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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 7th 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



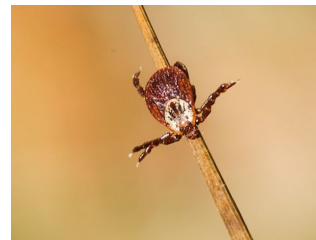
Metropolitan France

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

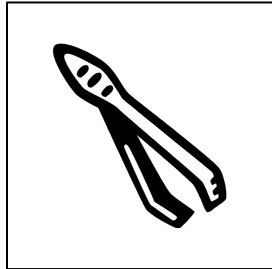


- *Crimean-Congo hemorrhagic fever*

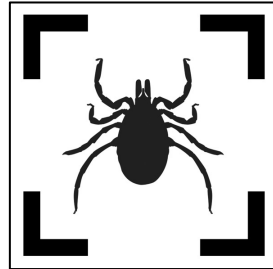
- Parasite
- Virus
- Bacteria

Ticks and tick-borne diseases

✓ Study and surveillance of ticks and ticks-borne diseases



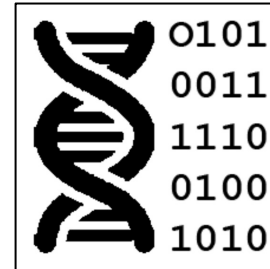
Collection
in the field



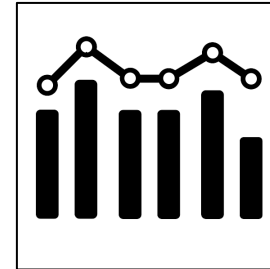
Identification



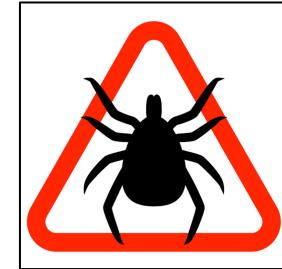
Pathogen
detection



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)

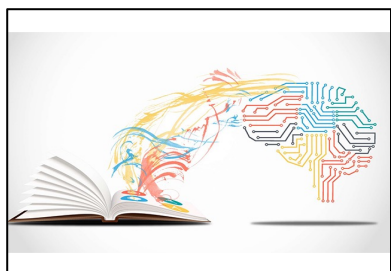
✓ France: 60 000 (source SPF)

Research projects

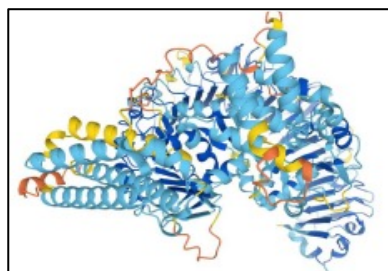
- ✓ **Two projects about Lyme disease and ticks surveillance**
 - ✓ **2018: DAPPEM Project**
 - ✓ Mobile application development for early skin signs of Lyme Disease (erythema migrans)
 - ✓ **2020: DCLIC Project**
 - ✓ Real-time ticks genus identification system
- ✓ **These projects are based on Artificial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

Artificial Intelligence

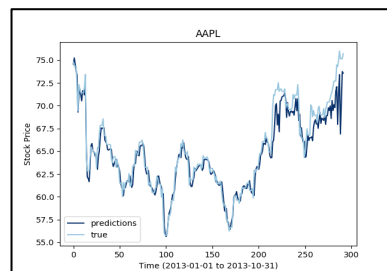
- ✓ **Artificial intelligence:**
 - ✓ **AI symbolic** : based on formal and logical descriptions (algorithms)
 - ✓ Experts systems
 - ✓ **AI connectionist** : the machine is able to "learn" by itself from data
 - ✓ Deep Learning
- ✓ **Since 2012, sufficient computing capacity for its application:**
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



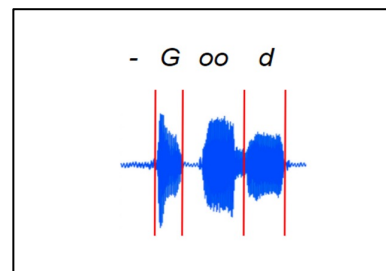
Text Mining



Bio-Informatics data analysis



Time series analysis



Sound analysis
Voice recognition



Medical diagnostic assistance

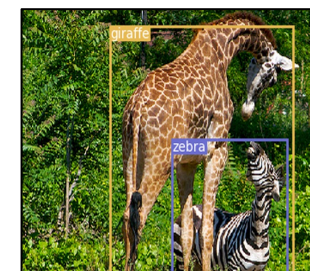


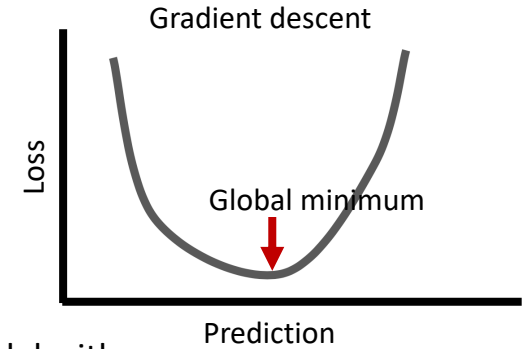
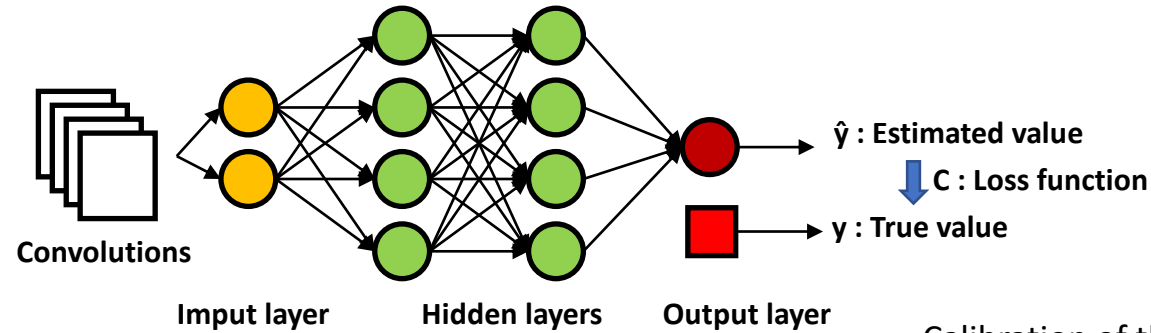
Image / video analysis

Artificial Intelligence

✓ Training of a neural network for image classification

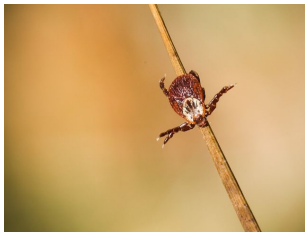


Image Datasets
Labeled and classified

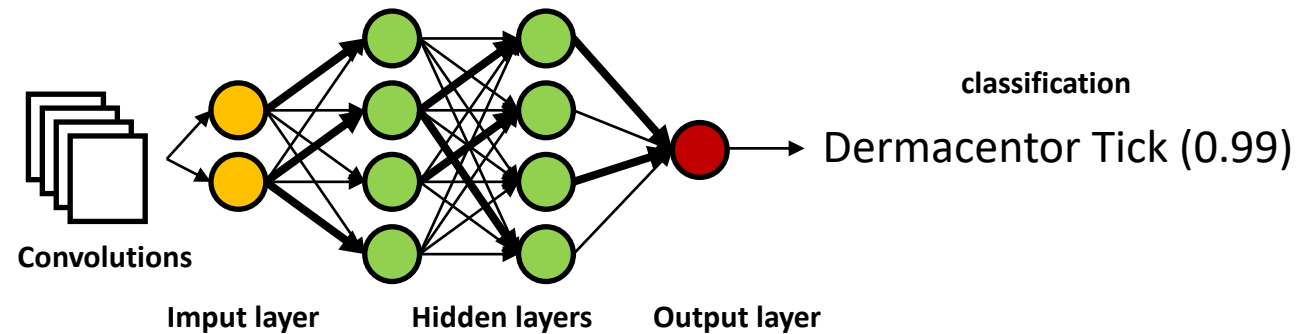


Calibration of the model with
backpropagation method

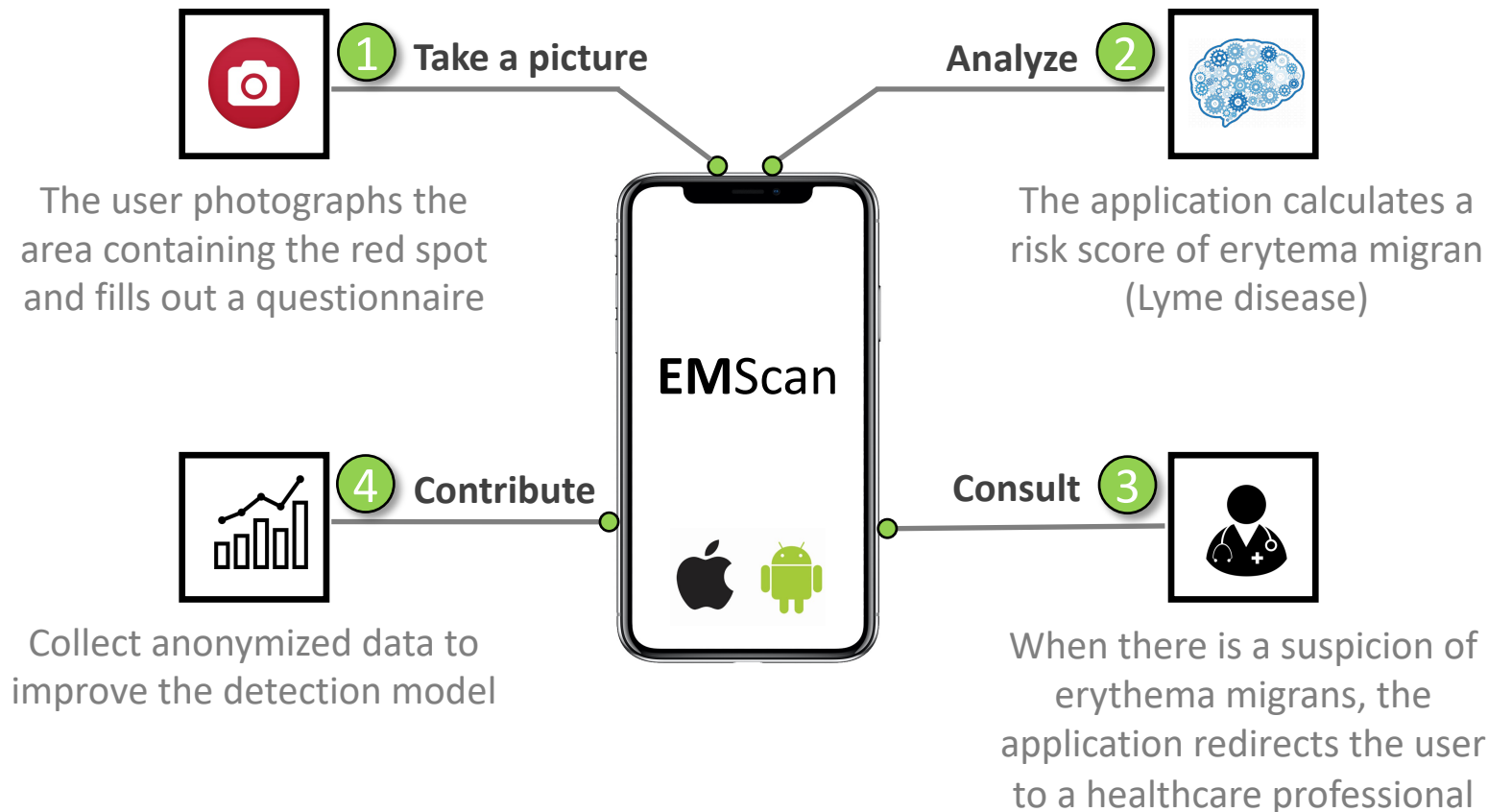
✓ Query from image



Query image



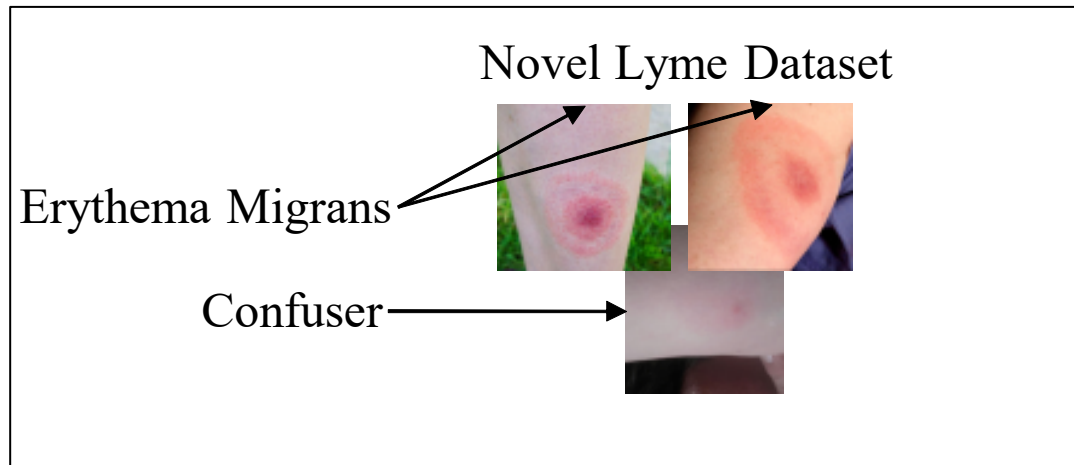
- ✓ **DAPPEM:** Développer une application permettant la détection des Erythèmes Migrants (premiers signes cutanés de la maladie de Lyme)
- ✓ Target users: Health care workers and general public



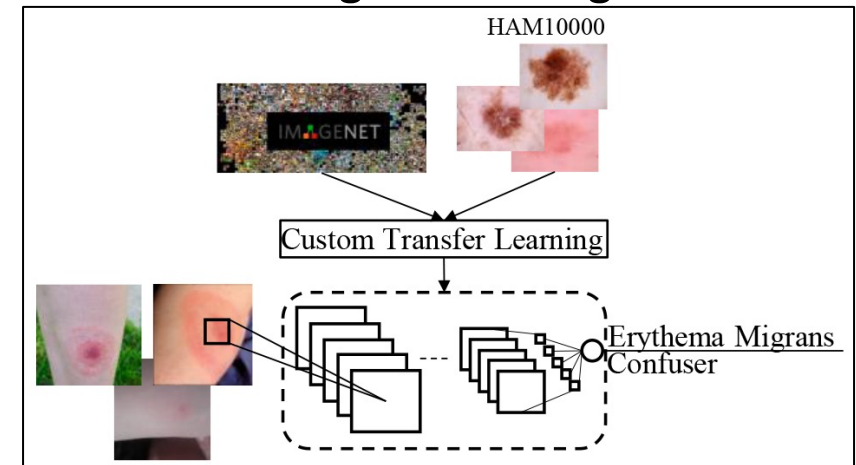
Erythema migrans
Early sign of Lyme disease

- ✓ **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

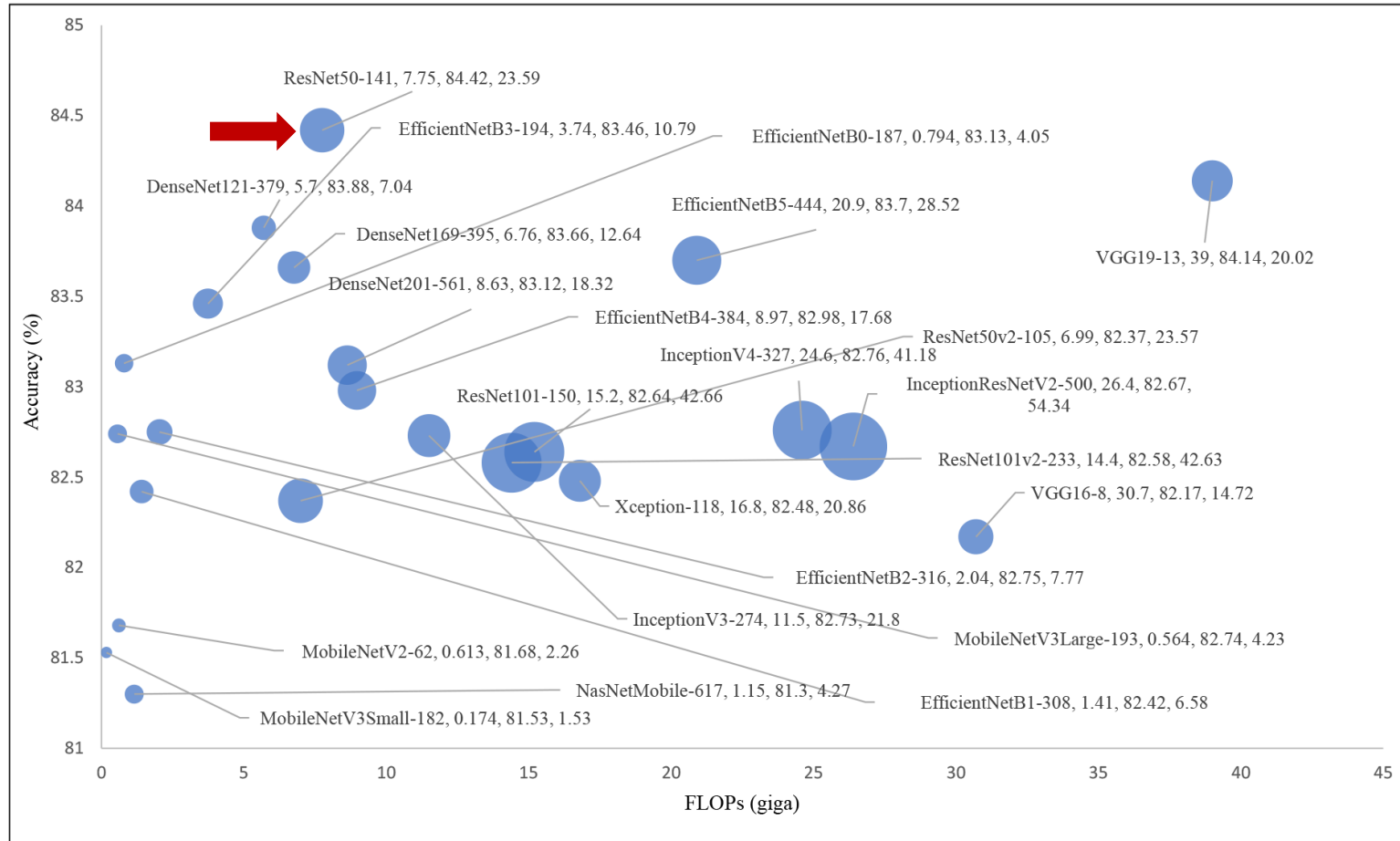


Work done by Imran Hossain, PhD student at LIMOS, supervised by E. Mephu-Nguifo and J. de Goër

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 %

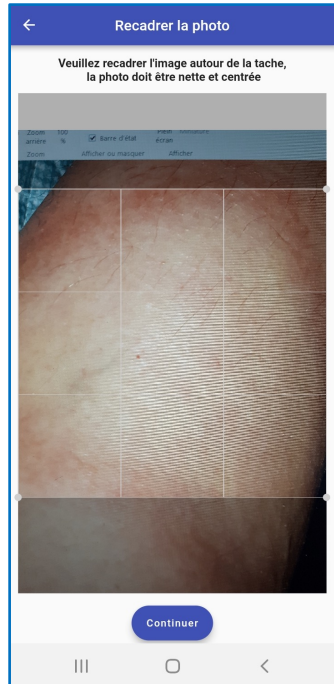
Specificity: 80,7 %

Parameters: 23 million

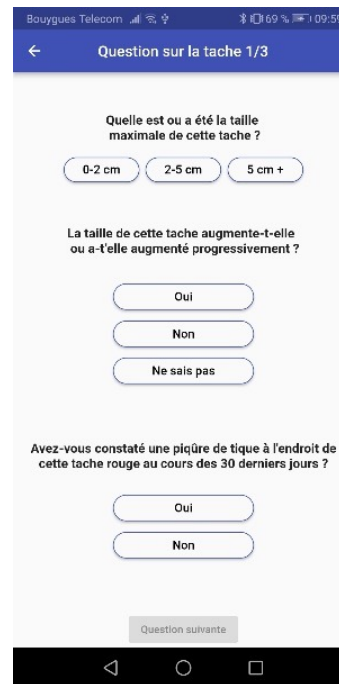
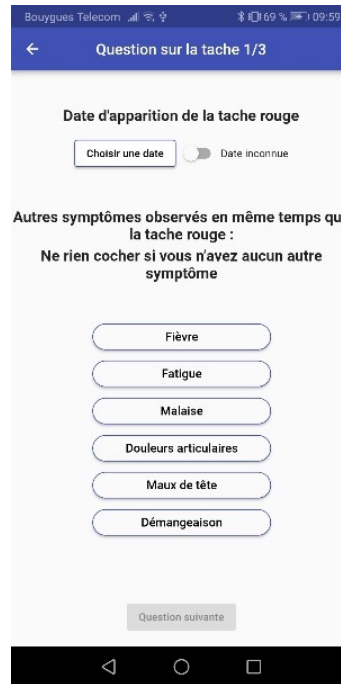
● Size represents number of model parameters (million units)

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

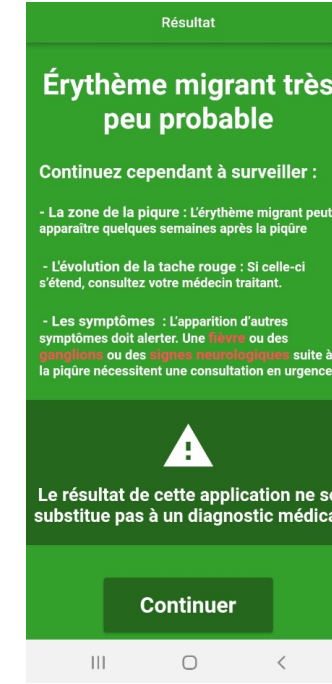
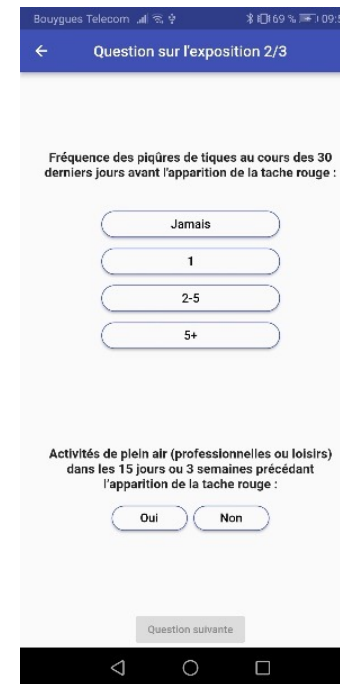
✓ EMScan mobile application mains screens:



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. Frenedo

✓ 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*

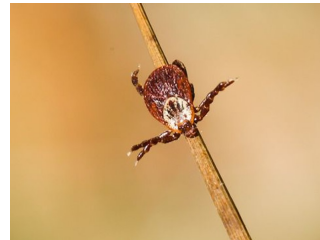
- ✓ **Precision:**
 - ✓ Real-time location and identification of one or more ticks at the same time
 - ✓ Tracking
 - ✓ Counting

✓ 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>

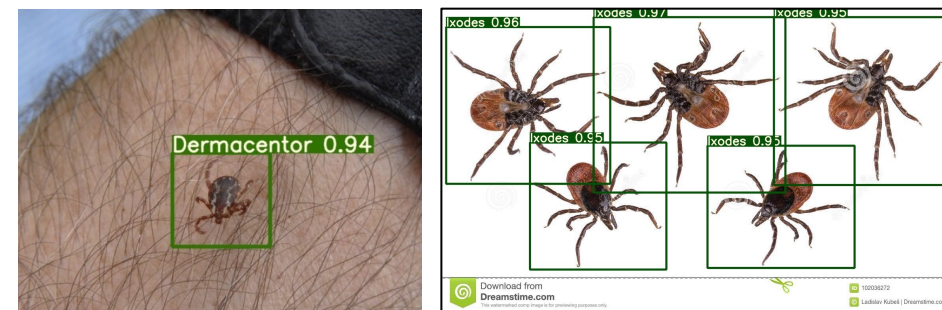


Thomisidae

- ✓ **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

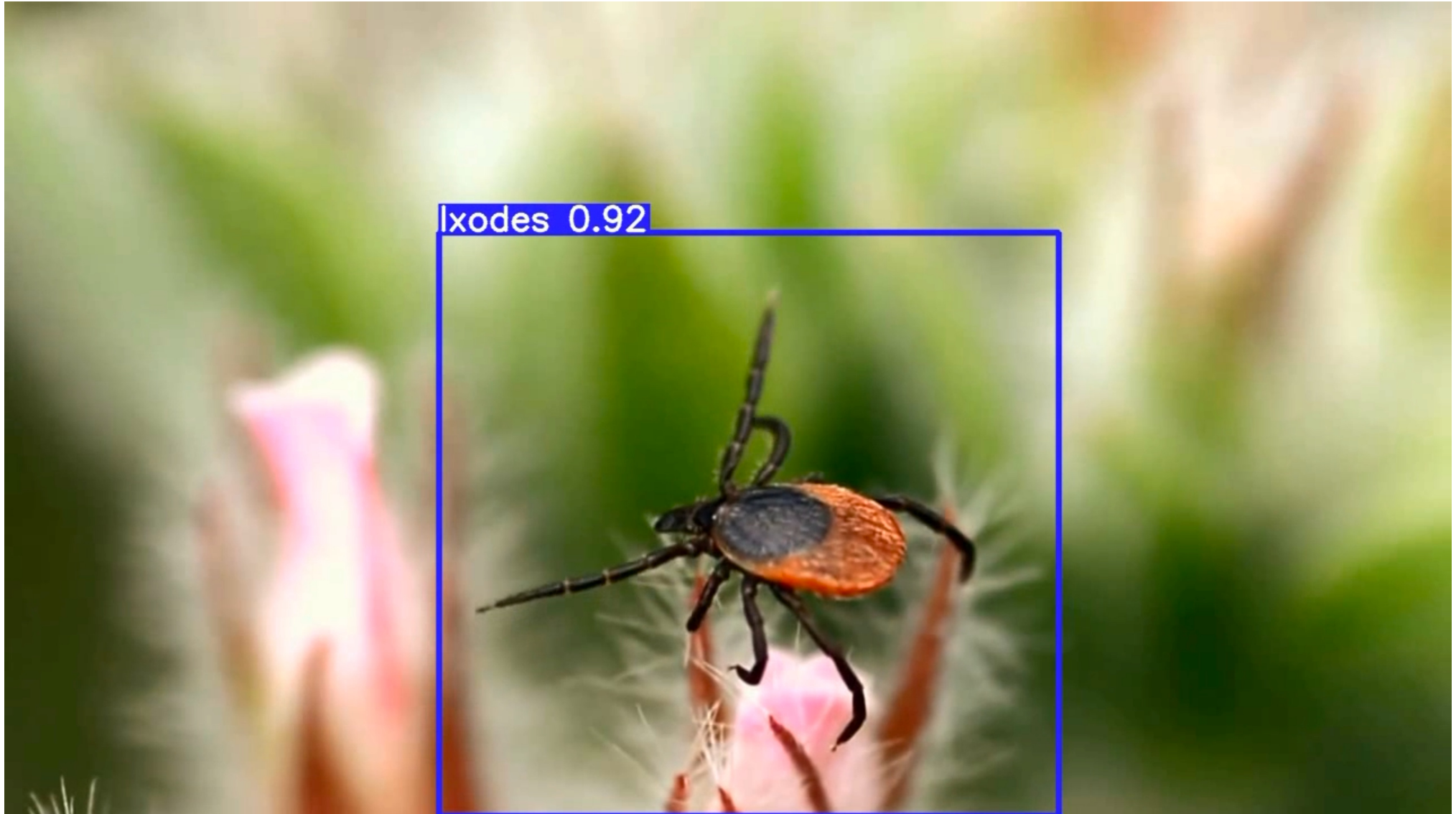
- ✓ **Limitations:**
 - ✓ Detection problem when ticks are too small on the image
 - ✓ Diversity of the training dataset
 - ✓ Limitations of current neural networks
 - ✓ A second experiment is in preparation



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 7th 2022