Validation of Innovative Tools to Assess and to Improve Microbiological Safety in the Food Chain

Moderator: Luca Cocolin University of Turin, Italy

Presenters: Pietro Cattaneo SwissDeCode, Switzerland

Pedro Lopez AI Talentum, Spain

Trevor Phister PepsiCo, United Kingdom

Sponsored by the IAFP FOUNDATION

Please consider making a donation

This webinar is being recorded and will be available to **IAFP members** within one week.

Webinar Housekeeping

- For best viewing of the presentation material, please click on ‘maximize’ in the upper right corner of the ‘Slide’ window, then click ‘Escape’ to return to normal view.
- **Audio is being transmitted over the computer**, so please have your speakers ‘on’ and volume turned up in order to hear. A telephone connection is not available.
- Questions should be submitted to the presenters during the presentation via the **Questions section** at the right of the screen. Questions will be answered at the end of the presentations.

Webinar Housekeeping

- It is important to note that all opinions and statements are those of the individual making the presentation and not necessarily the opinion or view of IAFP.

- This webinar is being recorded and will be available for access by IAFP members at www.foodprotection.org within one week.

Today's Presenters

Pedro J. López is Physicist and MSc on Data Science with research background. Expert in complex analysis and AI applications' building, he is responsible of making value out of data at Artificial Intelligence Talentum. His work is focused on advanced statistical analysis, data mining, and data visualization techniques, to create solutions that enable enhanced business performance.

Pietro Cattaneo, PhD in Life Sciences – University of Lausanne, Switzerland - M.Sc. in Cell Molecular Biology - University of Milano, Italy.

He contributed deciphering the molecular mechanisms of plant development by identifying and describing two genes involved in plant root growth.

He stepped into the biotech food sector joining the start-up SwissDeCode SA in 2018. He now holds many simultaneously roles such as developing new rapid DNA detection solutions, running wet-lab activities, interacting with customers during the pre- and post-sales process, and leading product demonstrations.

Dr. Trevor Phister received his PhD in Food Microbiology from the University of Minnesota in 2001. He held a number of academic positions in both the US and the UK before joining PepsiCo in 2013. He is currently a Principal Microbiologist in the Global Microbiology team based in Europe and a Co-Chair of the PepsiCo Global Microbiology Council. In his current role, he works with teams to develop and maintain microbiology programs ranging from the assessment of new microbial methods to the development of policies and tools to support risk assessment of materials, products and processes across the PepsiCo portfolio.

International Association for Food Protection

eit Food

WEBINAR

Validation of Innovative Tools to Assess and to Improve Microbiological Safety in the Food Chain

June 23, 2020

Luca Cocolin, Università di Torino

EIT Food is supported by the EIT
a body of the European Union

European Institute of Innovation & Technology

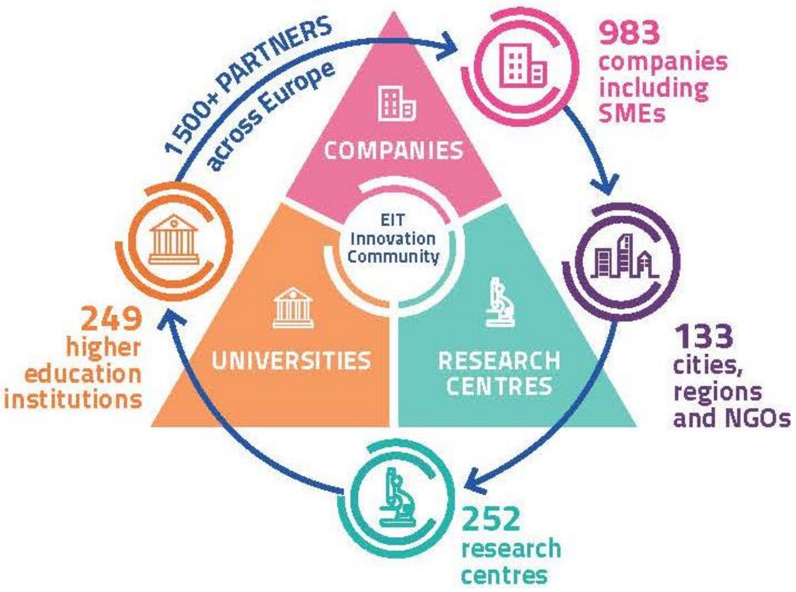
What is the EIT?

The European Institute of Innovation and Technology (EIT) drives innovation in Europe by supporting entrepreneurs, innovators and students across Europe to turn their best ideas into reality.

How does the EIT work?

- Trains a new generation of entrepreneurs
- Develops innovative products and services
- Power start-ups & scale-ups

Europe's largest innovation community



Europe's one-stop shop for innovation

- **6 100+** Jobs created
- **1.5B+€** Investment raised by EIT ventures
- **2 000+** Ventures supported
- **900+** New products and services
- **2 300+** Graduates completing EIT programmes
- **50+** Innovation Hubs across Europe

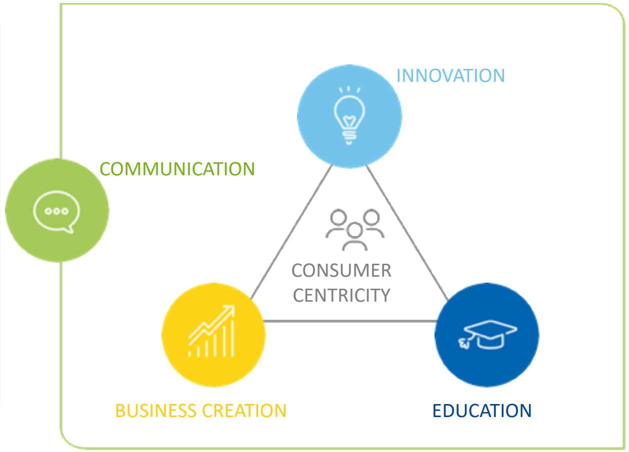
eit Food

International Association for Food Protection®

EIT Food – Transforming the Food System

We are on a MISSION

EIT Food is an ecosystem for solving complex societal challenges by deploying innovative solutions



EIT Food is the largest European consumer-centric open science innovation ecosystem

eit Food

International Association for Food Protection.

DÖHLER
KU LEUVEN
tastewise
Acesur
BÜHLER
Waitrose
Herbstreith&Fox
CONNECTING FOOD
FOOD MAESTRO
UAM Universidad Autónoma de Madrid
Innovatiesteunpunt
CSIC
entomics
natural machines
NutriLeads Ingredients for health
RouxMatok ENHANCING FLAVORS
flatev
Valio
imdea
UNIVERSITY OF HELSINKI
URBAN CROP SOLUTIONS
Swiss DeCode
UNIVERSITY OF HOHENHEIM
NATUFIA
UNIVERSITY OF WARSAW
SYNTEGON PROCESSING & PACKAGING
INNOVOPRO
eagle genomics
NOVOLYZE LEADING FOOD SAFETY REVOLUTION
Institute of Animal Reproduction and Food Research PAS
Stem! BETTER SUGAR. BETTER PLANET
QUEEN'S UNIVERSITY BELFAST
FOODPAIRING
azti tecnalia
AGRICOLUS
WHOLE SURPLUS
mimica
ALKION BIOINNOVATIONS
cropx
GLUCANOVA ADVANCED OATS
rikolto VECO
GROUPE SEB
eurofins
AARHUS UNIVERSITY
GrainSense
ROQUETTE Offering the best of nature
microbion
AI talentum
KOPPERT BIOLOGICAL SYSTEMS
University of Reading
SIEMENS
FLANDERS' FOOD
30MHz
ALEPH FARMS
elea
Givaudan
Nestlé Research
eit Food
Lactips
TIPA Sustainable Packaging
eit Food RISINGFOODSTARS
AgroPlatforma
wasteless Sell more, waste less
TECHNION Israel Institute of Technology
Strauss
eufic
sodexo QUALITY OF LIFE SERVICES
Fraunhofer
PEPSICO
abp Food Group
PeakBridge
Agrimetrics
DANONE NUTRICIA RESEARCH
NX FOOD
3FBIO
UNIVERSITY OF CAMBRIDGE
MASPEX
DSM BRIGHT SCIENCE. BRIGHTER LIVING.
Analytics Engines
Bank Żywności w Olsztynie
Puratos Reliable partners in innovation
essento DELICIOUS INSECTS
COLRUYT GROUP
Amai Proteins
Rethink Resource
DIL
VTT
fruitsapp
JOHN DEERE
A.I.A.
BIOAZUL WATER • ENERGY • ENVIRONMENT
ENERGY PULSE SYSTEMS DESIGNING ENERGY FOR LIFE
shift
BeYou
thorice enhanced cooling technology
LUNDS UNIVERSITET
zero
neiker tecnalia
Ambrosus
UNIVERSITA DEGLI STUDI DI TORINO
Trellis
ALBERTS
EPFL
ANGULAS AGUINAGA
PROCUPIN
NAPIFERYN BIOTECH
EuroFIR European Food Information Resource
matis
Quadram Institute
Science • Health • Food • Innovation
ETH zürich
PlantLab
Grupo AN
SatAgro
tellspec
BIOTREM
YPSICON
ALGAINNOVATION
Technische Universität München
TUM

VITAL concept

Food must be safe for the consumer (pre-requisite) but microbiological analysis are time consuming and unfit for the modern context. Rapid methods can be a possibility, but they need to be validated and validation costs a lot of money for food producing companies.

Proposed solution: Combine digitalisation and new sensor technologies to steer and improve efficiency in the food value chain.

VITAL ambition and impact

Assure food safety based on the smart exploitation of two innovative tools: artificial intelligence (AI) and lab-on-chip sensors, respectively. AI will be used to analyse available data provide a prediction tool that will allow a more effective validation scheme of rapid methods in an industrial setting.

It is expected that due to the lower demand requested for the validation of new rapid methods, those possibilities will be more often employed at industrial level resulting in better assessment of foodborne pathogens in the food chain and safer foods for the consumers.

eit Food

For information:

lucasimone.cocolin@unito.it

AI TALENTVM

VITAL Project: The AI-Approach

PEDRO JESÚS LÓPEZ ABENZA
MSc Data Scientist at AI Talentum

Email: plopez@aitalentum.com

Table of Contents

AI TALENTVM

Introduction: Who we are?

AI TALENTVM

eit Food

- AI start-up located in the south of Spain
- Experts on ITC solutions and Industry 4.0
- Partner of the EIT Food Consortium
- VITAL: Data Science Department

VITAL Project: Digitalization Process

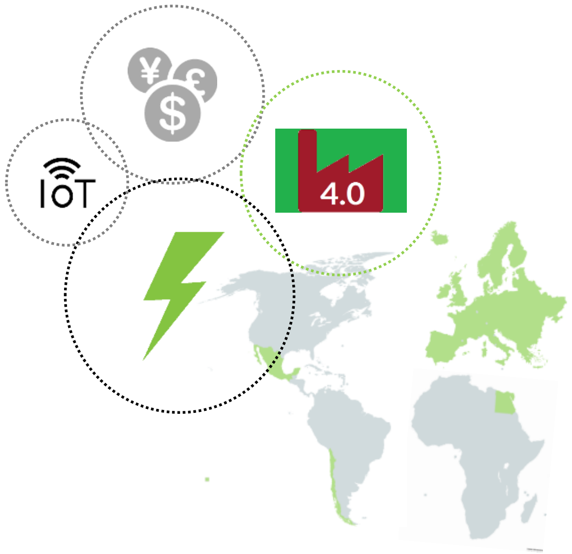
- Redefinition of tasks in order obtain better performance by digitalizing actions and new technologies.

- Digitalization technologies encompass a series of digital solutions, such as:

  1. Artificial Intelligence (AI)
  2. Cloud Infrastructure
  3. Internet of Things (IoT)
  4. Others (Blockchain & Cybersecurity)

- Identifying weaknesses from well-established processes and coping with new approaches capable of enhancing its performance

VITAL Project: The AI Role

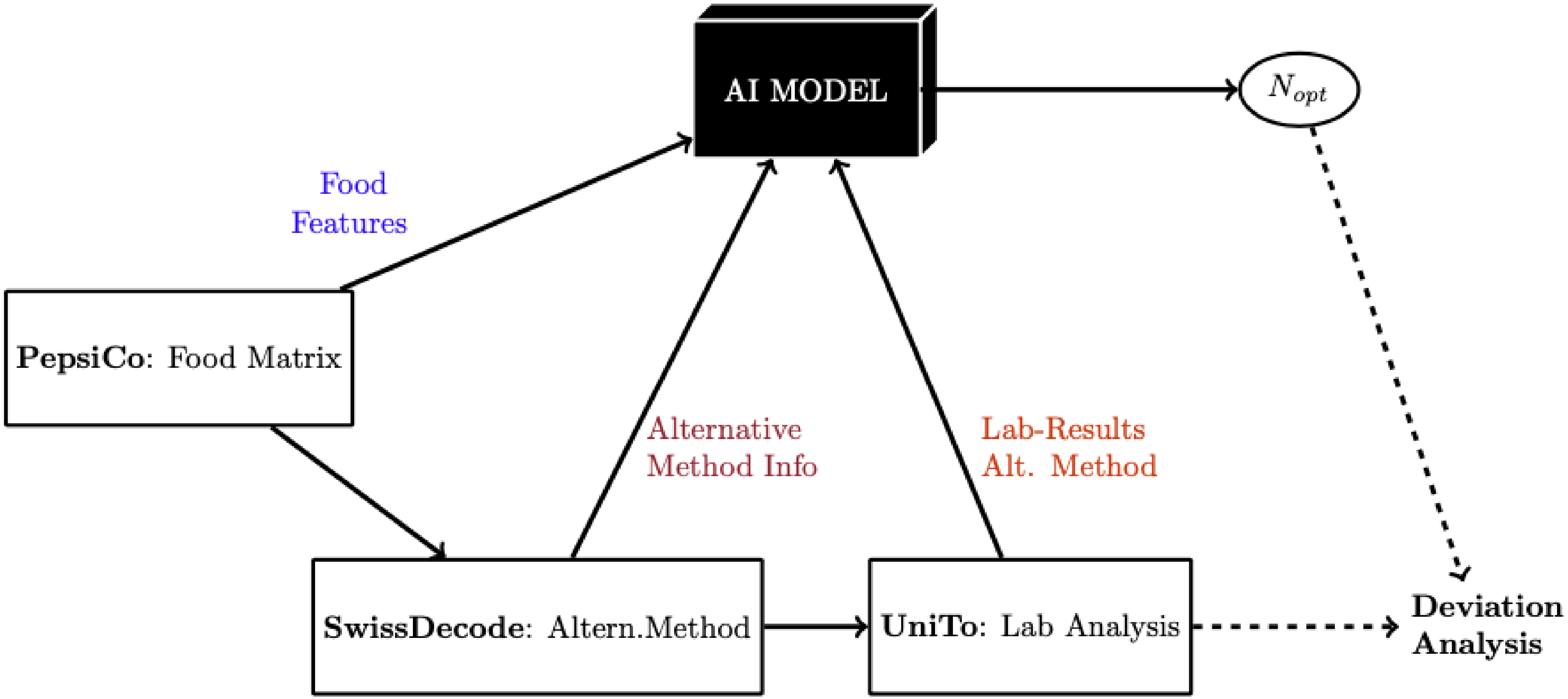


- New procedure for the rapid methods validation.

- Automated calculus for an optimized validation procedure for the analyzed method

- Reduce the numbers of samples to be tested, allowing to securily speed up the production

VITAL Project: Scheme

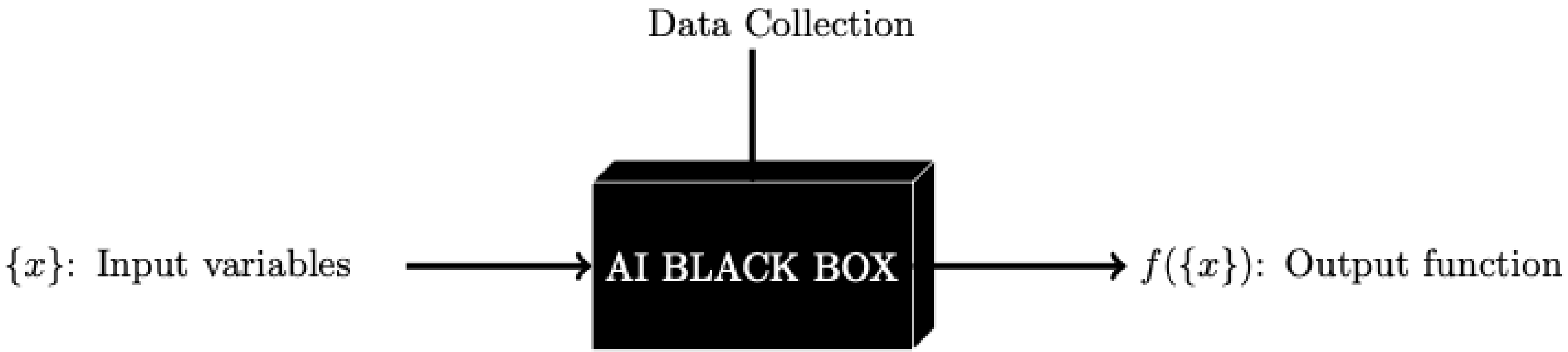


AI TALENTVM

Introduction to AI solutions

- AI systems use data in order to understand complex processes and learn about behavior and responses

- These solutions are based in a wide variety of techniques from Machine Learning, DL, NLP or even Computer Vision.



- The AI

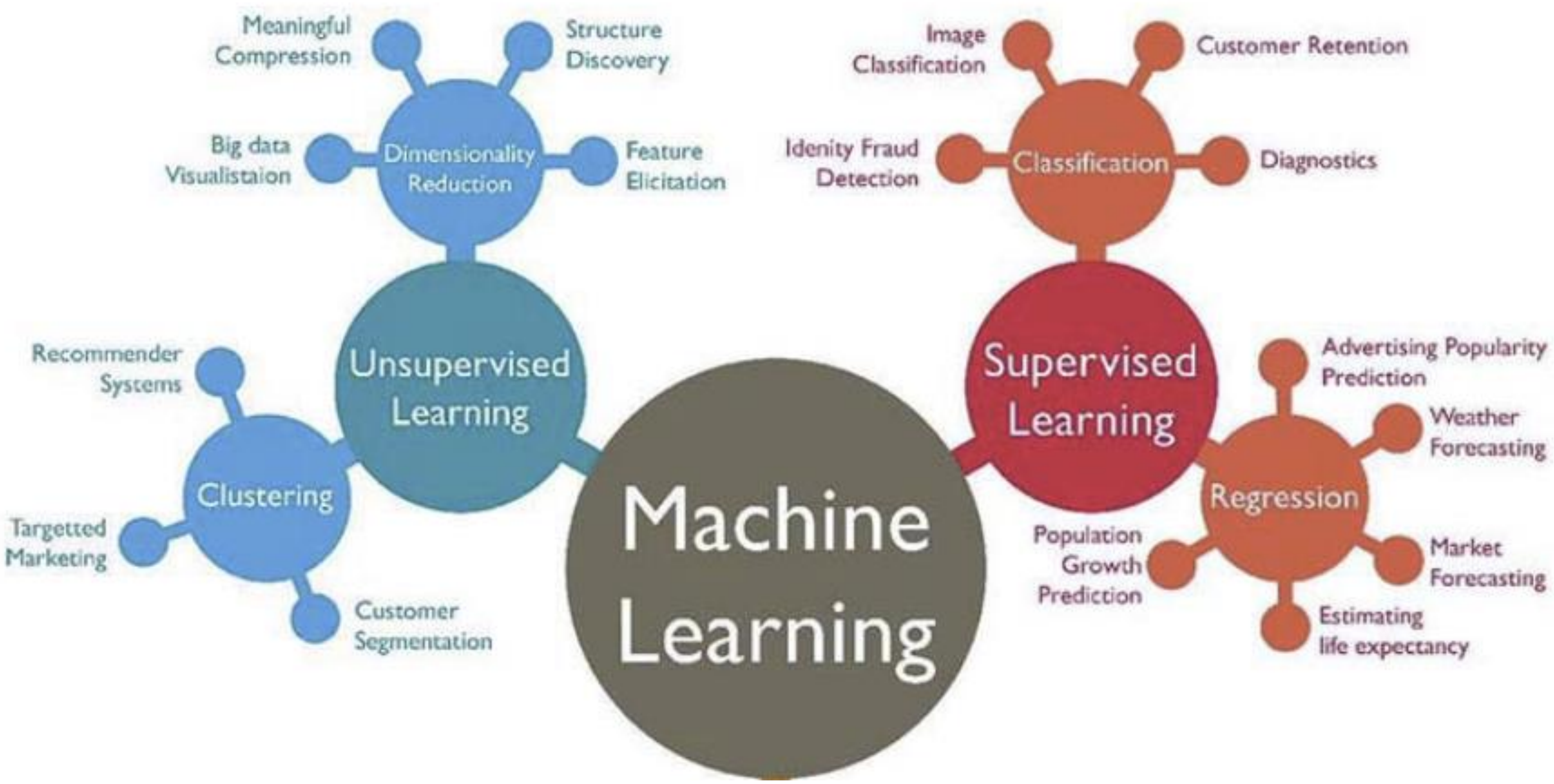
Introduction to AI solutions

- Data contain parametrized information about processes. They may come from many sources and have different structures
    1. Tabular data
    2. Unstructured data
    3. Images
    4. Raw text

- AI systems learn behavior from complex processes and their parametrized input-attributes
- Models are capable of predicting values by new incoming data from these processes

- Datatypes:
    1. Categorical: YES/NO, HIGH/MED/LOW
    2. Numerical: 1.6, 2.22, 1074…

Typical AI techniques: An overview



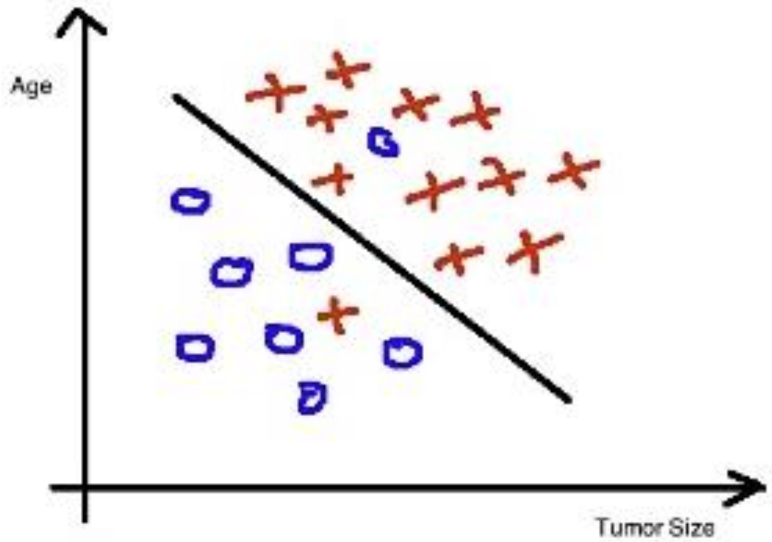
AI TALENTVM

Typical AI techniques: Classification

- **Supervised Learning**: Prediction of the value of an objetive attribute using IA techniques that learn from the training data.

  1. **Classification**: Categorical prediction
  2. **Regression**: Numerical prediction

Tid	SrcIP	Start time	Dest IP	Dest Port	Number of bytes	Attack
1	206.135.38.95	11:07:20	160.94.179.223	139	192	No
2	206.163.37.95	11:13:56	160.94.179.219	139	195	No
3	206.163.37.95	11:14:29	160.94.179.217	139	180	No
4	206.163.37.95	11:14:30	160.94.179.255	139	199	No
5	206.163.37.95	11:14:32	160.94.179.254	139	19	Yes
6	206.163.37.95	11:14:35	160.94.179.253	139	177	No
7	206.163.37.95	11:14:36	160.94.179.252	139	172	No
8	206.163.37.95	11:14:38	160.94.179.251	139	285	Yes
9	206.163.37.95	11:14:41	160.94.179.250	139	195	No
10	206.163.37.95	11:14:44	160.94.179.249	139	163	Yes



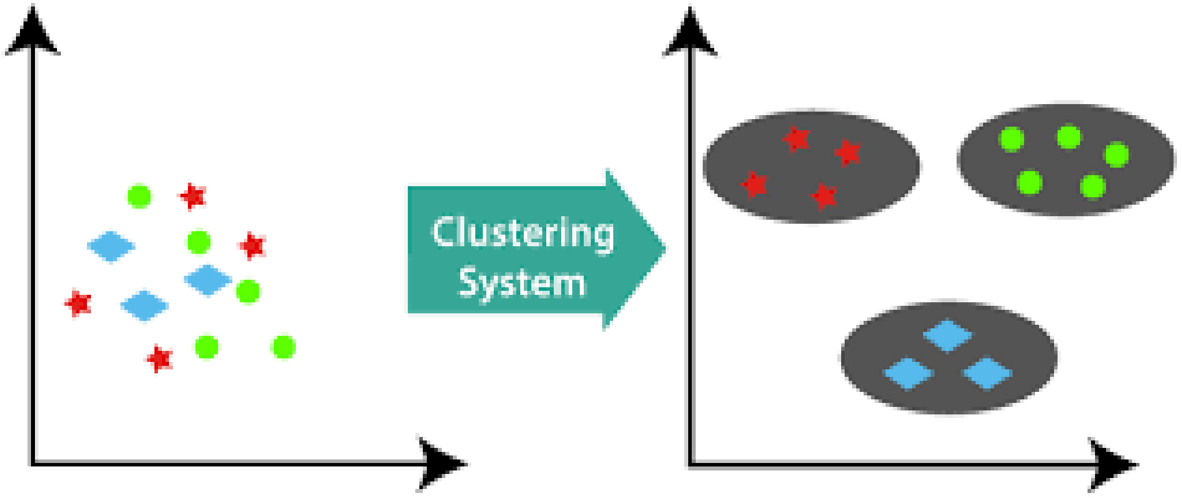
Some techniques:

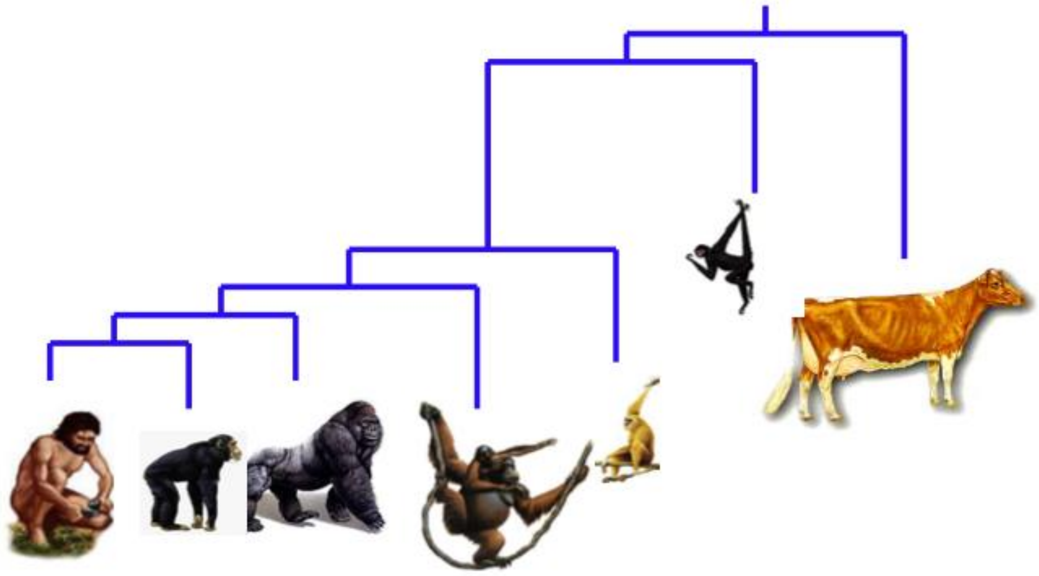
- Naïve Bayes
- Decision Tree
- Logistic Regression
- SGD
- Support Vector Machines
- Neural Network
- Ensembles

Typical AI techniques: Clustering

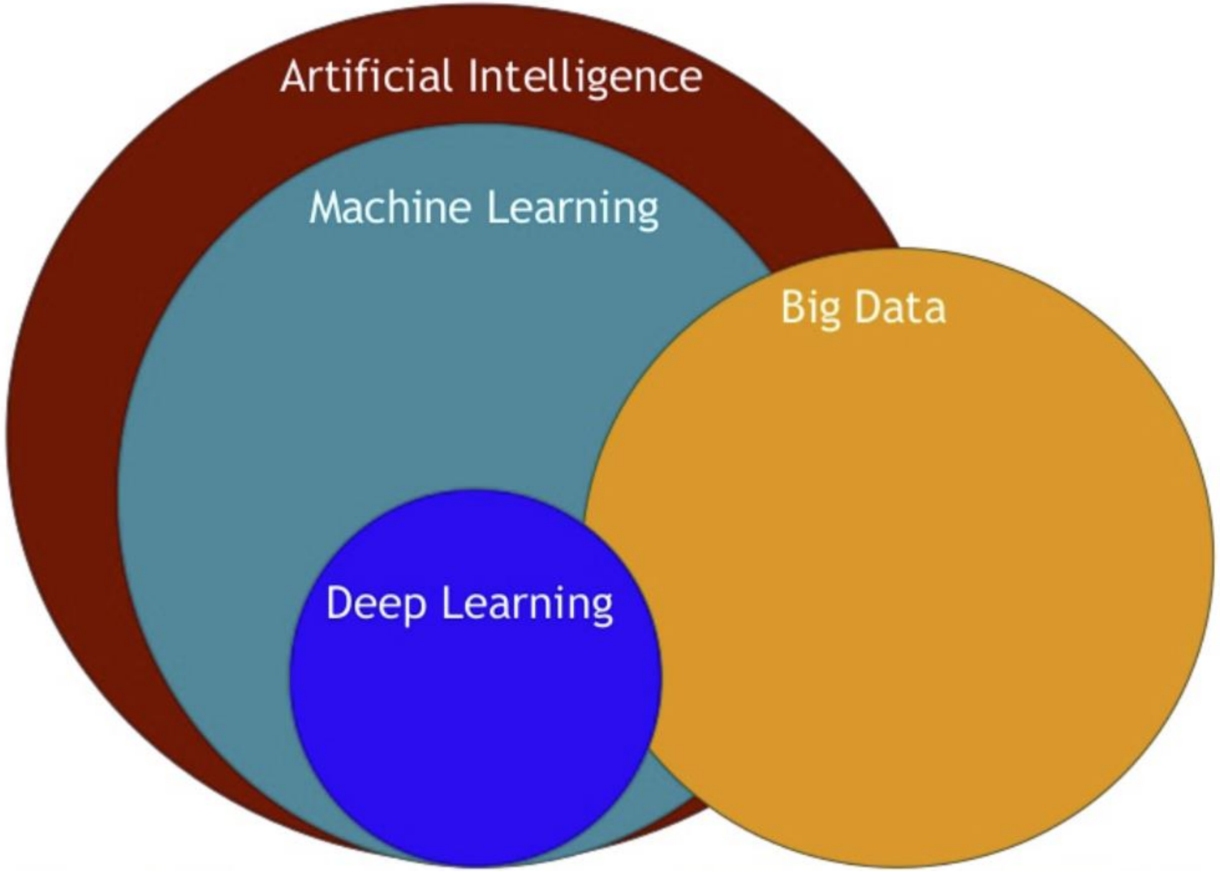
- **Clustering**: Group cases based on the similarity of their data attributes.
  Three main-approaches:

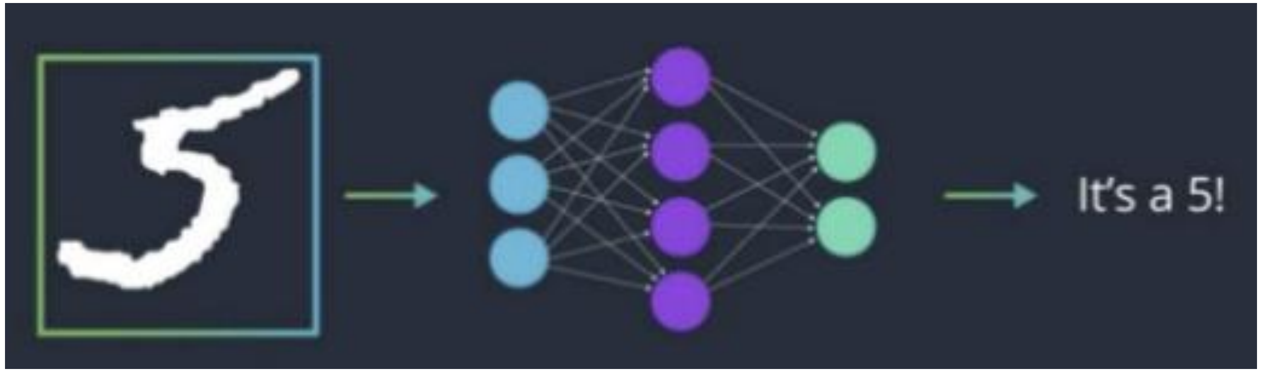
    1. **Partitional clustering**
    2. **Hierachical clustering**
    3. **Density-based clustering**

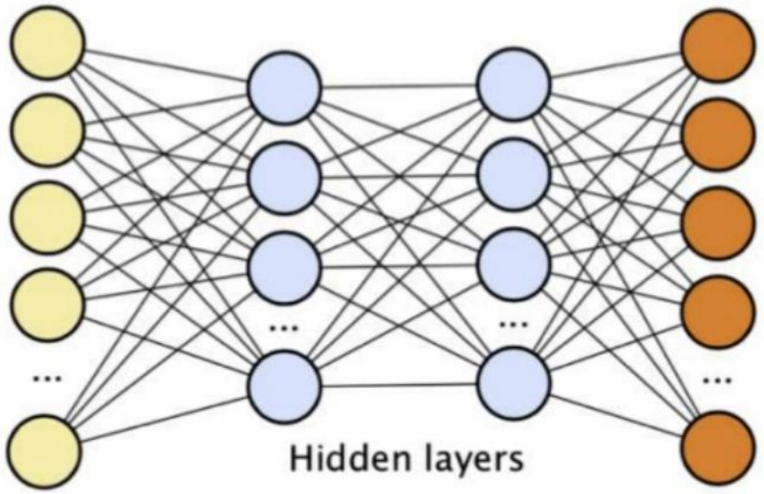




Typical AI techniques: Deep Learning







AI TALENTVM

Other food-related project: Automated inspection of caps

Tasks:

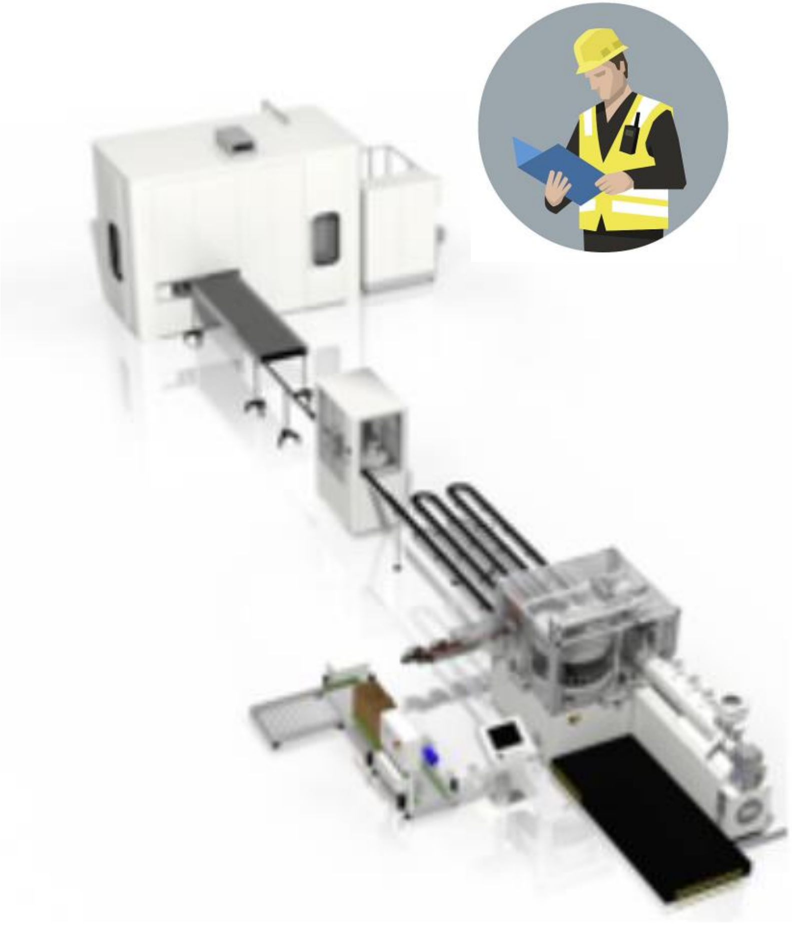
1. Intelligent assistant for an already implemented CV systems for the inspection a process of production of caps

2. Analysis of possible errors on the detection of wrong caps by different profiles analyzed by the vision system

3. Optimization of the number of human inspection on the caps production line

Tools: Classification techniques

1. **Logistic regression**
2. **Random Forest**



AI TALENTVM

AI in Food Manufacturing

- Manufacturing industry is being revolutionized by technology.

- Nevertheless, it has meant **new challenges** in the industry:

1. Sustainable adoption of advanced manufacturing technologies

2. Agile and flexible enterprise capabilities and supply chains

3. Close collaboration between industry and research to adopt new technologies.

AI examples in Biological Industry

- **Examples of applications**:

1. AI system for reducing the animal toxicity tests in consumer products (*CAAT* from *Johns Hopkins University*)

2. AI sensors for detecting foodborne pathogens at home (*IBM*)

3. AI system for reducing the pathogens in processing plants (*Luminous Group*)

Conclusions

- Understanding the role of the AI in VITAL project
- Presenting the motivation to using AI systems
- Introducing the main tools used by an AI system
- Exposing some applications of AI in biological environments

Q & A

Thank you very much for your attention !

Time for your questions !

AI TALENTVM

YOUR TECH PARTNERS

aitalentum.com

info@aitalentum.com

868 957 514

@aitalentum

MURCIA
Edificio CEEIM, Módulo 7
Campus Universitario Espinardo
30100 Murcia
868 957 514

AI TALENTVM

Current and Emerging Technologies for the Detection of Foodborne Pathogens

IAFP Webinar
June 2020

Pietro Cattaneo, PhD

SwissDeCode

The Invisible World of Microbiology

Foodborne Illness

What is Foodborne Illness?

Foodborne illness is a common, costly, sometimes life-threatening public health problem.

How is it caused?

Outbreaks and individual cases of foodborne illness result from consuming the two most common types of foodborne pathogens:

- Bacteria, like *Salmonella, E. coli O157:H7, B. cereus, S. aureus, and L. monocytogenes*
- Viruses, such as *norovirus* or *hepatitis A*

Who is at risk?

Anyone can get a foodborne illness. People such as pregnant women, young children, older people, and those with weak immune systems are more susceptible and at risk.

Scallan et al., 2011; http://www.fds.gov.

Foodborne Illnesses in Numbers

Pathogens-Food Pairs Causing Outbreaks 2016

Pathogens	Food	Number of Outbreaks	Number of Outbreaks - Associated Ilnesses
Scombroid toxin (histamine)	Fish	12	35
Ciguatoxin	Fish	11	33
Salmonella	Chicken	8	307
Campylobacter	Dairy (unpasteurized)	7	57
Norovirus	Mollusk	6	209
Salmonella	Pork	6	96
Vibrio parahaemolyticus	Mollusk	6	19

The US Centers for Disease Control and Prevention (CDC) estimates 48 million people are affected by foodborne illness annually, 128,000 people are hospitalized and 3,000 die.

US Centers for Disease Control and Prevention.

Foodborne Illness is Largely Preventable

At Home

- Practicing safe food handling
- Keeping your refrigerator clean and at 4º C/40º F, separating raw foods from cooked foods
- Cooking meats thoroughly
- Avoiding unpasteurized food products such as milk and cheese

Along the Food Supply Chain

- Following appropriate cleaning, manufacturing procedures, and adopting decontamination solutions
- Monitoring temperature and other important food conditions correctly
- Ensuring safe packaging, food warehousing, transportation, and inspection/QA practices

Tools to Assess the Microbiological Safety in the Food Chain

Current Issue

Foodborne diseases, caused by pathogenic bacteria, have become an important social issue in the field of food safety. True incidence of foodborne outbreaks is highly underestimated.

Need

It is urgent to detect foodborne pathogens in order to control foodborne pathogen spread and reduce foodborne disease occurrence as well as economic burden.

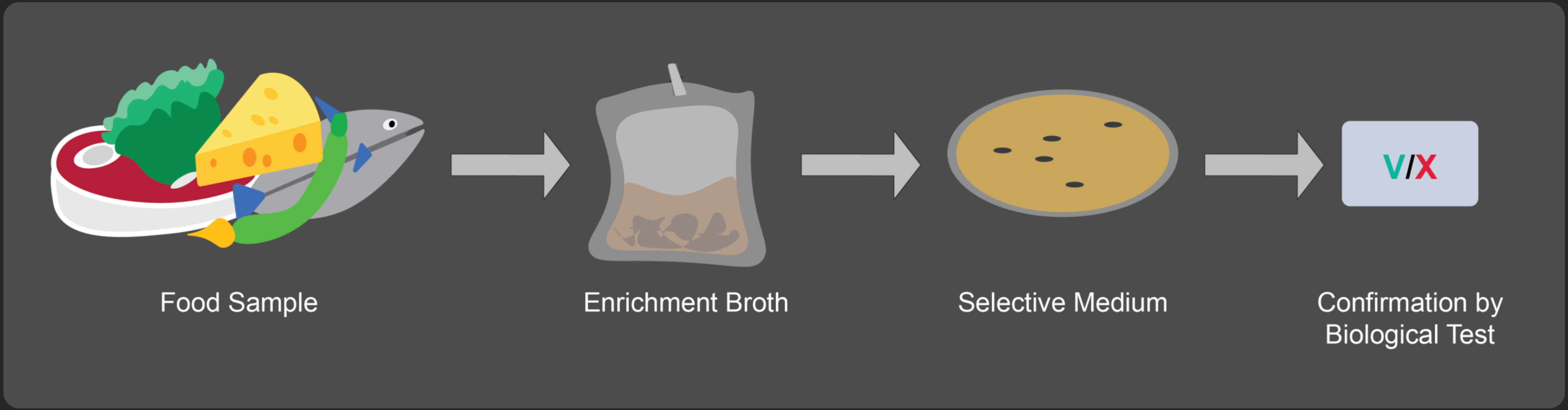
Solutions

Classical methods

New technologies for rapid detection of foodborne pathogens

Classical Methods: The “Gold Standards”

The conventional methods implemented in food analysis consist of sample homogenization and subsequent culturing of the microorganisms on agar plates followed by biochemical identification.



Vidic et al., 2019; Law et al., 2015.

Classical Methods: The "Gold Standards"

Disadvantages for the Food Industry Applications	
Workflow	• Laborious: pre-enrichment, selective enrichment, selecting plating, isolation and identification
Timing	• 2-3 days from sample preparation to result interpretation
Lab equipment/Facilities	• High demand of consumables such as Petri dishes and media
Operators	• Professional and trained personnel

Culture and colony-counting methods are inadequate for rapid detection of foodborne pathogens, especially for reduce foodborne disease occurrence in food industry.

Vidic et al., 2019; Law et al., 2015.

New technologies for Rapid Detection of Foodborne Pathogens

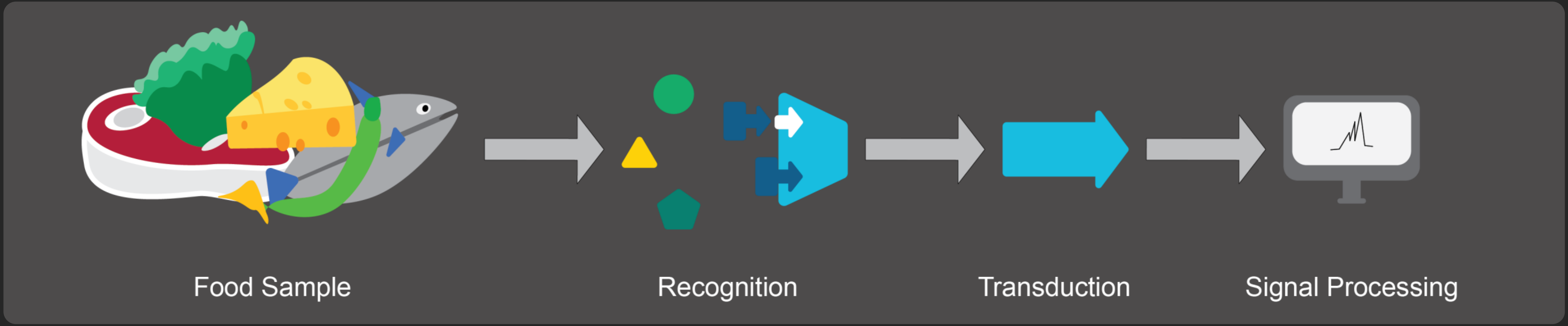
The growing amount of street foods and the increasing demand of ready-to-eat foods prompted the development of **advanced, sensitive, specific and labor-saving** detection methods that can identify pathogens accurately and rapidly in a timely manner.

Rapid detection methods can be categorized into:

1. **Biosensor-based**
2. **Immunological-based**
3. **Nucleic acid-based**

Biosensor-based

- Analytical device that consists of two main elements:
  1. The bioreceptor responsible for recognizing the target analyte can either be antibodies, nucleic acids, biological derived as well as synthetic polymers.
  2. The transducer that converts the biological interactions into a measurable electrical signal can be optical, electrochemical or mass based.
- Biosensors do not require sample pre-enrichment.



Vidic et al., 2019; Law et al., 2015.

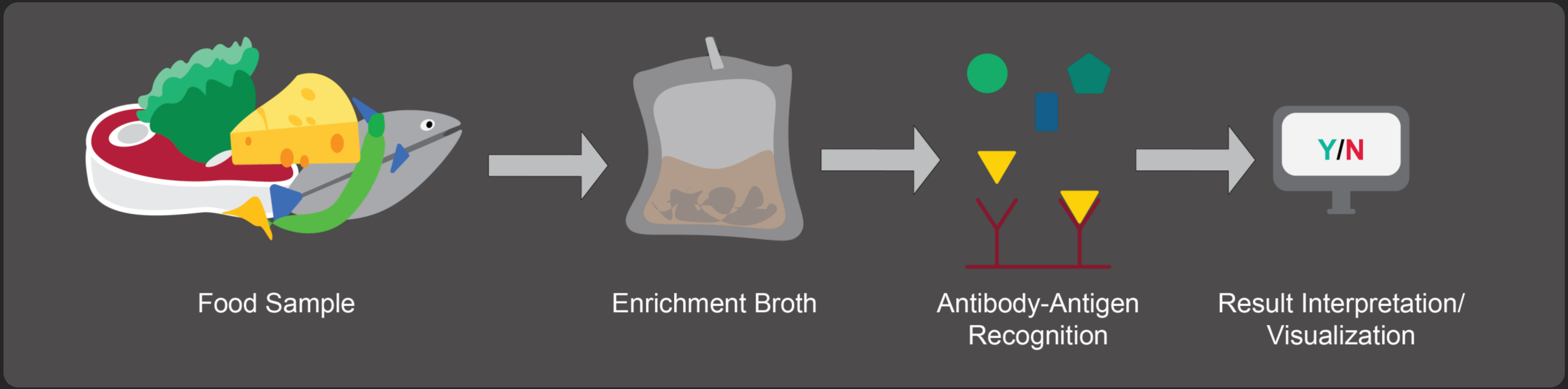
Biosensor-based: Advantages vs. Disadvantages

Method	Assay-time	Detection Limit	Advantages	Disadvantages
Optical Biosensors	Not stated	E. coli O157:H7 1.4 10^4 CFU/mL	• Sensitive • **Real time detection**	• Costly • Sensor calibration
Electrochemical biosensors	15 min	E. coli O157:H7 1.6 10^1 – 7.23 10^7 Cells/mL	• **High-throughput** • Automated	• Low specificity • **Food matrices interference** • Laborious
Mass-based biosensors	4 h	E. coli O157:H7 20 - 50 Cells/mL	• Cost effective • Easy • Real-time detection	• Low specificity and sensitivity • **Laborious** • Instrumentation design

Wang et al., 2013b; Shen et al., 2011; Varshney et al., 2005.

Immunological-based

- Interaction antibody-antigen, whereby a particular antibody will bind to its specific antigen.
- The binding strength of a particular antibody to its antigen determines the sensitivity and specificity.



Vidic et al., 2019; Law et al., 2015.

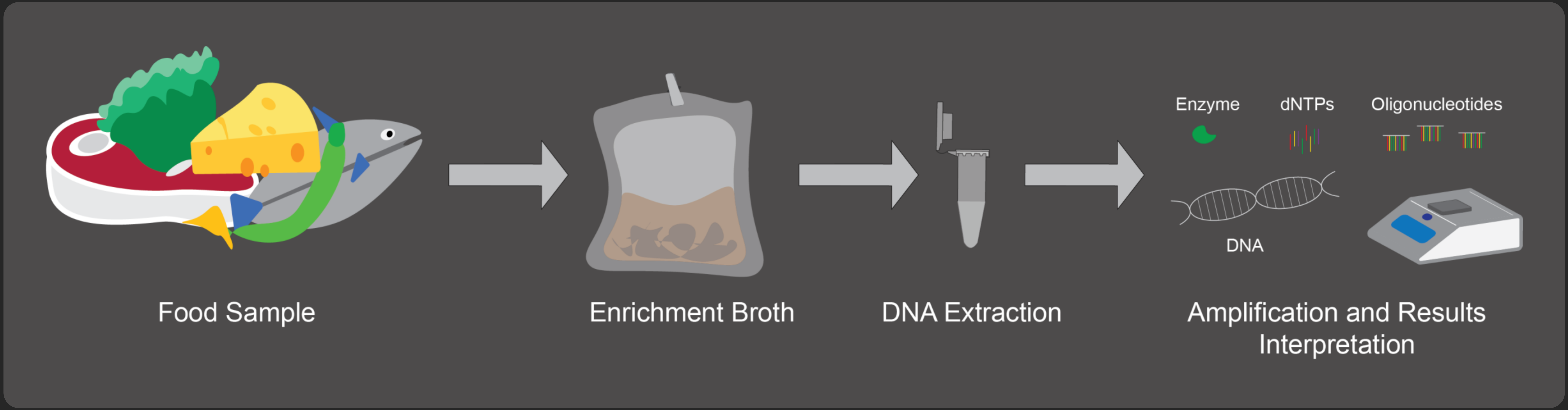
Immunological-based: Advantages vs. Disadvantages

Method	Assay-time	Detection Limit	Advantages	Disadvantages
ELISA	3 h	E. coli O157:H7 6.8 10^3 CFU/mL	• Specific • **High-throughput and automatized** • Detection of bacterial toxins	• Low sensitive • False negatives • **Cross-reactivity** • Trained personnel
Lateral flow immunoassay	10 h	Salmonella Typhi 10^4-10^5 CFU/mL	• **Cost effective** • Easy to operate • Sensitive	• Labelling of antibodies or antigens required • **False positive** • Specificity

Shen et al., 2014; Kumar et al., 2008.

Nucleic acid-based

- Detection of DNA or RNA specific sequences in the target pathogen.
- Hybridization between the target nucleic acid sequence and a synthetic oligonucleotide which is complementary to the target sequence.
- Detection of specific genes such as toxin-related genes, prevents ambiguity and wrong result interpretation.



Vidic et al., 2019; Law et al., 2015.

Nucleic acid-based: Advantages vs. Disadvantages

Method	Assay-time	Detection Limit	Advantages	Disadvantages
Multiplex polymerase chain reaction – mPCR	24 h	Salmonella spp. 10^3 CFU/mL	• **Detection of several pathogens at a time** • Less costly • Detection of groups of pathogens	• **Post-PCR result visualization** • Skilled technical personnel • Required reaction conditions optimization
Real-time or quantitative PCR - qPCR	<30 h	Salmonella spp. 5 CFU/25g	• Amplification can be monitored at real time • **Quantitative assay** • Amplification product confirmed by melting curve	• **Skilled technical personnel** • Difficult in multiplex assay • False-positive results • High cost
Loop mediated isothermal amplification – LAMP	<20 h	Salmonella spp. 5 CFU/10 mL	• High specificity • Isothermal conditions with great efficiency • **Tolerance to biological inhibitors** • Rapid	• Complex primer design • **Required multiplex reaction optimization**

Ruiz-Rueda et al., 2011; Shao et al., 2011; Silva et al., 2011

SwissDeCode - SDC

- SwissDeCode is a Swiss based start-up founded in 2016.
- SDC helps farmers and food manufacturers to grow and produce food that is safe to eat.
- SDC develops and provide rapid DNA detection solutions applied to:

Food Safety	*Salmonella spp.*	*L. monocytogenes*	
Food Adulteration - Contamination	Porcine DNA	Vegetal DNA	Fish and Meat
Food Authenticity	Cheese AOC	A1 Milk	

SwissDeCode into the VITAL Project

- SwissDeCode is developing a Lab on chip Solution - BEAMitup™ - to empower the quality control processes along the entire food supply chain, from farm to fork.

- SwissDeCode BEAMitup™ solution advantages:

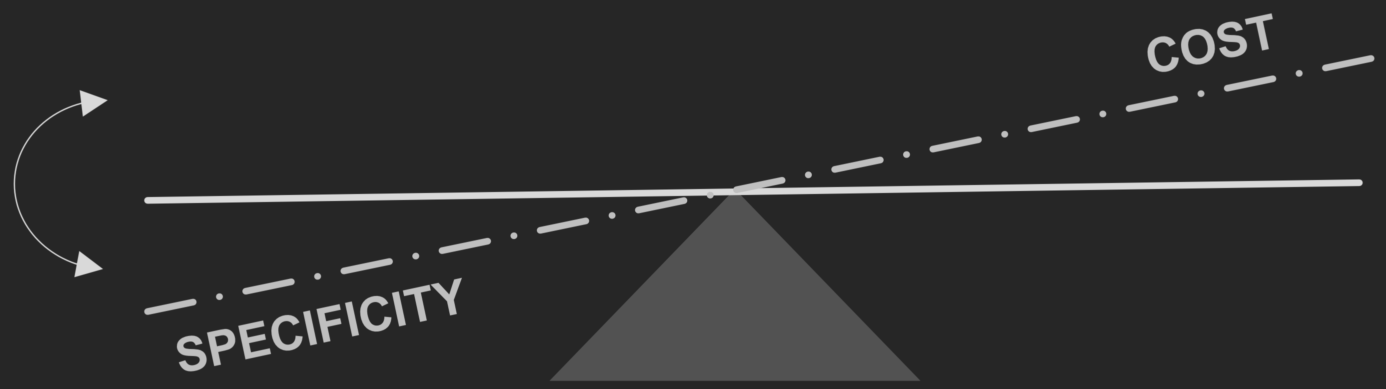
  - Sensitivity
  - Specificity
  - Robustness
  - Cost
  - Labor-saving and simplicity
  - High-throughput
  - On-site detection

Take Home Message

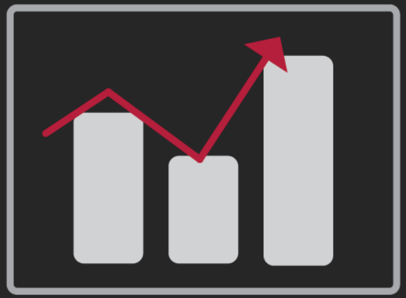
- There is no a universal method for foodborne pathogens detection.

- Methods comparison and choice are based on:

    - Sensitivity and Accuracy
    - Specificity
    - Robustness
    - Cost
    - Labor-saving
    - Choice of matrix/Organism
    - Target foodborne pathogen
    - On-site detection



Impact of Recalls: Time to Act



Number of food recalls between 2012 and 2017 in the US

+300%

The average direct cost of a food recall

$10 M

People who would choose the same brands following a recall

-45%

Open Questions

- What can be implemented in rapid detection methods for foodborne pathogens?
- Which are the key requirements demanded by the Food Industry?
- How do we validate a new rapid detection method?

SwissDeCode SA │ Chemin du Closel 5 │ CH-1020 Renens

Pietro Cattaneo, PhD – Field Application/Product Development Scientist

Email: pietro.cattaneo@swissdecode.com

Mobile: +41 78 235 52 35

Questions?

Questions should be submitted via
the **Questions section** at the right of the screen.

This webinar is being recorded and will be available for access by **IAFP members** at www.foodprotection.org within one week.

Not a Member? We encourage you to join today.
For more information go to:
www.FoodProtection.org/membership/

All **IAFP webinars** are supported by the IAFP Foundation with no charge to participants.
Please consider making a donation to the **IAFP Foundation** so we can continue to provide quality information to food safety professionals.

Contact information for presenters

Pedro Lopez	AI Talentum, Spain	plopez@aitalentum.com
Trevor Phister	PepsiCo, United Kingdom	Trevor.Phister@pepsico.com
Pietro Cattaneo	SwissDeCode, Switzerland	pietro.cattaneo@swissdecode.com