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## Use of deep learning methods applied to the study of ticks and tick-borne diseases

Sk Imran Hossain, Yann Frenco, Valerie Poux, Isabelle Lebert, Olivier Lesens, Delphine Martineau, Engelbert Mephu Nguifo, Gwenaël Vourc'h, Jocelyn de Goër de Herve

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## Use of deep learning methods applied to the study of ticks and tick-borne diseases

*I. Hossain, Y. Frenco, V. Poux, I. Lebert, D. Martineau, O. Lesens, E. Mephu-Nguifo, G. Vourc'h, J. De Goër*

Session - Management and integration of agronomical, phenotypical and environmental data

**Jocelyn DE GOËR**  
UMR EPIA

July 7<sup>th</sup> 2022

# Ticks and tick-borne diseases

- ✓ Ticks are acarians, ectoparasites and hematophagous
  - ✓ 12 genus, 700 species of hard ticks in the world
  - ✓ 4 genus in France
- ✓ Ticks are vectors of diseases:
  - ✓ Transmission during blood feeding



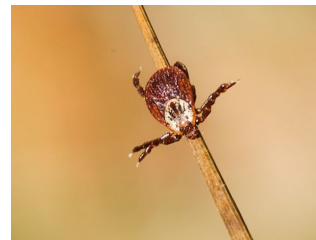
Metropolitan France

*Ixodes*



- *Babesia*
- *Powassan*
- *Anaplasma*
- *B. miyamotoi*
- *Ehrlichia*
- *F. tularensis*
- *Bartonella*
- *B. burgdorferi* (Lyme)

*Dermacentor*



- *Babesia*
- *Colorado Tick Fever*
- *Rickettsiae*
- *F. tularensis*

*Rhipicephalus*



- *Babesia*
- *Rickettsiae*
- *Bartonella*

Southern France

*Hyalomma*

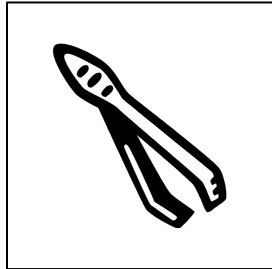


- *Crimean-Congo hemorrhagic fever*

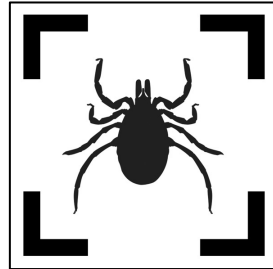
- Parasite
- Virus
- Bacteria

# Ticks and tick-borne diseases

## ✓ Study and surveillance of ticks and ticks-borne diseases



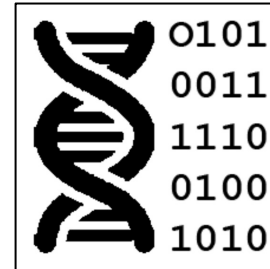
Collection  
in the field



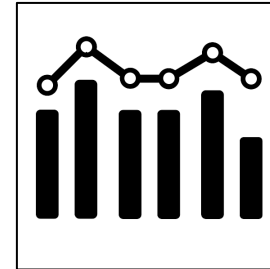
Identification



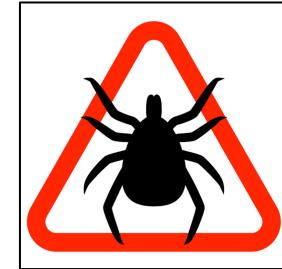
Pathogen  
detection



Bio-informatics



Statistics



Prevention

## ✓ Lyme disease

✓ Lyme disease is the most reported tick-borne disease in US and Europe

✓ Estimation of cases each year:

✓ USA: 400 000 (source CDC)

✓ France: 60 000 (source SPF)

# Research projects

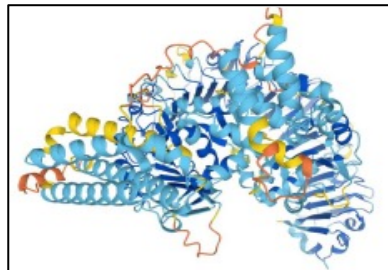
- ✓ **Two projects about Lyme disease and ticks surveillance**
  - ✓ **2018: DAPPEM Project**
    - ✓ Mobile application development for early skin signs of Lyme Disease (erythema migrans)
  - ✓ **2020: DCLIC Project**
    - ✓ Real-time ticks genus identification system
- ✓ **These projects are based on Artificial Intelligence methods**

# Artificial Intelligence

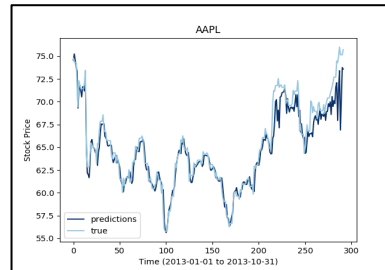
- ✓ **Artificial intelligence:**
  - ✓ **AI symbolic** : based on formal and logical descriptions (algorithms)
    - ✓ Experts systems
  - ✓ **AI connectionist** : the machine is able to "learn" by itself from data
    - ✓ Deep Learning
- ✓ **Since 2012, sufficient computing capacity for its application:**
  - ✓ GPU-based computing (Graphics Processing Units)
- ✓ **Deep Learning is used in many domains:**



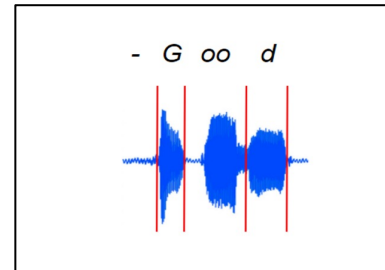
Text Mining



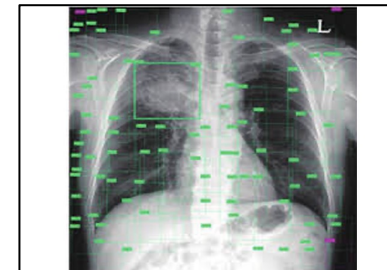
Bio-Informatics data analysis



Time series analysis



Sound analysis  
Voice recognition



Medical diagnostic assistance

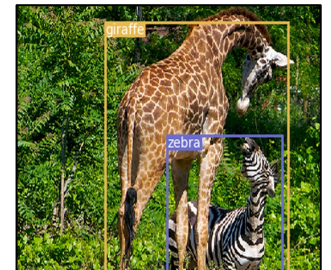


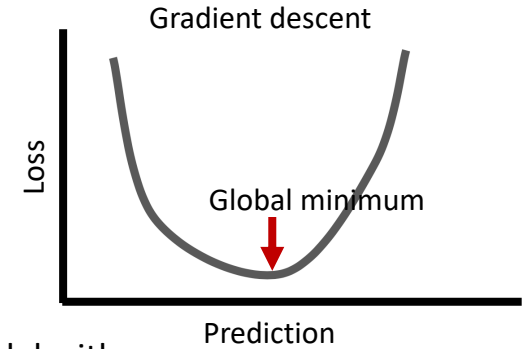
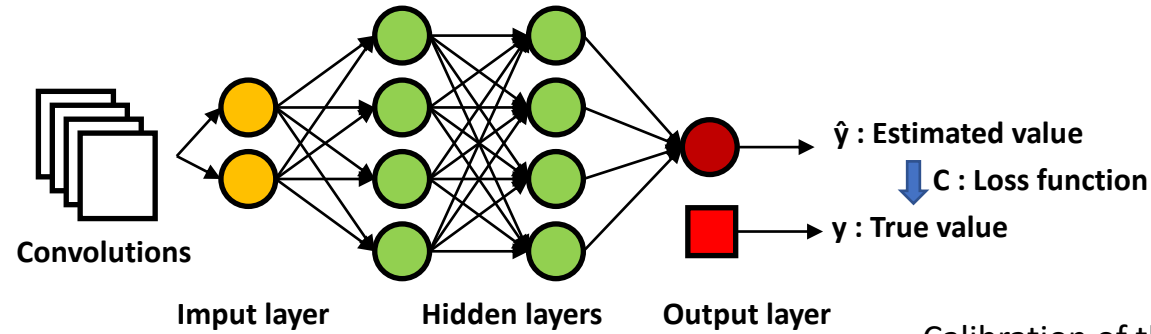
Image / video analysis

# Artificial Intelligence

## ✓ Training of a neural network for image classification

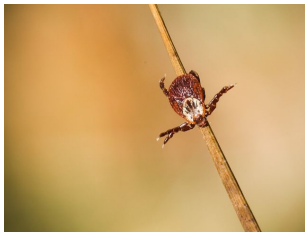


Image Datasets  
Labeled and classified

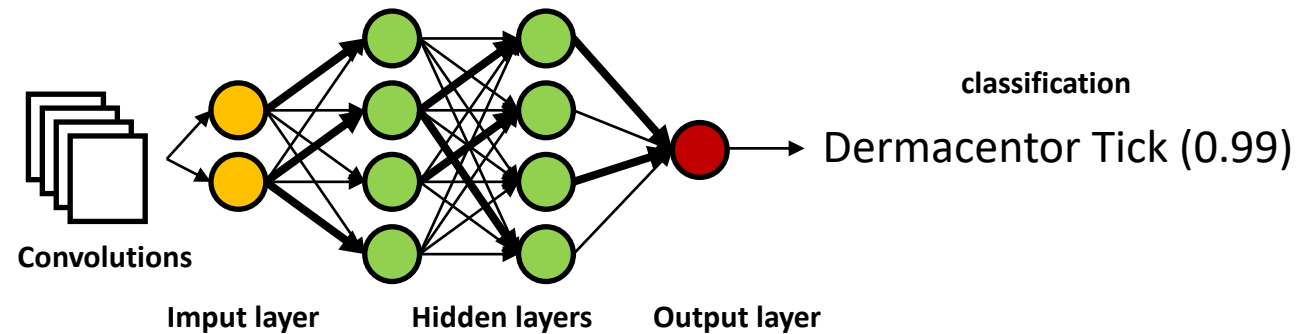


Calibration of the model with  
backpropagation method

## ✓ Query from image

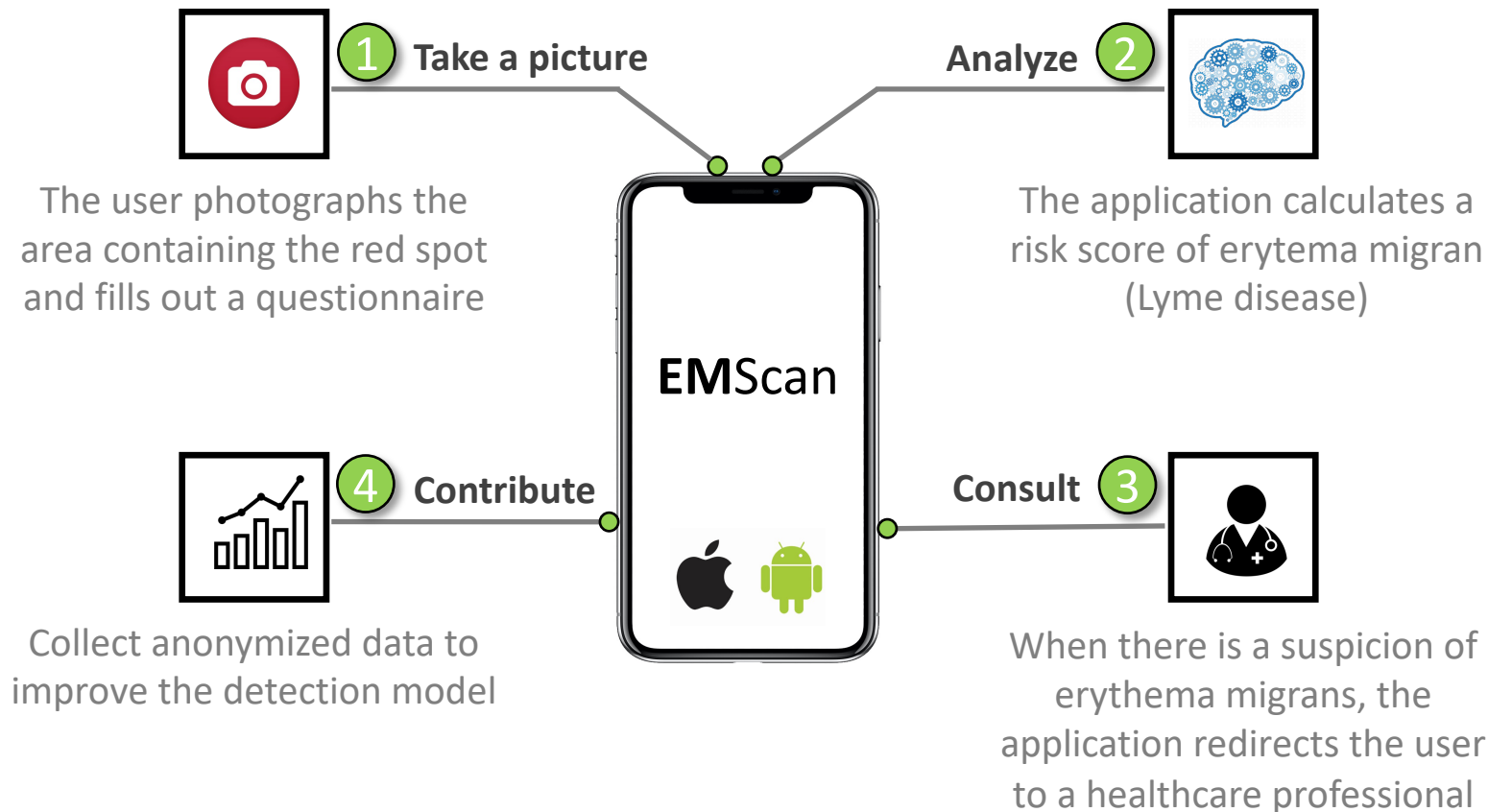


Query image





- ✓ **DAPPEM:** Développer une application permettant la détection des Erythèmes Migrants (premiers signes cutanés de la maladie de Lyme)
- ✓ Target users: Health care workers and general public

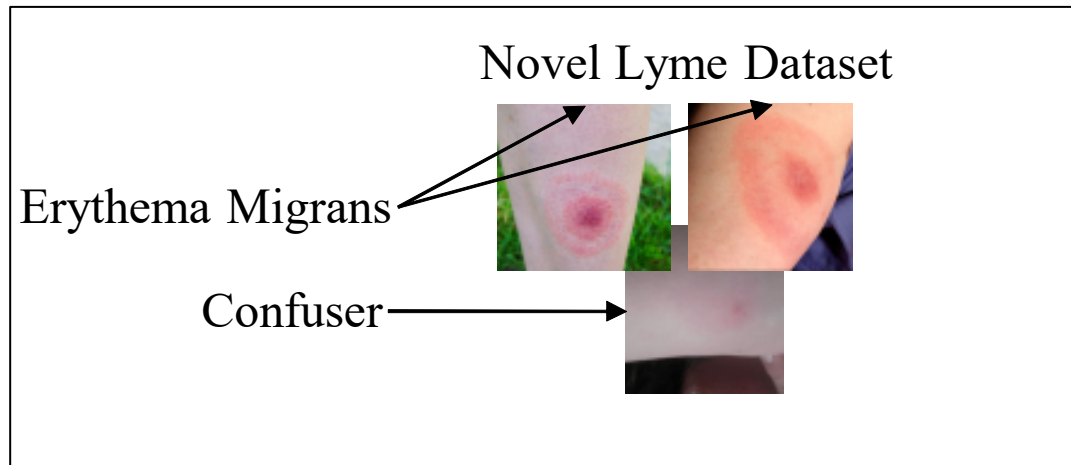


Erythema migrans  
Early sign of Lyme disease

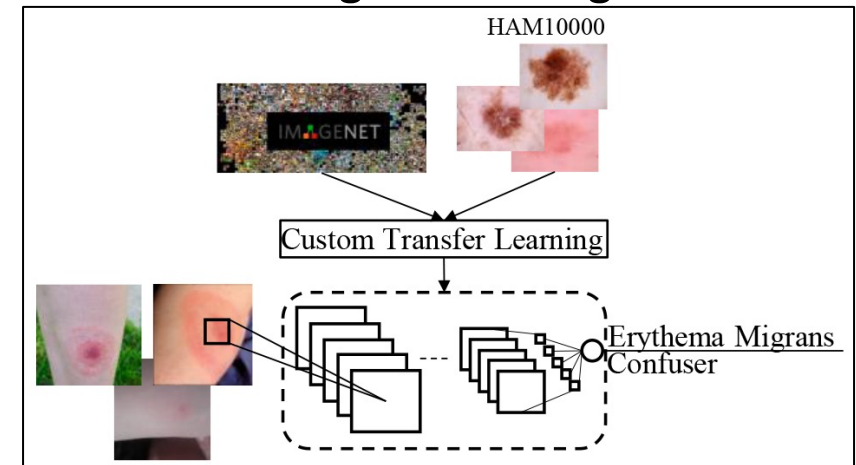


- ✓ **Develop and train an artificial neural network to identify EMs from a photo**

- ✓ Creation of a training dataset
  - ✓ 866 images of EM identified by doctors
  - ✓ 806 images of non EM (confuser class)



- ✓ Training 23 CNN architectures
  - ✓ Transfert Learning
  - ✓ Adding other image dataset

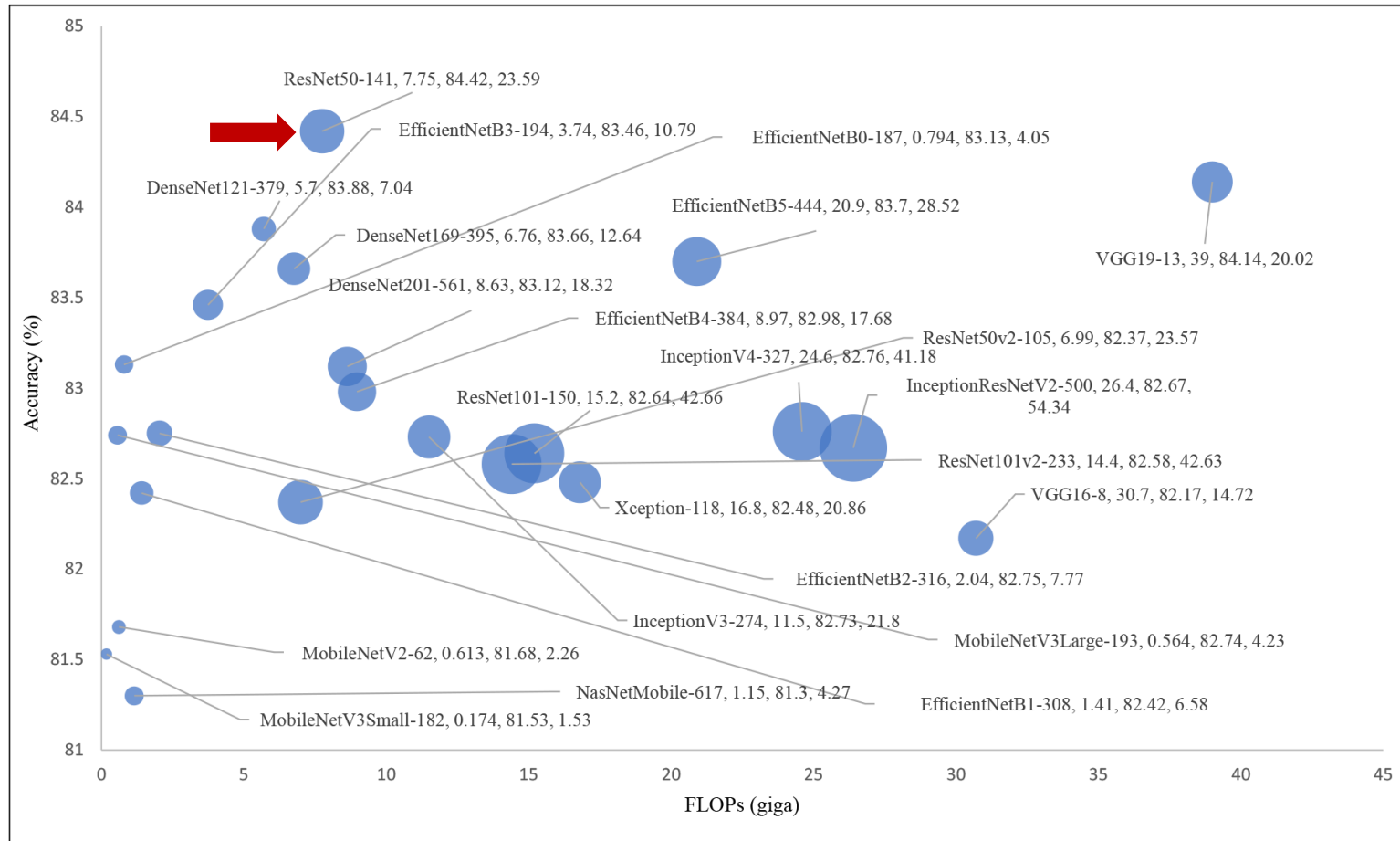


**Work done by Imran Hossain, PhD student at LIMOS, supervised by E. Mephu-Nguifo and J. de Goër**

Publication: Sk. Imran Hossain and al, *Exploring convolutional neural networks with transfer learning for diagnosing Lyme disease from skin lesion images*

Journal Comput. Methods Programs Biomed., 2022

## ✓ 23 CNN trained models comparison



**Selected model:**

**Architecture:** ResNet50-141

**Accuracy:** 84,4 %

**Sensitivity:** 87,9 %

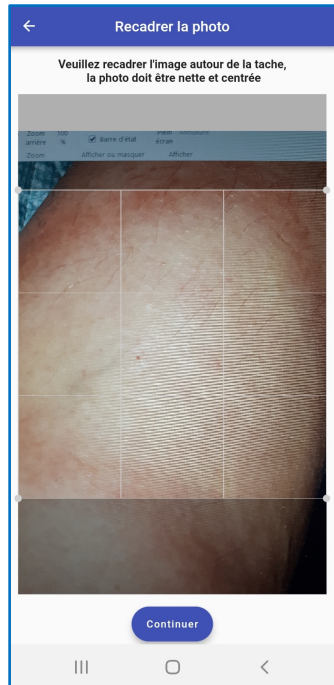
**Specificity:** 80,7 %

**Parameters:** 23 million

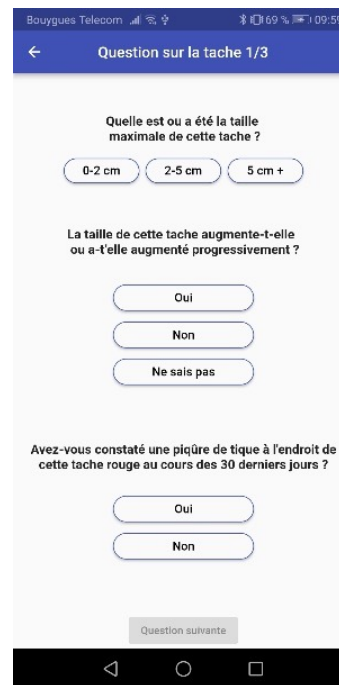
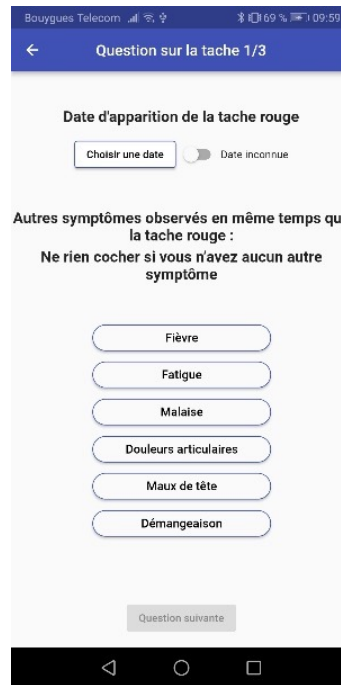
● Size represents number of model parameters (million units)

Hossain et al. 2022. Computer Methods and Programs in Biomedicine

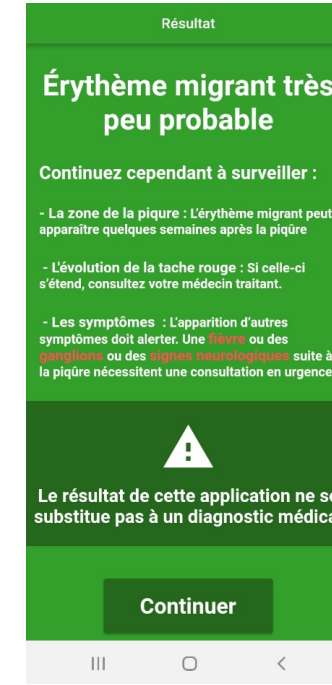
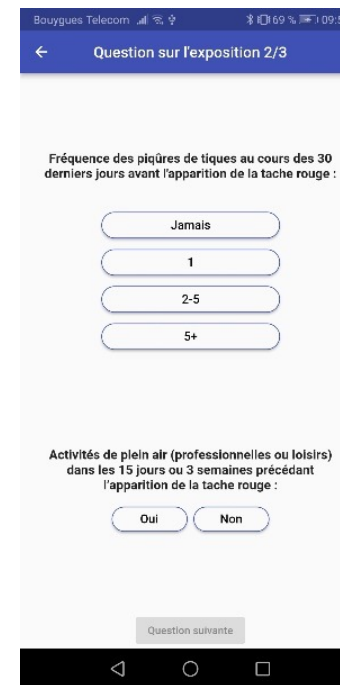
## ✓ EMScan mobile application mains screens:



Take picture



Questionnaire



Result screens



## ✓ Research units:

- ✓ EPIA (UMR INRAE – VAS). J. de Goër, I. Lebert, G. Vourc'h
- ✓ LMGE (UMR UCA-CNRS) / CHU : O. Lesens, D. Martineau
- ✓ LIMOS (UMR UCA-CNRS-EMSE). E. Mephu-Nguifo, I. Hossain (Ph.D student), Y. Frendo

## ✓ Non-academic partners:

- ✓ ONF, Office National des Forêts. C. Planchette
- ✓ MSA, Mutualité Sociale Agricole. M. Ruols
- ✓ CNPF, Centre National de la Propriété Forestière et CRPF. M. D. Mourisset

## ✓ Funding:

- ✓ European Auvergne–Rhône-Alpes Regional Development Fund: 190k€
- ✓ MSA 2019 et 2020: 30k€

## ✓ EMScan application will be available in june 2023

- ✓ Under certification as medical device by ANSM



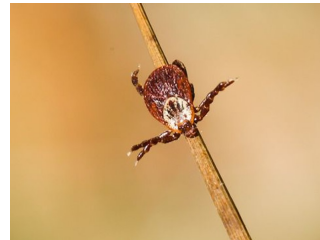
- ✓ **Propjet DCLIC:** Deep Convolutional Learning for *Ixodidae* Characterization
  
- ✓ **Objective of the project:**
  - ✓ Evaluate the use of Deep Learning to identify ticks genus from photo or video
    - ✓ Ticks present in France: *Ixodes*, *Dermacentor*, *Rhipicephalus* et *Hyalomma*
  
- ✓ **Precision:**
  - ✓ Real-time location and identification of one or more ticks at the same time
  - ✓ Tracking
  - ✓ Counting

## ✓ Creation of a dataset for training

- ✓ Photos with enough detail to be identified
- ✓ 1,636 photos of ticks manually classified by genus



391 *Ixodes*



253 *Dermacentor*



170 *Hyalomma*



50 *Rhipicephalus*



*Tetranychidae*

## ✓ Adding images without ticks

- ✓ 15,375 images of insects, acarians and spiders

391	<i>Halyomorpha</i>	68	<i>Tetranychidae</i>	2 278	<i>Odonata</i>
2 107	<i>Lepidoptera</i>	2 049	<i>Hymenoptera</i>	2 388	<i>Hemiptera</i>
2 030	<i>Dipter</i>	2 111	<i>Coleoptera</i>	2 419	<i>Araneae</i>



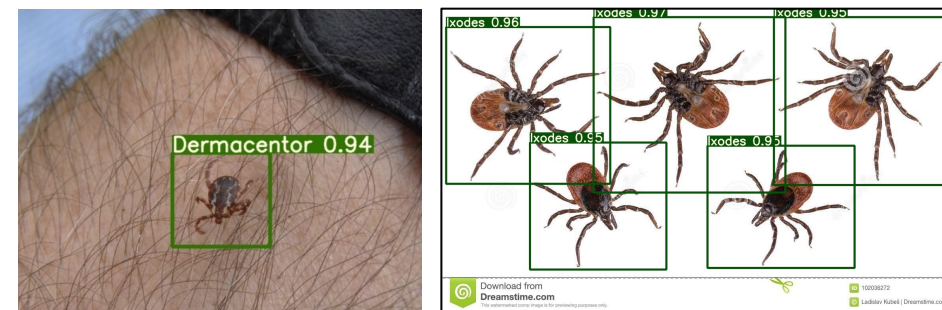
*Thomisidae*



- ✓ **Characteristics of the model:**
  - ✓ Family of architecture: YoloV5 (<https://github.com/ultralytics/yolov5>)
  - ✓ Number of layers: 500
  - ✓ Number of parameters: 46 652 890
  - ✓ Size of images: 640x640px
  - ✓ Training time 500 epochs: 45h (2x NVIDIA RTX 8000)
    - ✓ 5 trainings were necessary

- ✓ **Results:**
  - ✓ Accuracy: 0.96
  - ✓ Real-time detection (@30fp/s) on a smartphone

- ✓ **Limitations:**
  - ✓ Detection problem when ticks are too small on the image
    - ✓ Diversity of the training dataset
    - ✓ Limitations of current neural networks
  - ✓ A second experiment is in preparation

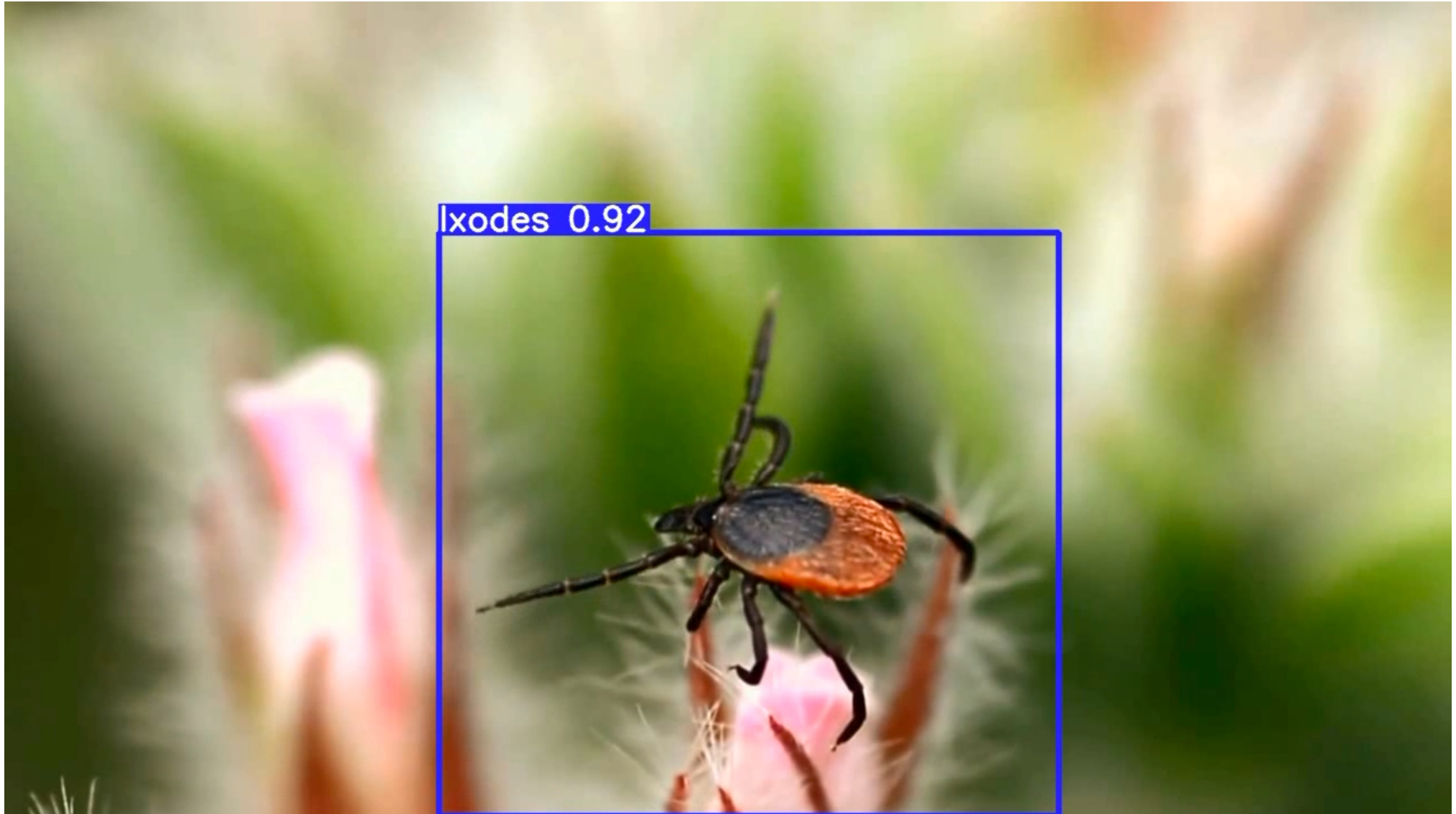


*Simple and multiple identification*



*Tick not detected*





## ✓ Research units:

- ✓ UMR EPIA (UMR INRAE – VAS): J. de Goër, V. Poux, M. Rene-Martelet, G. Vourc'h
- ✓ UMR BioEpar: O. Plantard
- ✓ UMR ASTRES: F. Stachurski, L. Vial
- ✓ Programme CiTIQUE: J. Durand, A. Brun-Jacob, J. Marchand, I. Carravieri, P. Frey-Klett

## ✓ Funding:

- ✓ INRAE Animal Health Department: 10k€

## ✓ Perspectives:

- ✓ Integration into the CiTIQUE participatory action research project
- ✓ Share the model with the community



<https://citique.fr>

# Conclusion

- ✓ **Deep Learning is a great tool**
  - ✓ Allowed significant improvements in image and analysis
- ✓ **Requires:**
  - ✓ Sufficient representative data
  - ✓ GPU computing resources
- ✓ Methods could be improved, especially in terms of the explicability of the results
- ✓ It is necessary to take into account the context



Tree or broccoli



Apple or owl



Chihuahua or muffin

**Thank you !**

**Mini-symposium - Management and integration of agronomical, phenotypical and environmental data**

**Jocelyn DE GOËR**

UMR EPIA

July 7<sup>th</sup> 2022