Exploiter les motifs d'interférence des ailes pour la classification taxonomique à l'aide de la vision par ordinateur

Décrypter le langage caché des ailes

Denis SERENO (IRD)

Journée d'animation scientifique du Réseau Vectopole Sud

Apport de l'intelligence artificielle à la surveillance et à la gestion des ravageurs, des vecteurs et des pathogènes

18 Septembre 2025

WHY IDENTIFYING INSECTS

Ecosystemic function : pollination to nutrient cycling

Bioindicators of ecosystem health: sensitivity to human disturbances

Food security: Pollination services, Pests

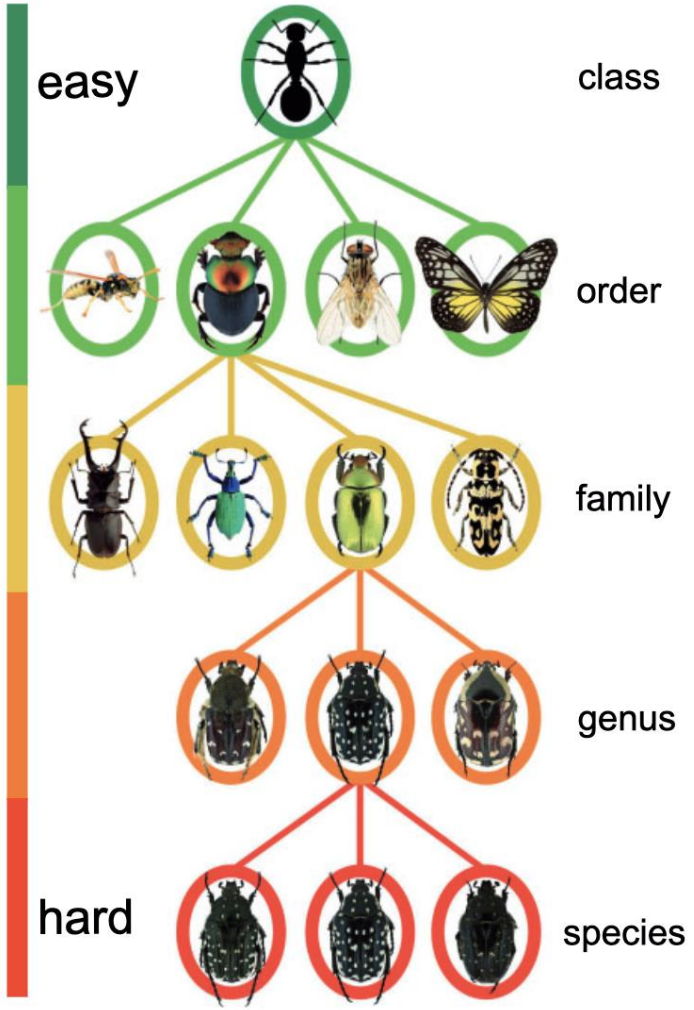
Diseases vectors (Animal and plants)

- Biodiversity conservation, disease prevention, food security etc..
- The species is one of the taxonomic level of interest

HOW TO IDENTIFY INSECTS ?

- Traditional insect identification methods, such as keys and field guides, are time-consuming and require expert knowledge

- Subjective interpretation and difficulty in distinguishing closely related species based on visual characteristics alone



Clearly visible external criteria

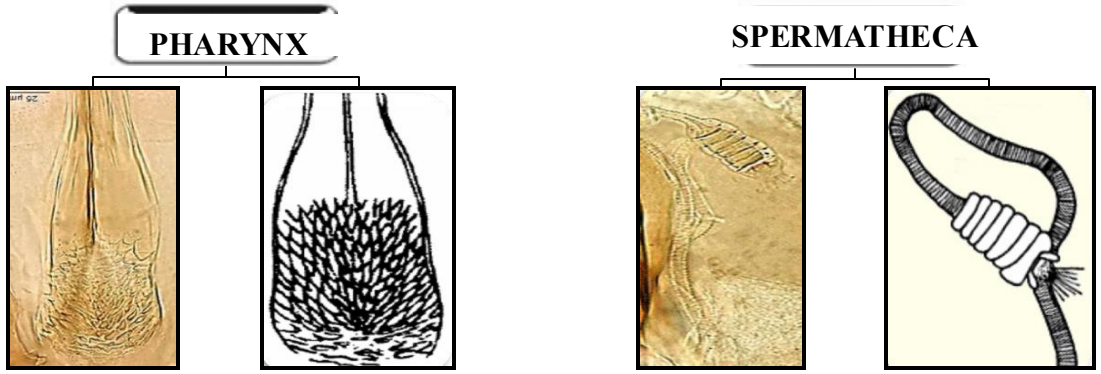
Faintly observable external criteria. Internal diagnostic criteria

NON DNA BASED-TRADITIONNAL IDENTIFICATION METHODS

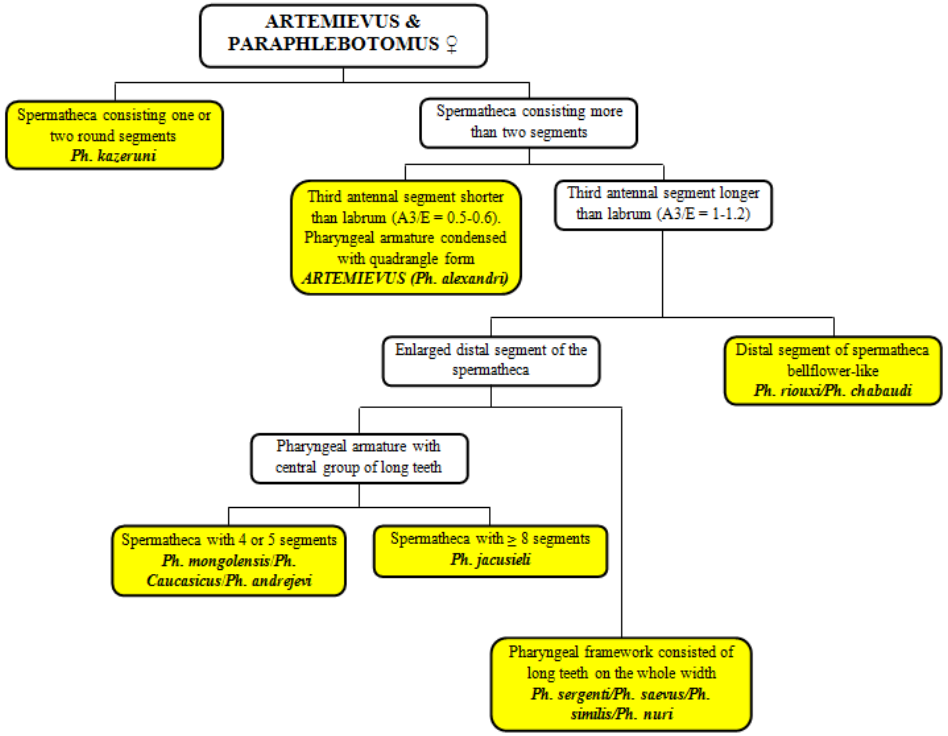
Dichotomic keys, **discriminant characters**

Polynomic keys based on systematic collection of quantitative and qualitative traits

Limited in the diversity, often local, not available for all families, Genus.



From Akhoundi *et al.*, 2025

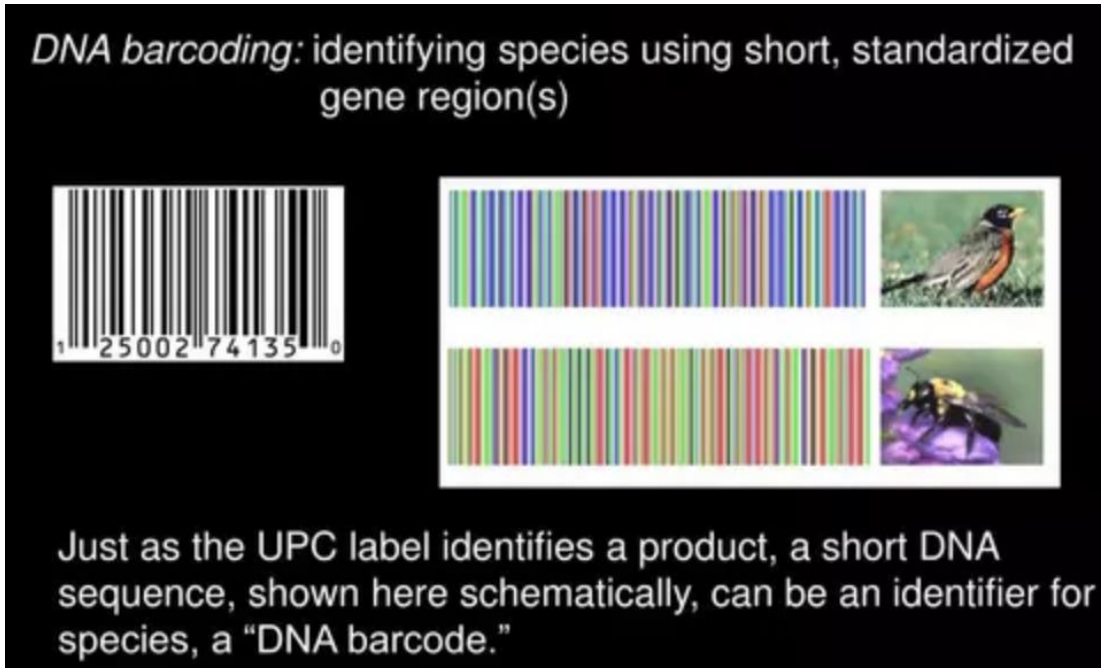


From Akhoundi *et al.*, 2025

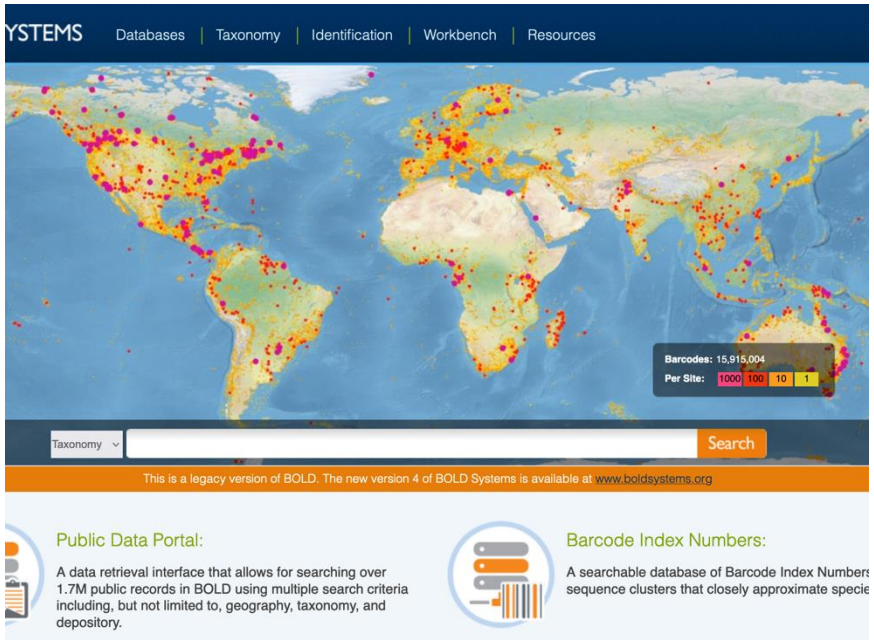
Phlebotominae, transmission of *Leishmania*-Leishmaniasis

Dissection of the genitalia or other organs

DNA BARCODING & META-BARCODING



BARCODE OF LIFE WEBSITE



- Short DNA regions (COI gene for metazoan) for taxon identification
- Any stage of life (i.e. both adults and immature stage including eggs),
- Environmental DNA

- BC for 256 345 species of the Insecta over 1 million
- Error prone, false annotation …
- Destructive, expensive, not amenable in field conditions

OTHER LESS CONVENTIONAL METHODS

Category	Techniques	Example Use
Bioacoustic & Light 🎤💡	Microphones, infrared, phototransistors, LDV, ultrasonic, piezoelectric, accelerometer	Wing-beat detection, vibration signals
Imaging 📷	Cameras (whole-body imaging)	Morphological ID across orders
RADAR / LIDAR / Chemical 📡🔬	Radar, LIDAR, odor/nose sensors	Remote tracking, spectral ID, pheromone/odor detection

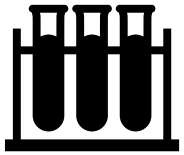
From Sereno (2025) submitted

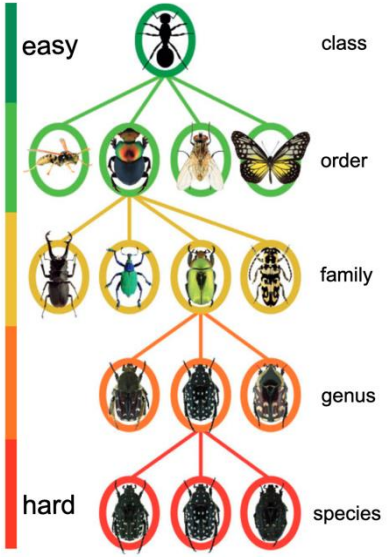
CHALLENGES IN INSETCT IDENTIFICATION

Now

Morphology — Expertise

DNA..

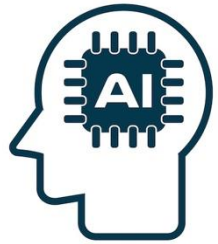




Hurry up

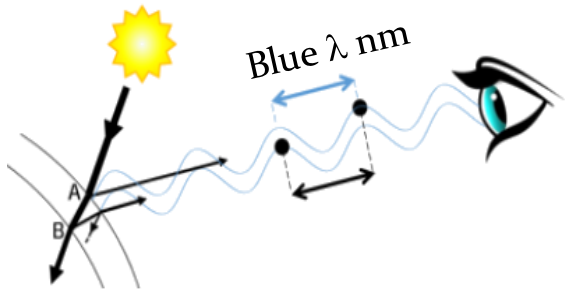
Future ?

Expertise

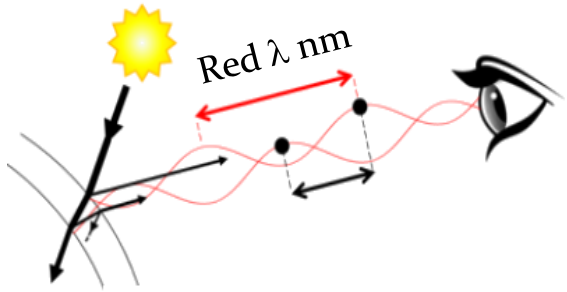



GOINSECT
Insecta class
members belonging to the
observed in almost all
WIPs can be
Sauvion N

WHAT ARE WING INTERFERENTIAL PATTERNS (WIP)?

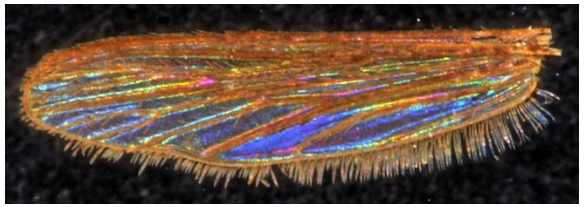


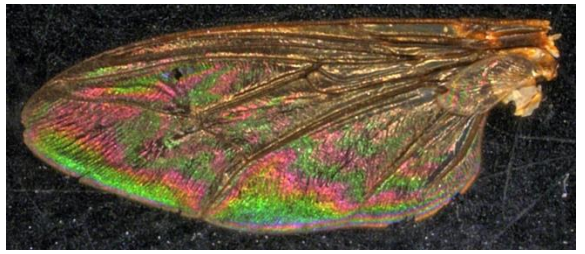
Wing Delay = 1 λ–> brighter blue



Wing Delay = 1/2 λ–> attenuation of red

Thickness





- **Interaction with thin and transparent layers->thickness** sets the **phase difference** between reflected light waves.
- **Constructive** & **destructive interference of light** waves.
- C**olorful**, often **iridescent** patterns.

CAN WIP ACT AS A VISUAL LANGUAGE FOR CONGENER RECOGNITION?

How

- Train a **classifier:** computer vision approach.
- **Characteristics of interest:** color distributions, spatial banding, texture patterns, local contrast, excluding venation (bof: batch of features)…
- **Imaging protocols, calibration** files, **preprocessing** steps, and specimen **metadata**.

On what samples

An insect's family from which a **representative number of species** can be feasibly obtained to ensure adequate **biodiversity coverage.**

Culicidae 3500-3700 named species

Psychodidae >2700

Glossinidae >30

IRD-CIRAD (ARIM) host a collection of specimen and colony reared *Glossina*

GLOSSINA WIPS: A PICTORIAL KEY

(Diptera, Glossinidae) – Tse-Tse->Sleeping sickness, animal trypanosomes

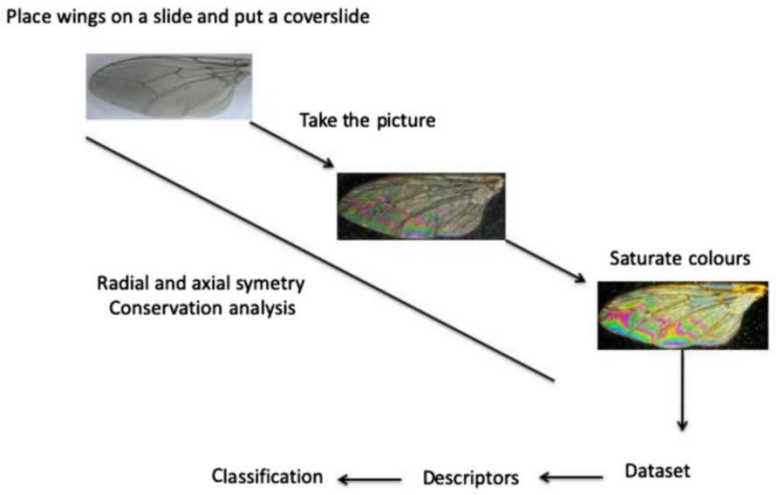
Specimen selection

33 species/subspecies
good model

Selection and/or
trapping of
representatives of 23
Glossina sp

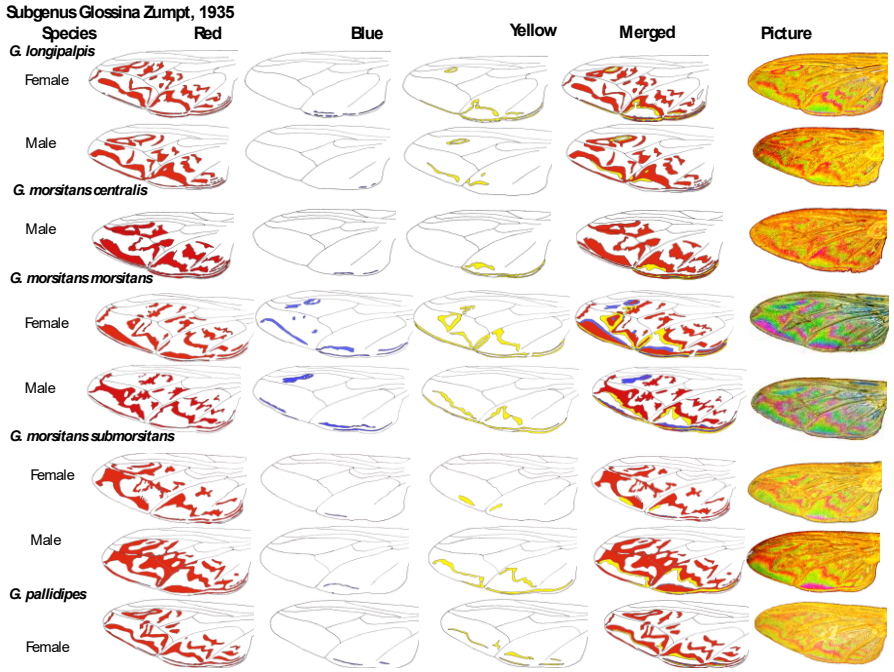
75% of the recorded
Glossina diversity

Database construction



1766 pictures

Pictural key based on WIPs



Specific colors and **patterns** indicative of the glossina **species**

COMPUTER VISION BASED GLOSSINA WIP IDENTIFICATION

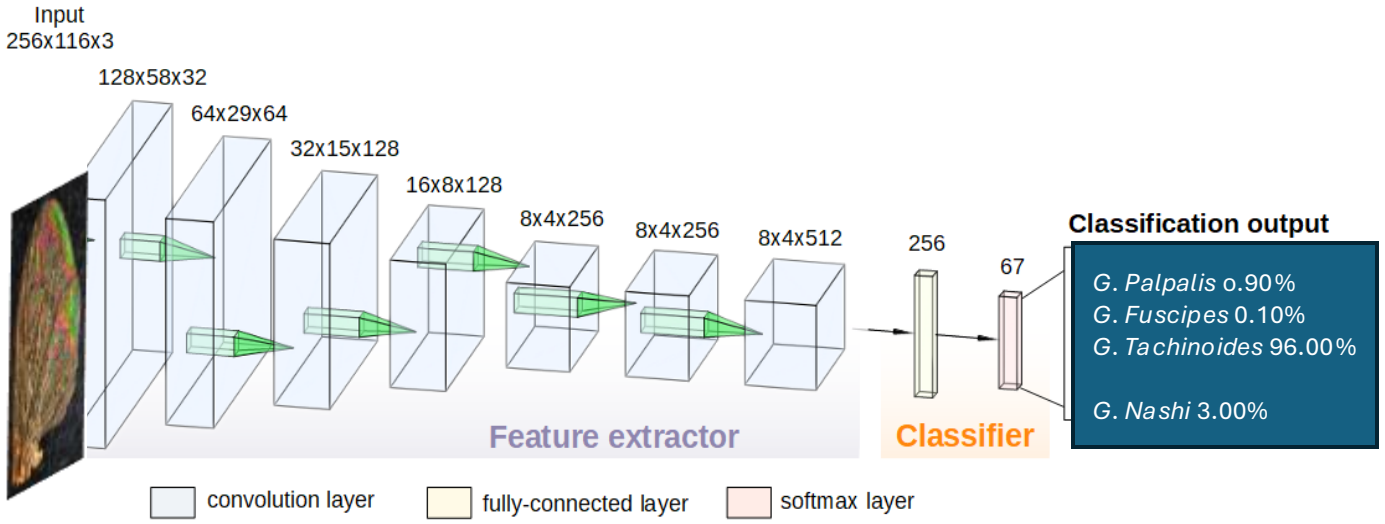
Image acquisition: Standardized imaging & controlled light conditions.

Pre-processing:
- Segmentation.
- Normalization of size and orientation.
- Conversion into numerical descriptors (color texture.)

Feature extraction:
- Color information (RGB/HSV histograms).
- Texture descriptors (Local Binary Patterns, Gabor filters..).

Classification models tested:
- Supervised machine learning classifiers (**Support Vector Machines (SVMs)** and **Random Forests)**.
- Models trained on extracted WIP features

Evaluation:
- Cross-validation approach (k-fold).
- Metrics: classification accuracy and confusion matrices.

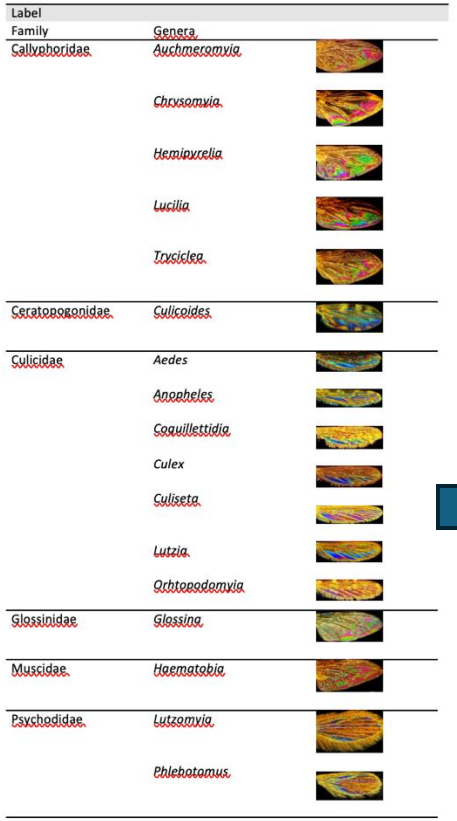


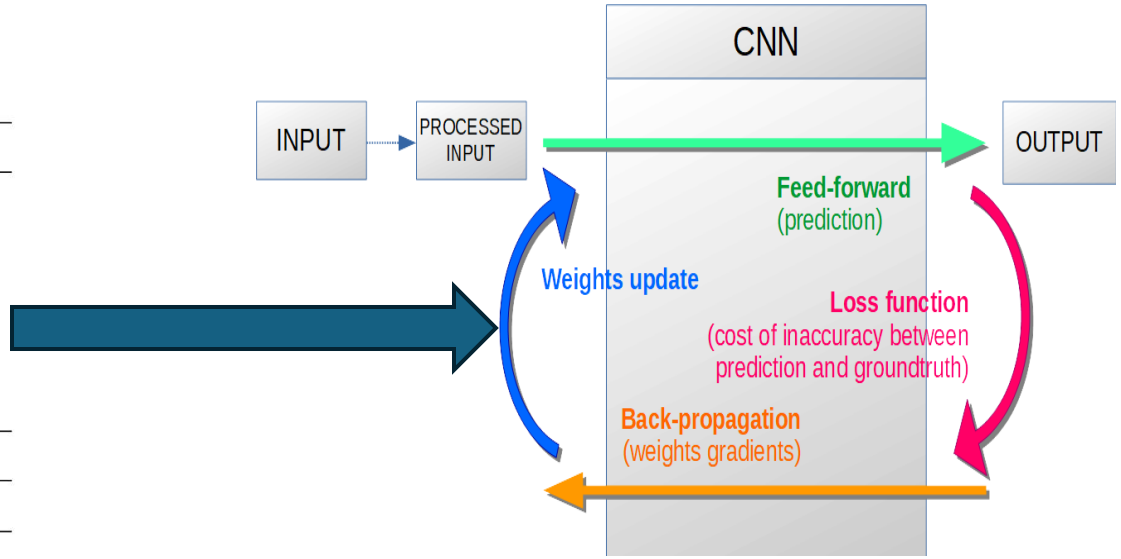
Overall accuracy >90%,

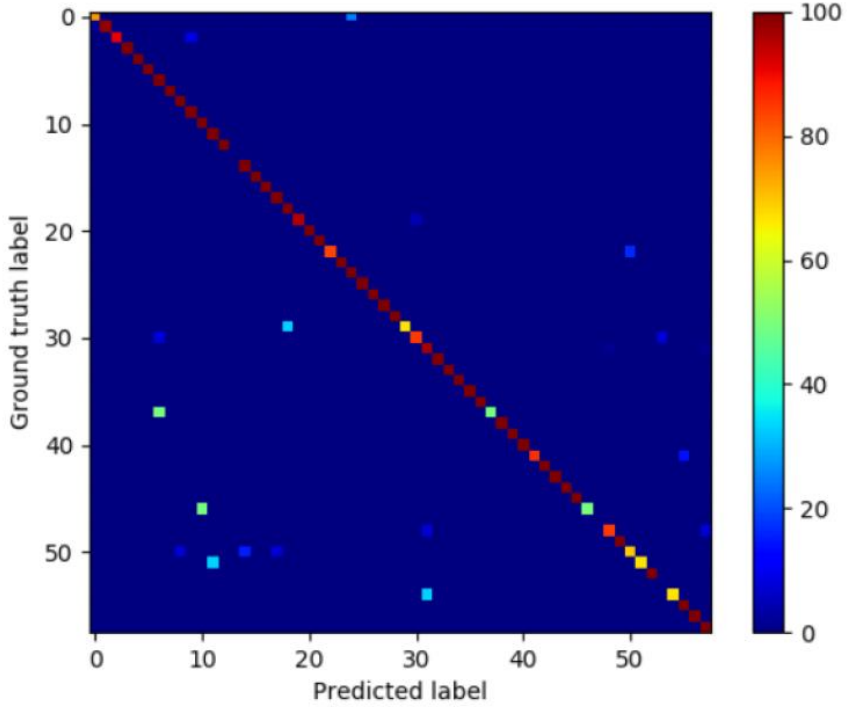
WIPS BASED COMPUTER VISION ALLOW AUTOMATIC DIPTERA SPECIES CLASSIFICATION

WIPs database

Diptera order: 100 000 species (ITIS), Malaria, Leishmaniasis, Dengue, Zika…







5516 pictures of 7 families (Culicidae, Calliphoridae, Muscidae, Glossinidae, Tabanidae, Ceratopogonidae, Psychodidae)

21 genera, 105 species!!!

Representativity 0.1% of named Dipteran species

Accuracy >90% at high taxonomic level (Genus, family)

Accuracy >90% for most of species tested

UNCOVERING PATTERNS IN WIP FEATURES

Anopheles genus: >500 species worldwide, major malaria vectors; grouped in complexes morphologically close but ecologically and epidemiologically distinct.

Genus level: > 99% accuracy.

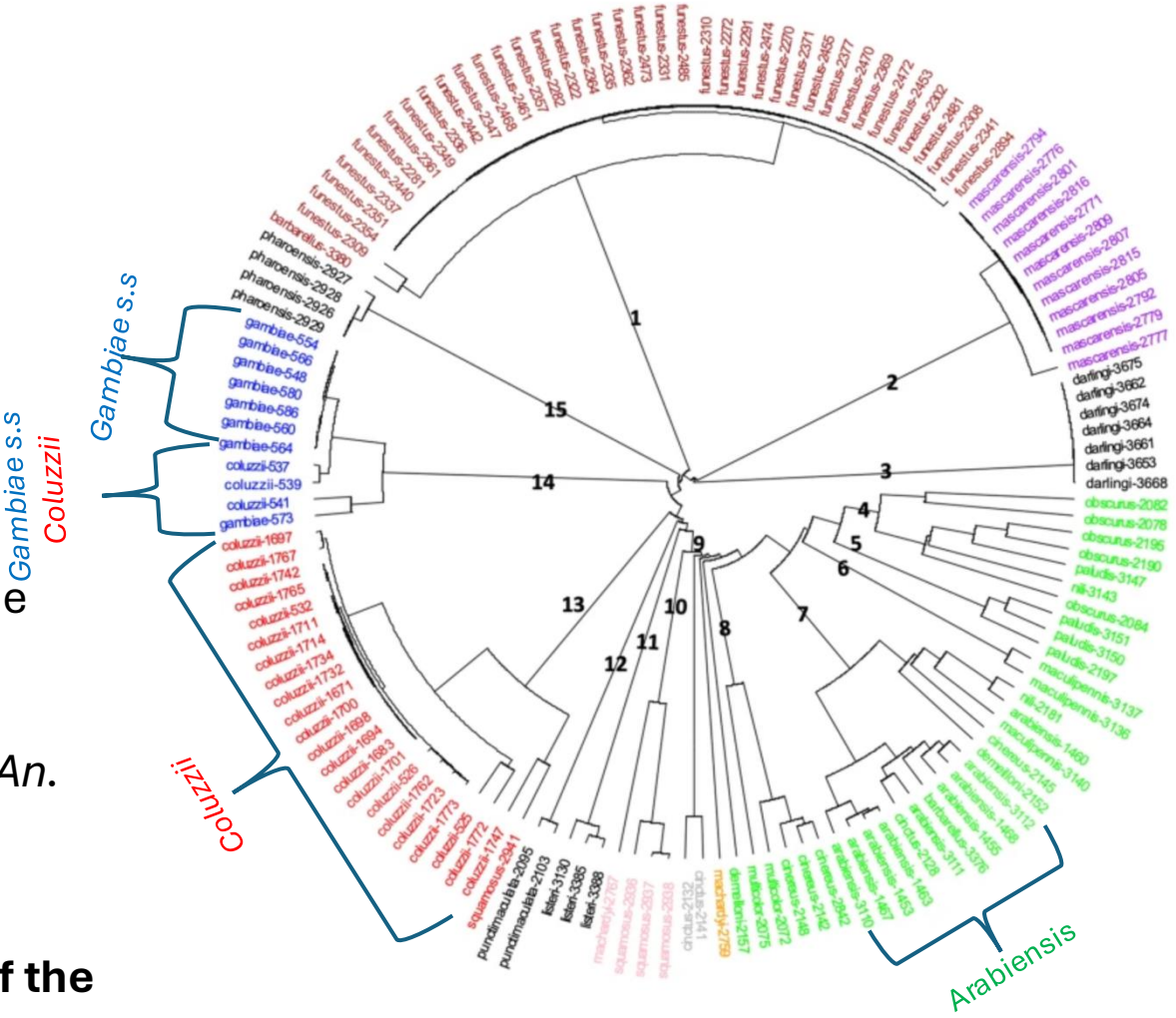
Subgenus level: ~ 39% to ~ 97%, depending on subgenus representation.

Species level: 10 species 100%; others varied, but >90% gambiae complex.

Limited overlap at the **subgenus level**, variable results at the **species level**.

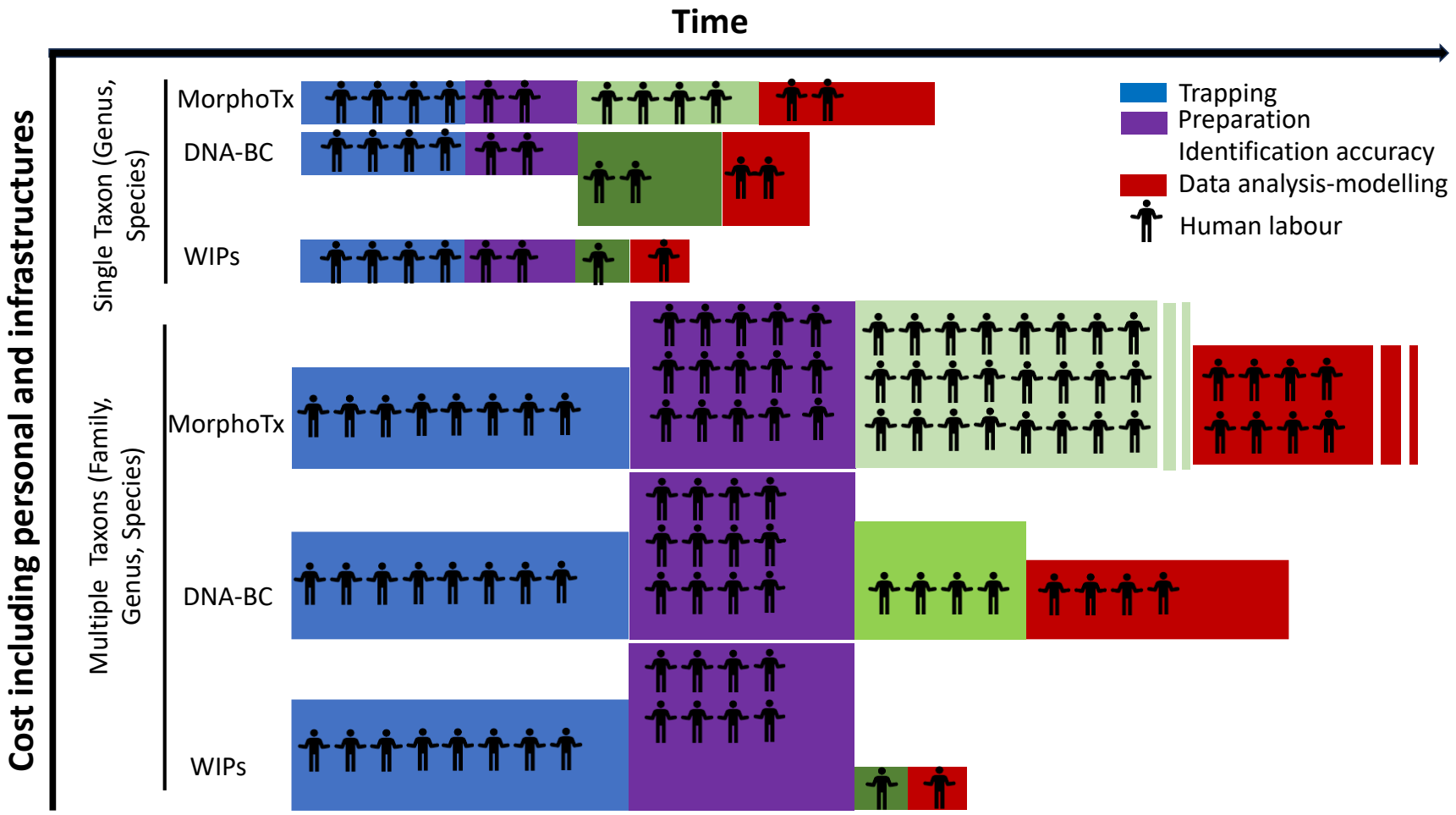
An. gambiae s.s and *An. arabiensis* cluster distinctly, some *An. coluzzii* images overlaps partly with *An. gambiae*.

WIPs carry enough information to separate species of the gambiae complex visually.



Mapping by predicted probability profiles

AI BOOST TAXONOMIC IDENTIFICATION WHEN TRAINED WITH WIP



Neural networks analyze insect wing patterns to accurately identify species, surpassing human capabilities in speed and precision for entomologists worldwide.

THE FUTURE LOOKS BRIGHT!!!!!

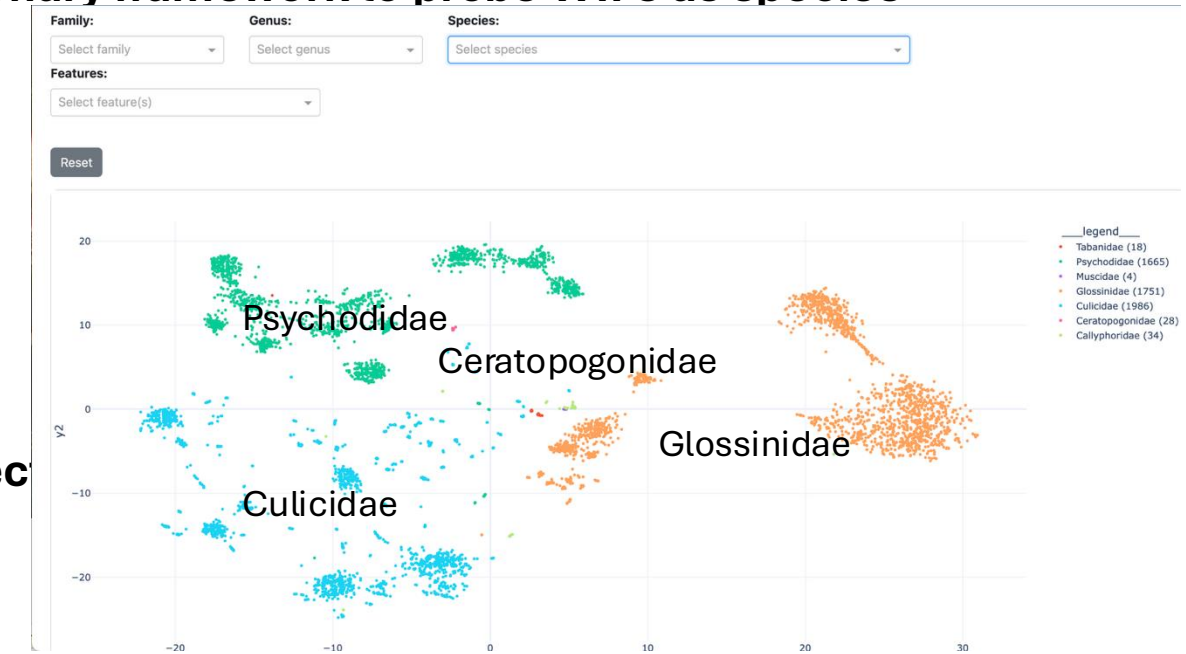
New species/vs new specimen how to distinguish them?->Purpose vs Biodiversity

In field application ->lowering human manipulation for image acquisition (Image quality, specimen quality, low labor to capture the taxonomic marker of interest…)

Citizen contribution?->Insect of patrimonial interest-Large insects-Insects of interest for citizens

FAST-WING-ID : ***Fast*** *Taxonomic Profiling of Agronomic Insects Using Wing Interferential Pattern Imaging and Deep Learning*
Diptera, Hymenoptera, Hemiptera: an evolutionary framework to probe WIPs as species-recognition signals

WIP-ATLAS: *A **WIP**-based insect **atlas**: An interpretable, open-set approach to insect identification and trait inference*
Toward a global WIP-based reference for insec ID and traits



Denis Sereno
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Nicolas Sauvion

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