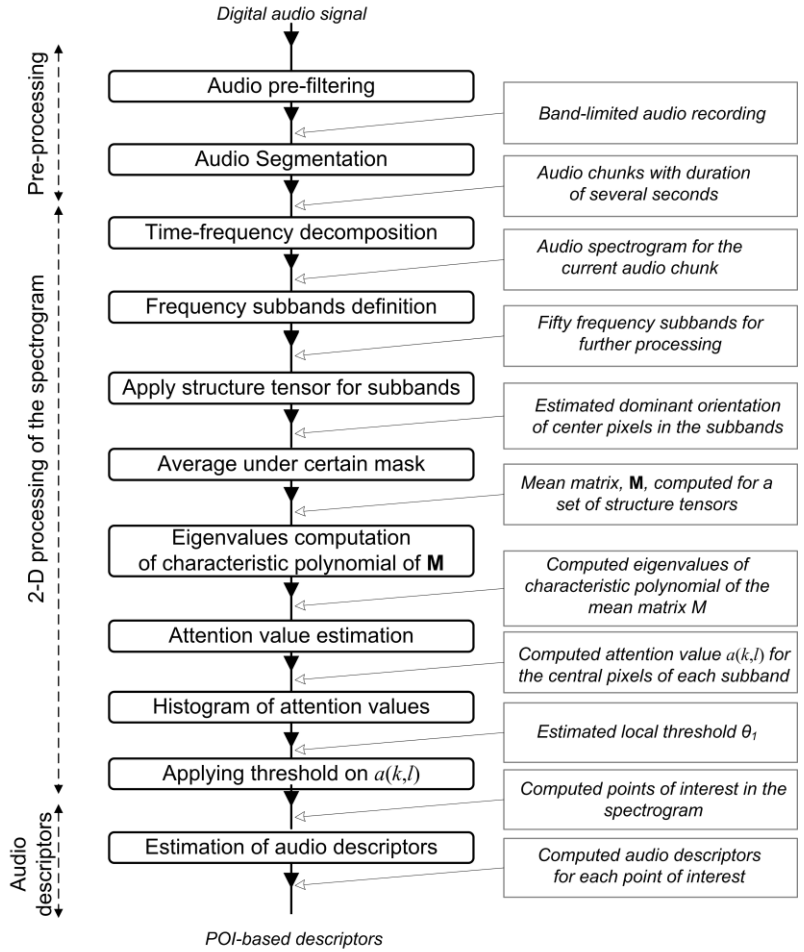


Points of Interest

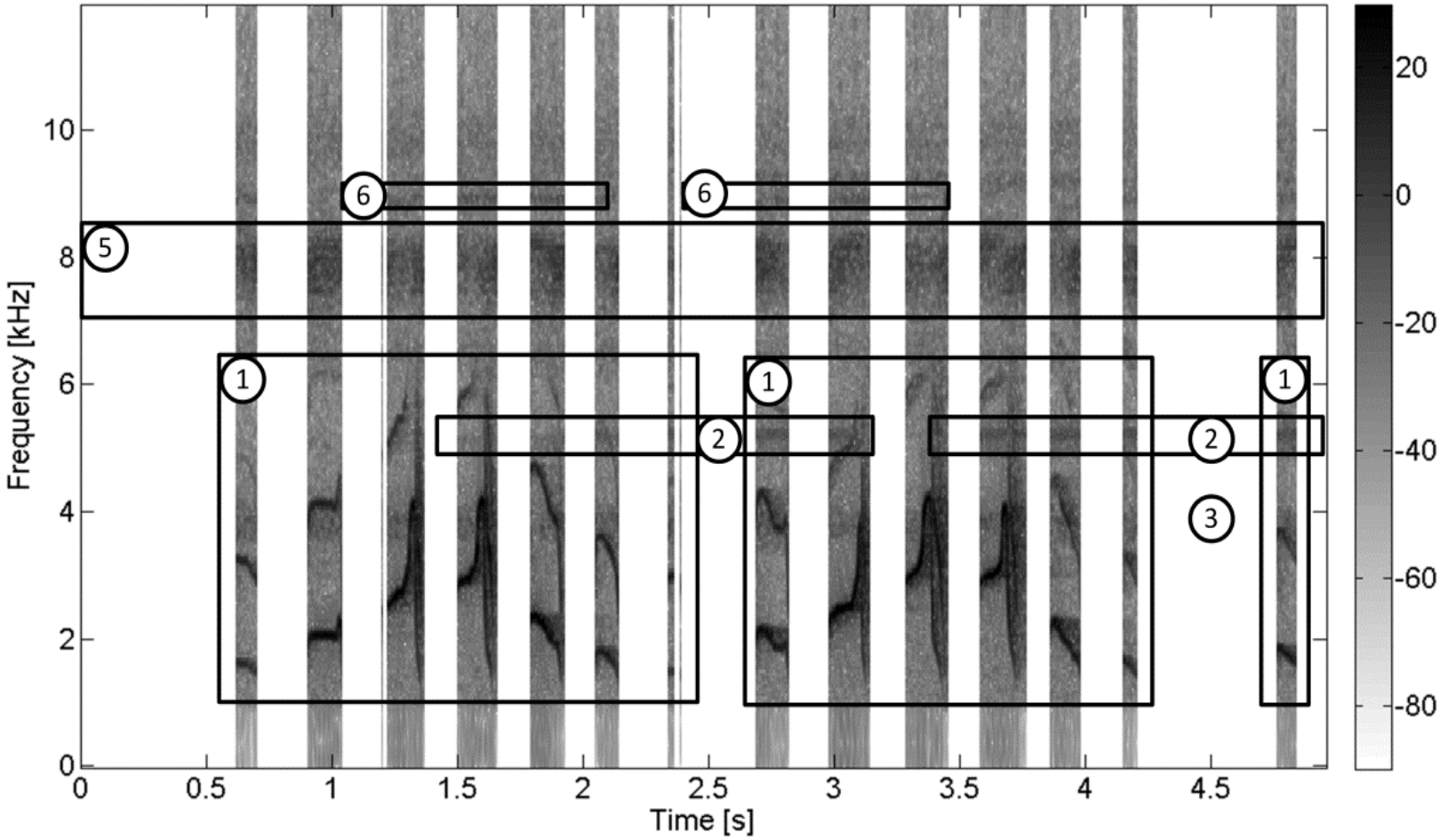


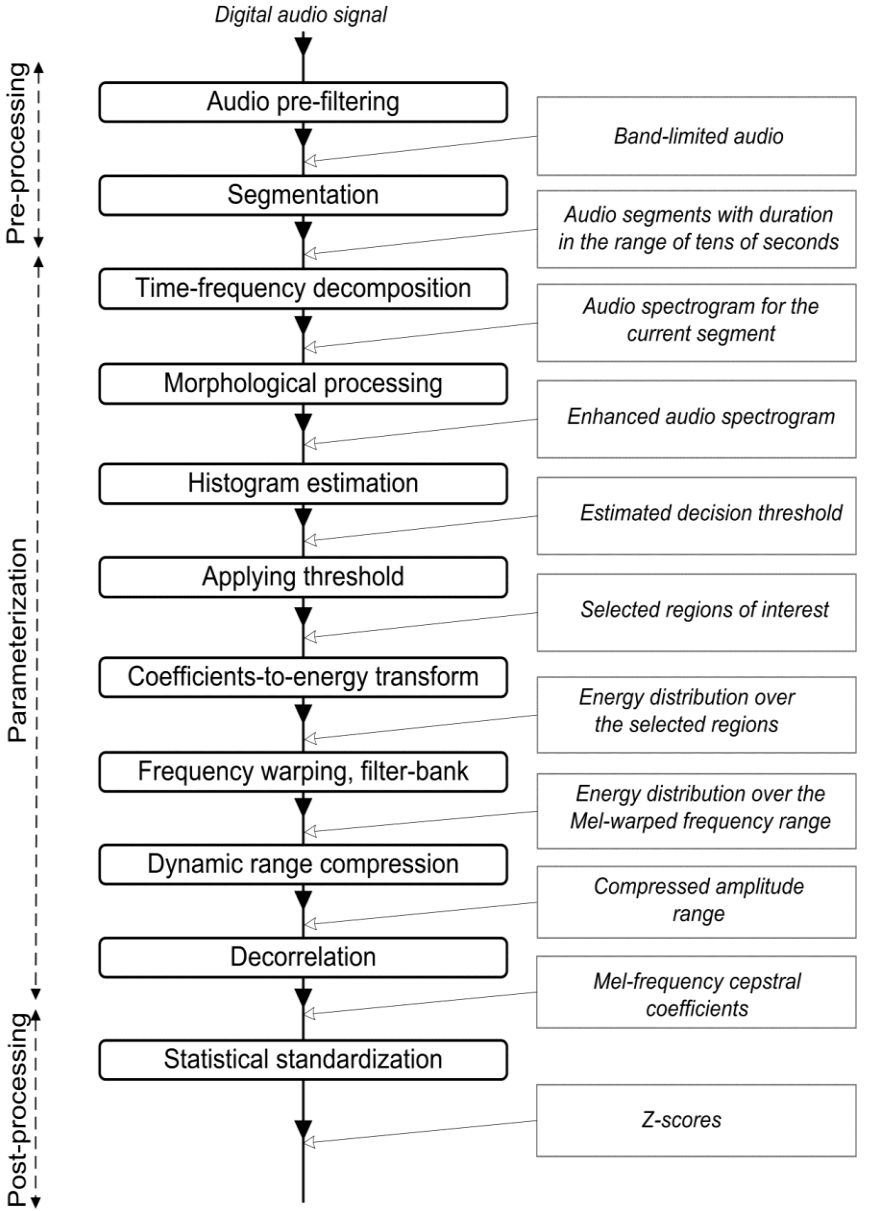
Points of Interest



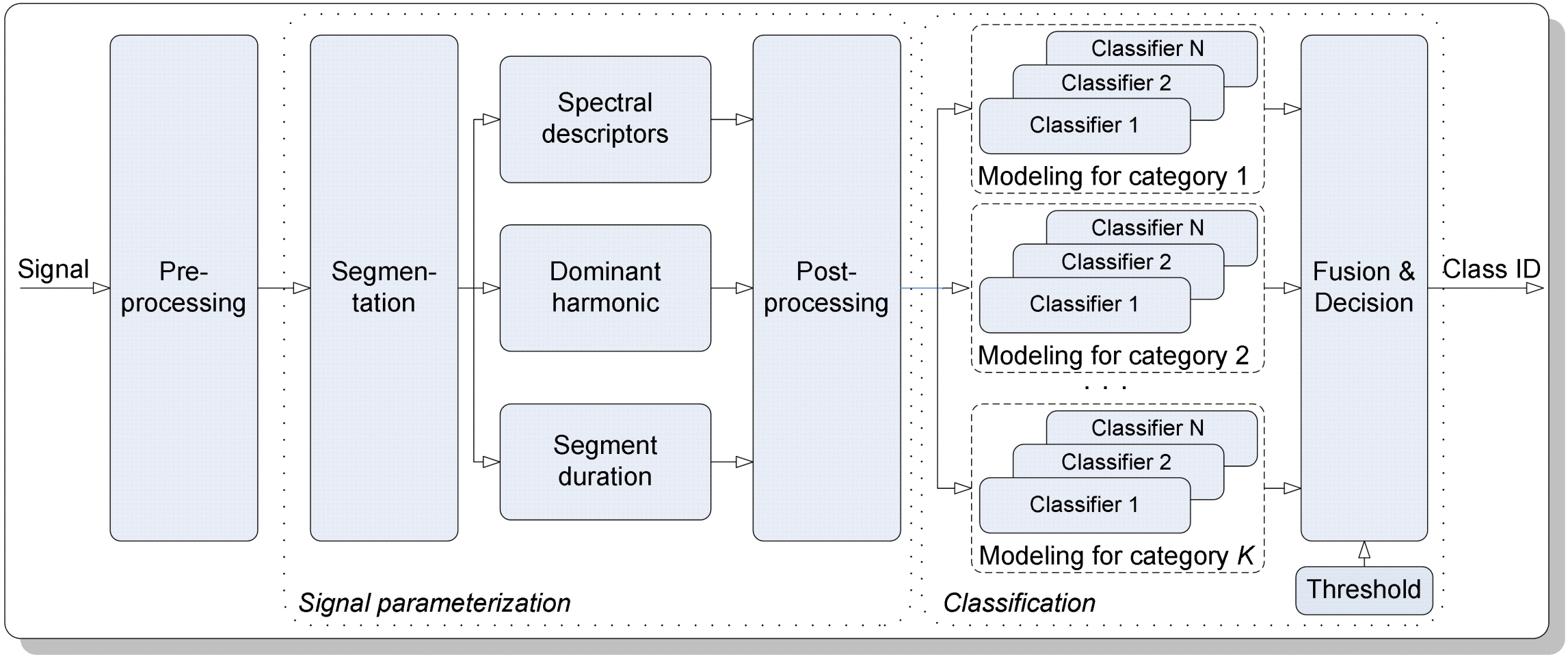


Robust Frame Selection





Recognition/Identification/Detection



Success Stories

A Traditional Approach

Photo: Characteristic habitat of *Vanellus Chilensis Lampronotus* at the Pantanal wetlands (Brazil).
Courtesy of Dr Olaf Jahn

Computational Bioacoustics

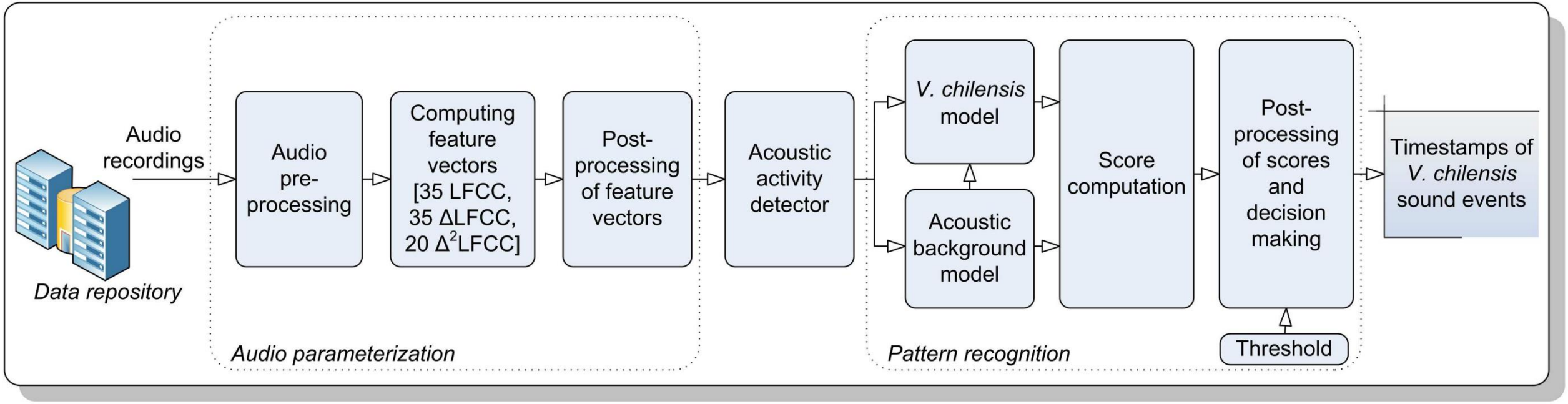
Traditional approaches (when domain knowledge is available)

RESEARCH ARTICLE

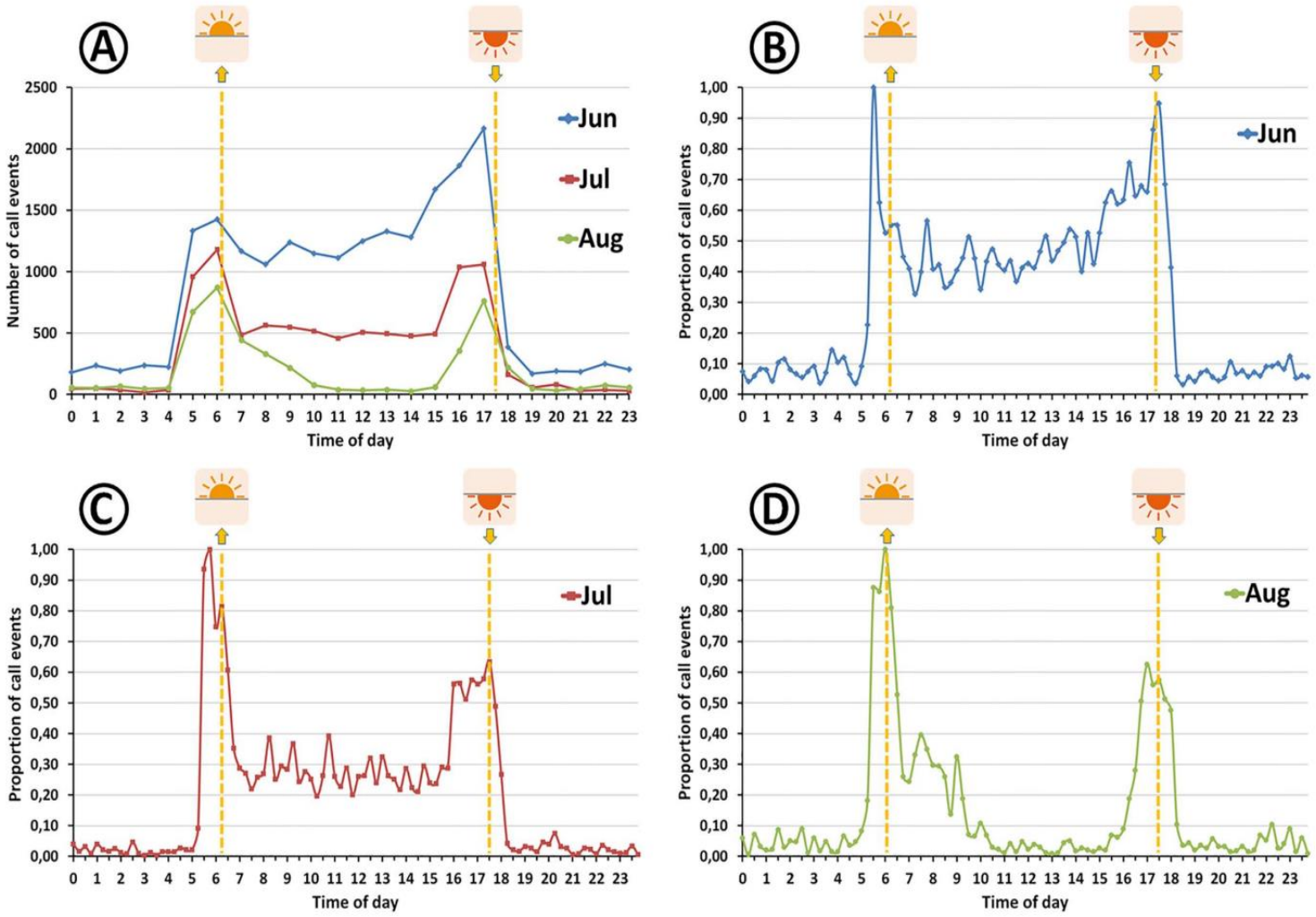
Automated Sound Recognition Provides Insights into the Behavioral Ecology of a Tropical Bird

Olaf Jahn[1,2]*, Todor D. Ganchev[1,3], Marinez I. Marques[1,4], Karl-L. Schuchmann[1,2,4,5]

1 National Institute for Science and Technology in Wetlands (INAU), Science without Borders Program, Federal University of Mato Grosso (UFMT), Cuiabá, Mato Grosso, Brazil, **2** Zoological Research Museum A. Koenig (ZFMK), Bonn, North Rhine-Westphalia, Germany, **3** Department of Computer Science and Engineering, Technical University of Varna, Varna, Varna, Bulgaria, **4** Institute of Biosciences, UFMT, Cuiabá, Mato Grosso, Brazil, **5** University of Bonn, Bonn, North Rhine-Westphalia, Germany



Computational Bioacoustics



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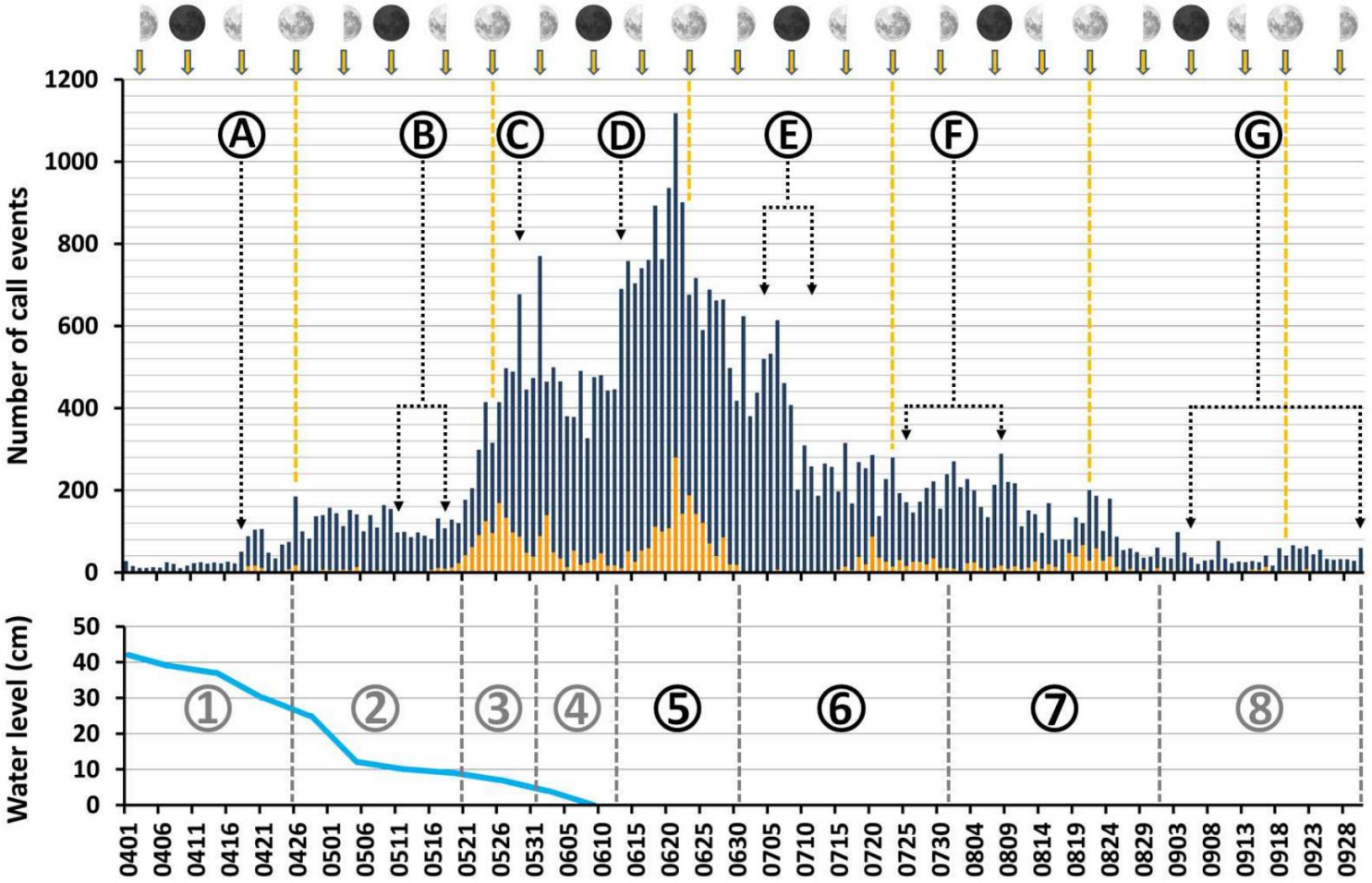
A: The acoustic activity detections on "per hour" basis for the three months of interest (June, July, Aug.);

B-D: Monthly proportion of detections of acoustic activity when monitoring "per quarter hour" for each month ot interest.

Computational Bioacoustics



Cumulative acoustic activity "per day" over 6 months

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Blue vs red bars = diurnal vs nocturnal activity.

A = occupancy of territory;

B = egg-laying;

C = day 12 of incubation;

D = earliest date of hatching;

E = change from downy to juvenile plumage;

F = acquisition of flight (fledging), and

G = attainment of independence by juveniles.

Computational Bioacoustics

CNN-based approaches (larger datasets are required)

BIOACOUSTICS
https://doi.org/10.1080/09524622.2024.2309362

Taylor & Francis
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The importance of acoustic background modelling in CNN-based detection of the neotropical White-lored Spinetail (Aves, Passeriformes, Furnaridae)

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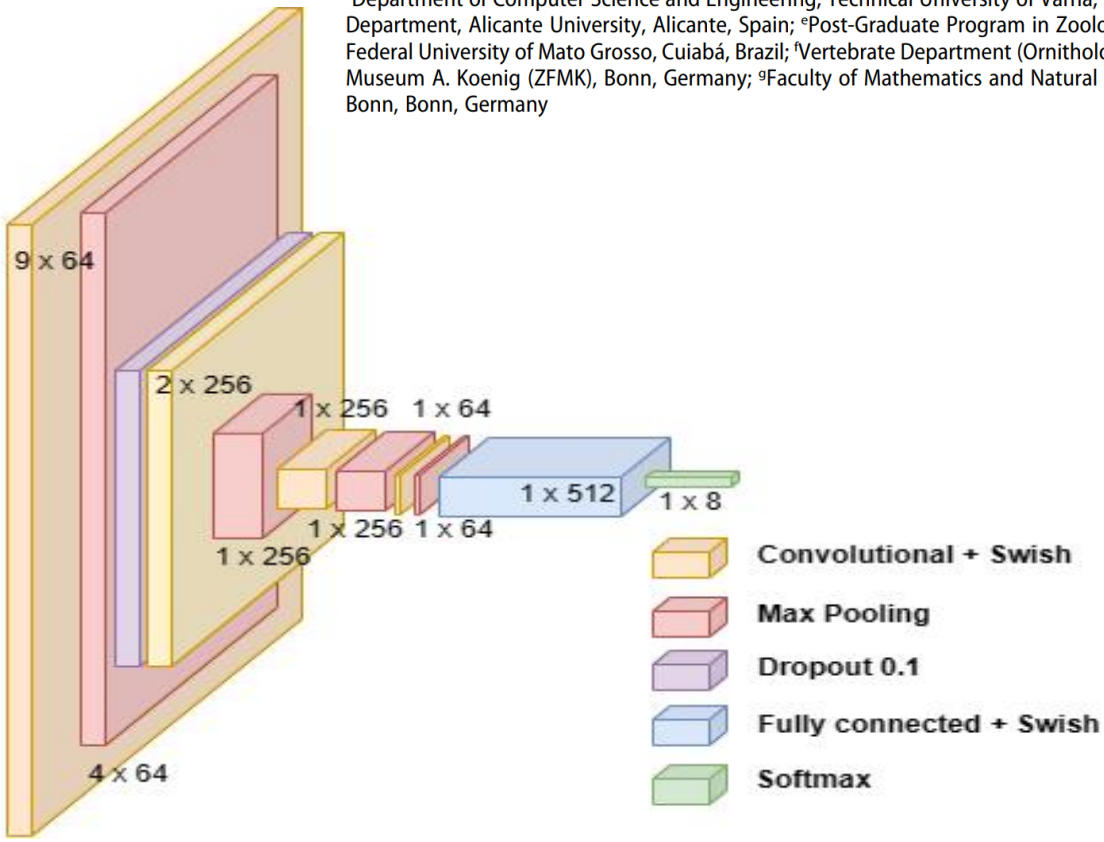
[a]National Institute for Science and Technology in Wetlands (INAU), Federal University of Mato Grosso (UFMT), Cuiabá, Brazil; [b]Institute of Computing, Federal University of Mato Grosso, Cuiabá, Brazil; [c]Department of Computer Science and Engineering, Technical University of Varna, Varna, Bulgaria; [d]Ecology Department, Alicante University, Alicante, Spain; [e]Post-Graduate Program in Zoology (PPGZOO/UFMT), Federal University of Mato Grosso, Cuiabá, Brazil; [f]Vertebrate Department (Ornithology), Zoological Research Museum A. Koenig (ZFMK), Bonn, Germany; [g]Faculty of Mathematics and Natural Sciences, University of Bonn, Bonn, Germany



BIOACOUSTICS
https://doi.org/10.1080/09524622.2024.2309362

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Computational Bioacoustics

Purposely developed CNN vs ResNet-152 with transfer learning

Model	Accuracy (%)				Precision (%)				Recall (%)			
	no-BG	BG-Wet	BG-Dry	BG-Wet +Dry	no-BG	BG-Wet	BG-Dry	BG-Wet+ Dry	no-BG	BG-Wet	BG-Dry	BG-Wet +Dry
Proposed CNN	81.2	76.9	80.2	84.5	40.8	34.7	39.3	48.4	55.4	61.3	58.6	50.4
ResNet-152	83.7	83.8	49.9	80.0	35.3	25.4	17.2	20.6	9.9	4.1	61.1	11.7

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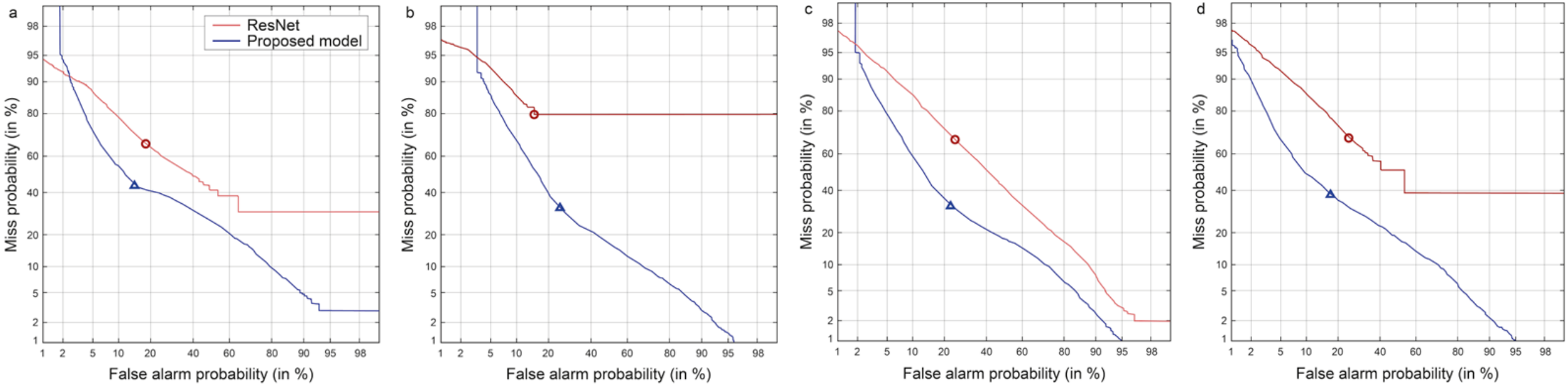
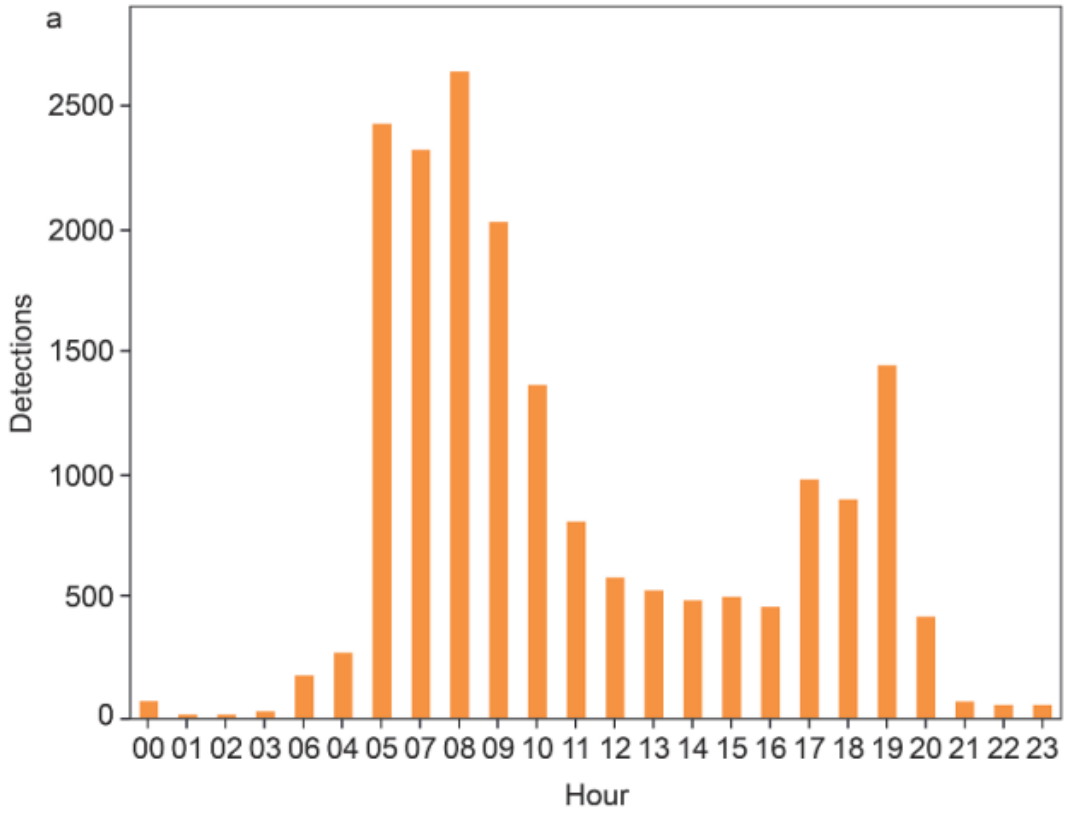
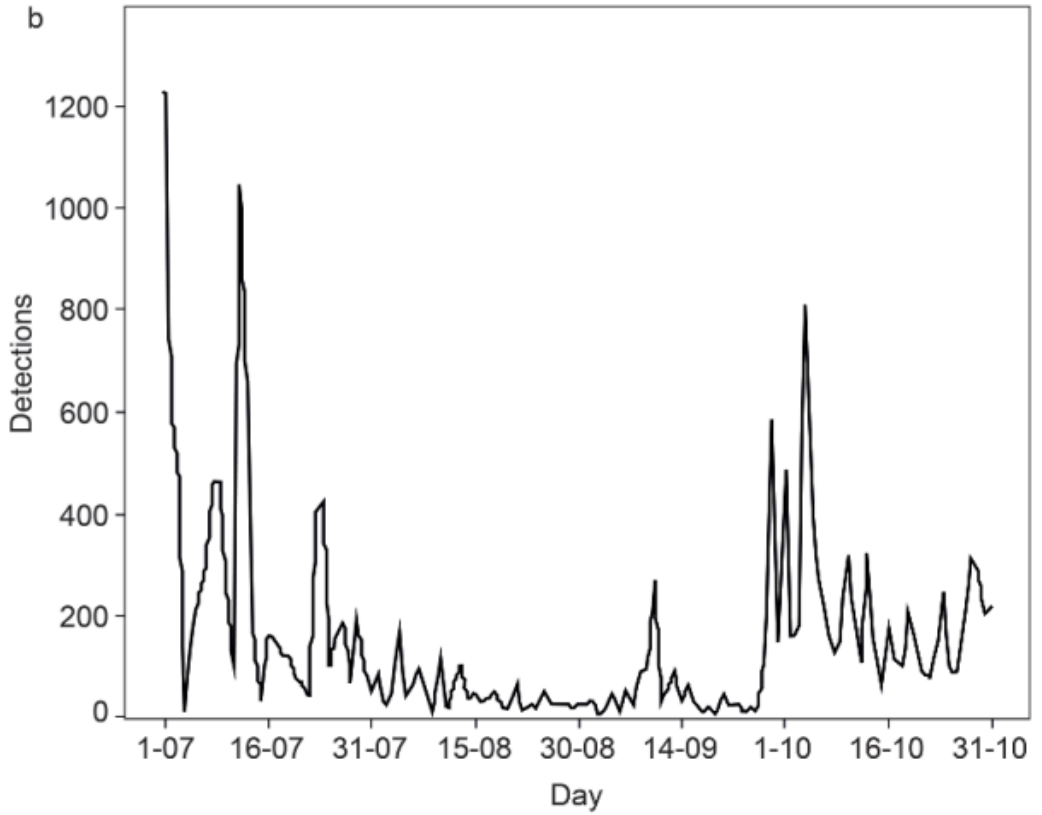


Computational Bioacoustics offers Scalability

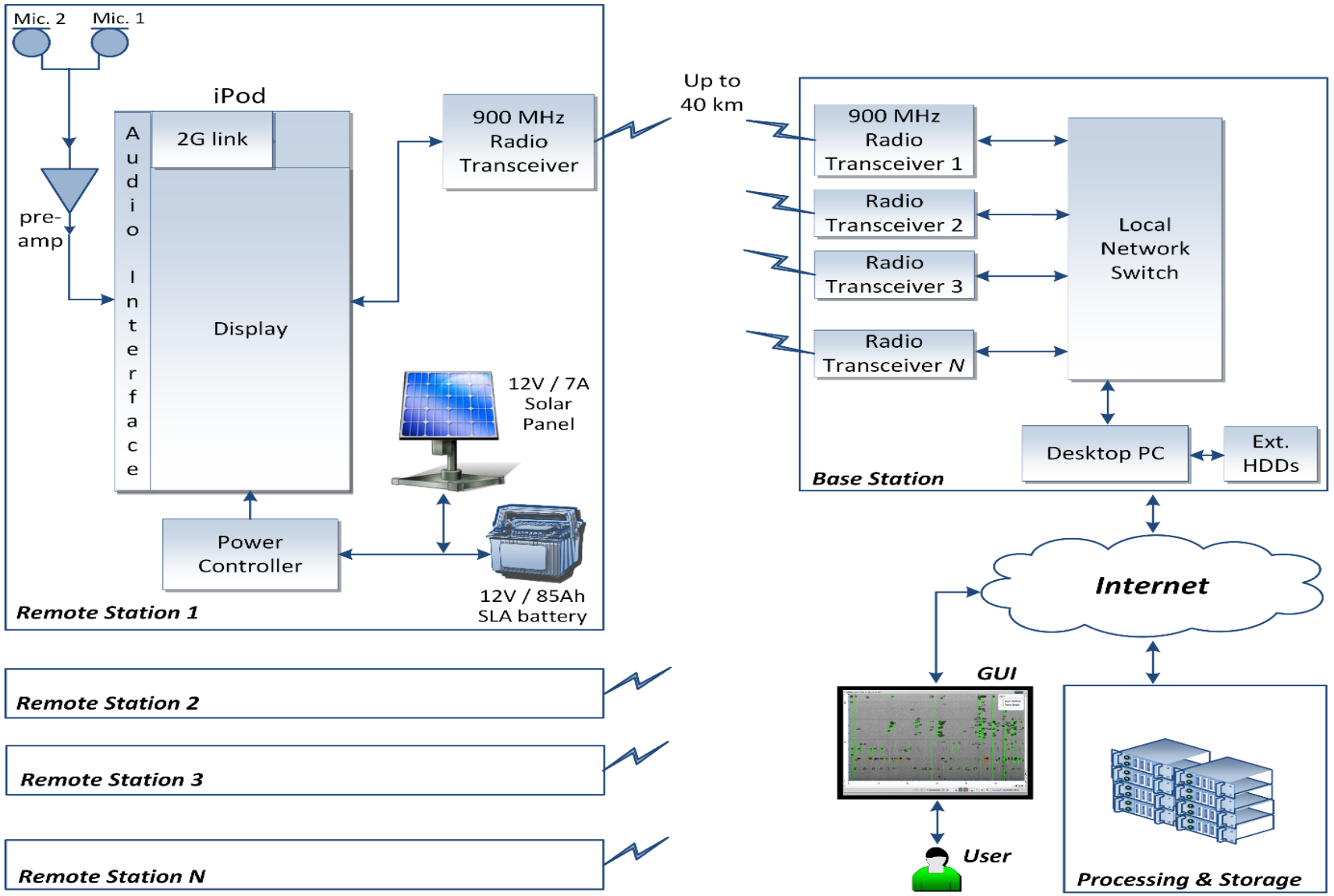


a) Acoustic activity "per hour" over 24 h



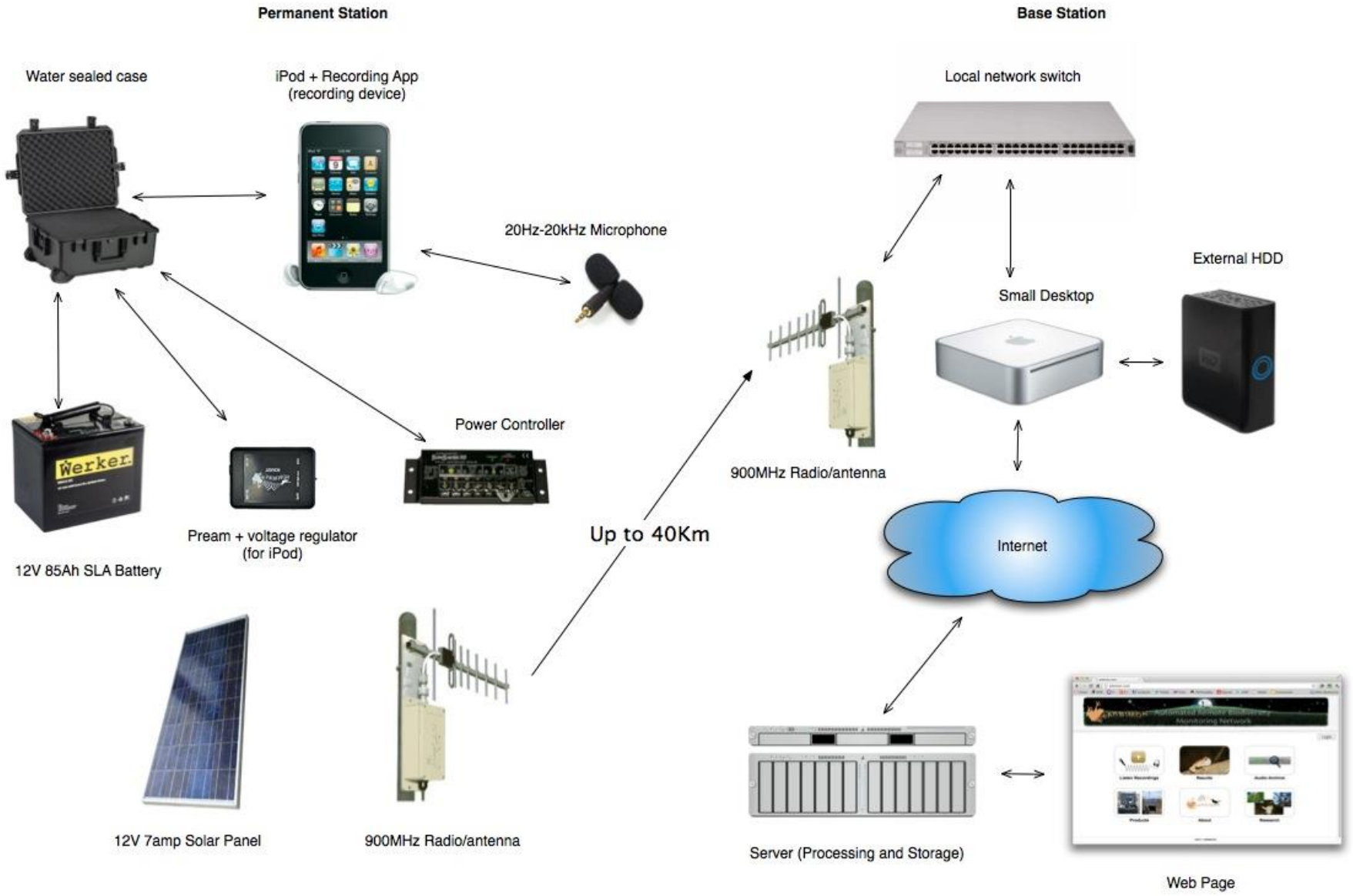
b) Acoustic activity "per day" over 4 months

The Arbimon project(s) (2006-)



The Arbimon project was conceived and implemented by Prof. M. Aide et al. University of Puerto Rico, USA
https://arbimon.org/

The Arbimon project(s) (2006-)



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The AmiBio project (2008-2013), EC LIFE+ "Best-of-the-Best"

Remote Station 1

Remote Station 2

3G Network

Internet

Data Center

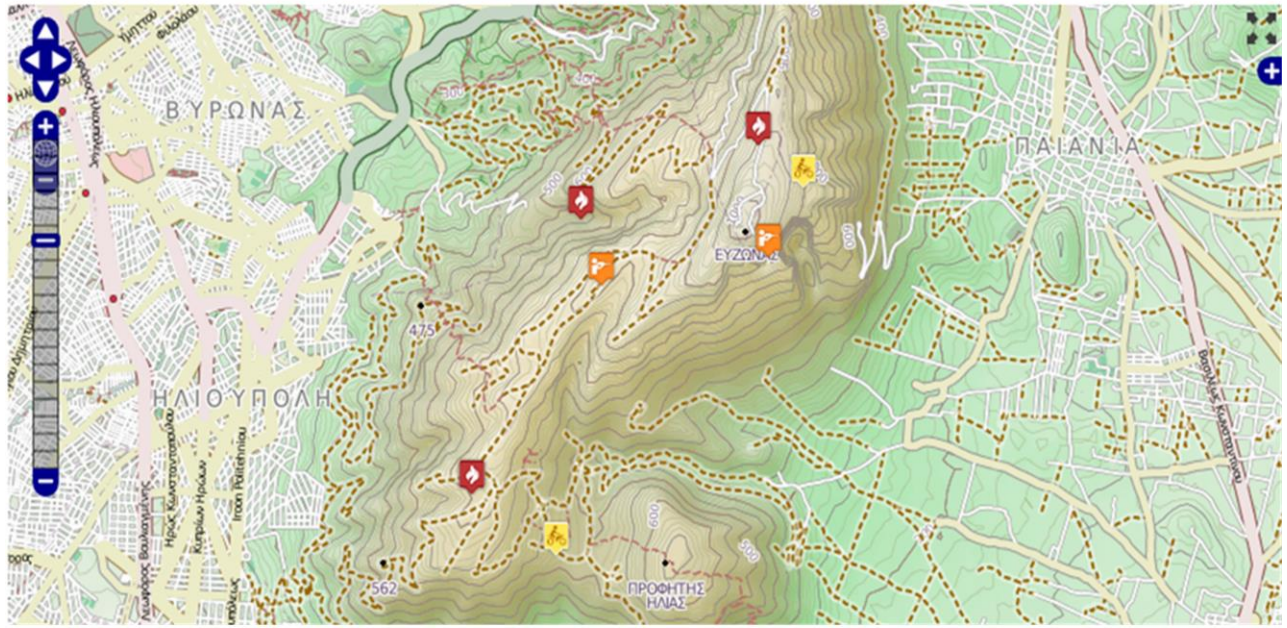
GUI

3G Tower

User

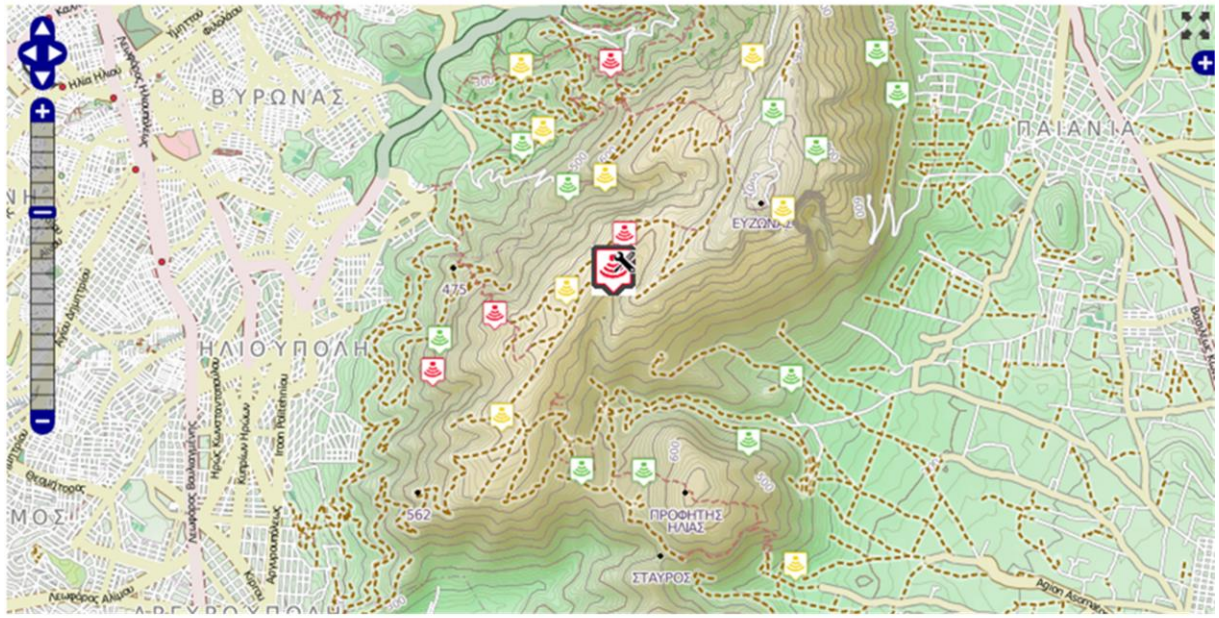
The AmiBio project (2008-2013), EC LIFE+ "Best-of-the-Best"

Summary | Stations Description | Stations Status | Stations Map | Alerts | **Alerts Map**



Title	Threat type	Timestamp	Alert status	Location Name	Audio information	Description
HYM005-000001	Fire	12.11.2011 - 14:03	Unconfirmed	Lake Vouliagmeni shore	Link	**Temperature:** 36 C **Wind Speed:** 42 km/h
HYM006-000002	Fire	23.11.2011 - 00:02	Unconfirmed	Lake Vouliagmeni cliff	Link	Test Alert
HYM009-000009	Fire	28.05.2011 - 11:15 - 13:38	Confirmed	Ergani marble quarry	Link	Fire alert test
HYM010-000003	Motocross race	28.11.2011 - 00:01 - 00:20	Unconfirmed	Mount Efzonas I	Link	Motocross race alert!
HYM011-000013	Gun shot	22.09.2010 - 16:33 - 18:52	Confirmed	Mount Efzonas II		Interdico esse facilisi dignissim. Nulla valde rusticus metuo macto dolus tum. Quidem brevitas immitto. Camur

Summary | Stations Description | Stations Status | **Stations Map** | Alerts | Alerts Map



Title	Location Name	Station Status	Battery Status	Microphone Status	Battery Level (%)	Memory Capacity (%)	Activity Indicator (dB)	Microphone Gain
HYM005	Lake Vouliagmeni shore	MAINTENANCE NEEDED	non-charging	idle	100	90		0.75
HYM006	Lake Vouliagmeni cliff	MAINTENANCE NEEDED	non-charging	idle	100	90		0.75
HYM007	Xerovrachos cliff	WORKING	non-charging	active	95	10	-7	0.7
HYM008	Heliopolis cliff	WORKING	non-charging	active	95	10	-7	0.7
HYM009	Ergani marble quarry	MAINTENANCE NEEDED	non-charging	idle	100	90		0.75
HYM010	Mount Efzonas I	WORKING	non-charging	active	95	10	-10	0.75

More ?!?!

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Artificial Intelligence Laboratory

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Thanks!

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The AmiBio project was implemented during my work at the Artificial Intelligence Group (part of the Wire Communications Laboratory) at the University of Patras, Greece, in an excellent collaboration with Prof. Ilyas Potamitis, Prof. Iosif Mporas, Dr. Otilia Kocsis and many others.

What do you say?

H1 or H0 ?

Hypothesis test:

H1: Animal communication is a fascinating field – observations reveal the complexity and diversity of the natural world.

H0: Well …, the available data do not support H1.