# RoboCup MSL Scientific Challenge 2021

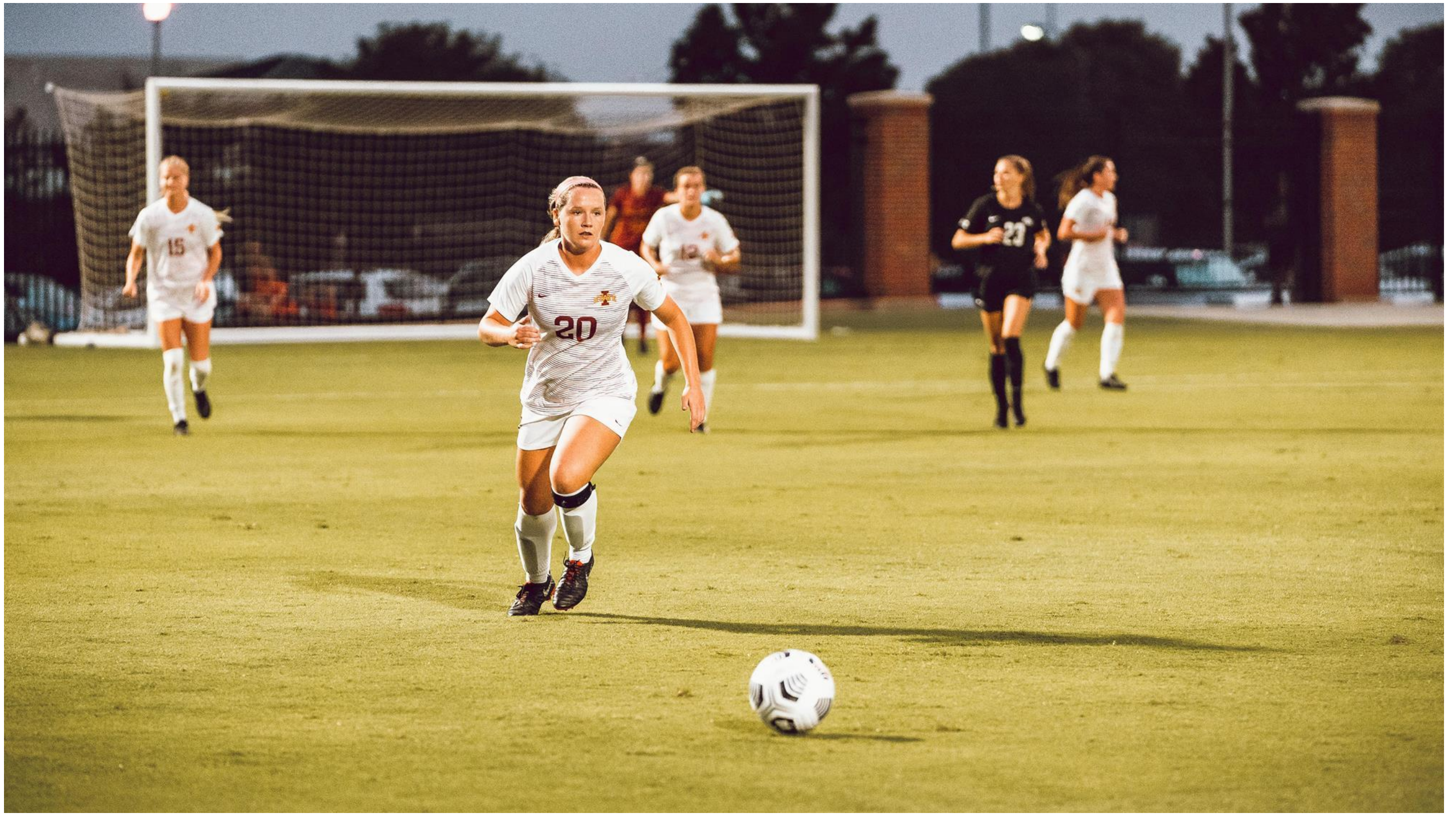
## Playing with humans : improving embedded perception

UNIVERSITÉ DE TOULON

ROBOT CLUB TOULON

RoboCup

- Playing with humans : the (near) future of RoboCup MSL
  - A major step on the road to 2050



- Playing with humans raises major challenges
  - Improving robot skills : *(technical challenge)*
    - Require to be competitive with humans
  - Playing without wireless communications : *(technical challenge)*
    - Except for the referee
  - **Require improving drastically embedded perception**
    - No more shared perception
    - Requires Robots/humans/landmarks identification and localisation
    - Limited hardware computational capabilities.

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## Playing with humans : improving embedded perception

- What is an improved perception ?
  - Identification – Who ?
    - Teammates / opponents / referee / landmarks
  - Positioning – Where ?
    - Teammates / opponents / referee / landmarks
  - Postural communication : What ?
    - What is « told » by gesture of teammates / opponents / referee / coach ?
      - See excellent Tech United Technical Challenge ☺

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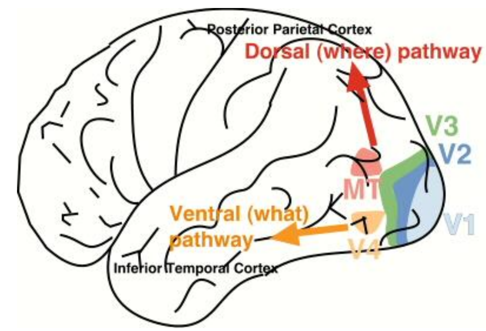
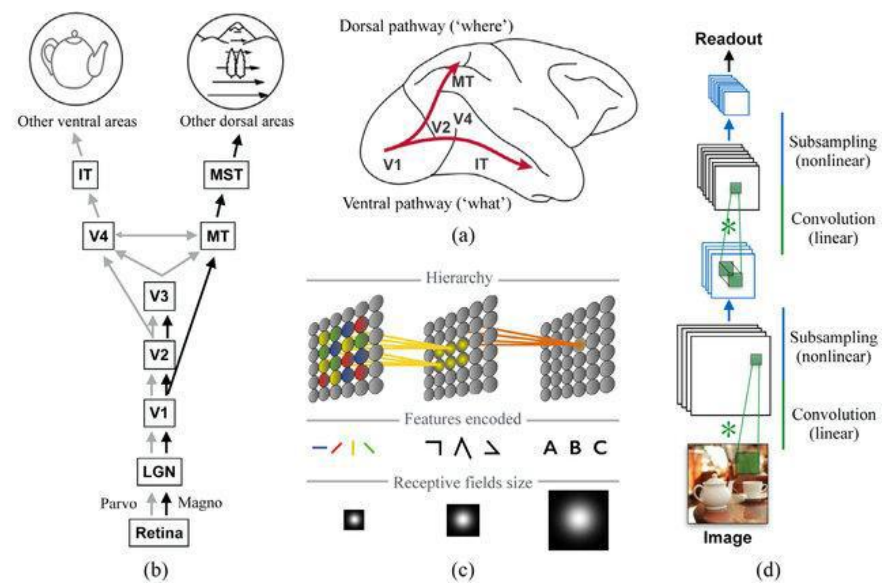
## Playing with humans : improving embedded perception

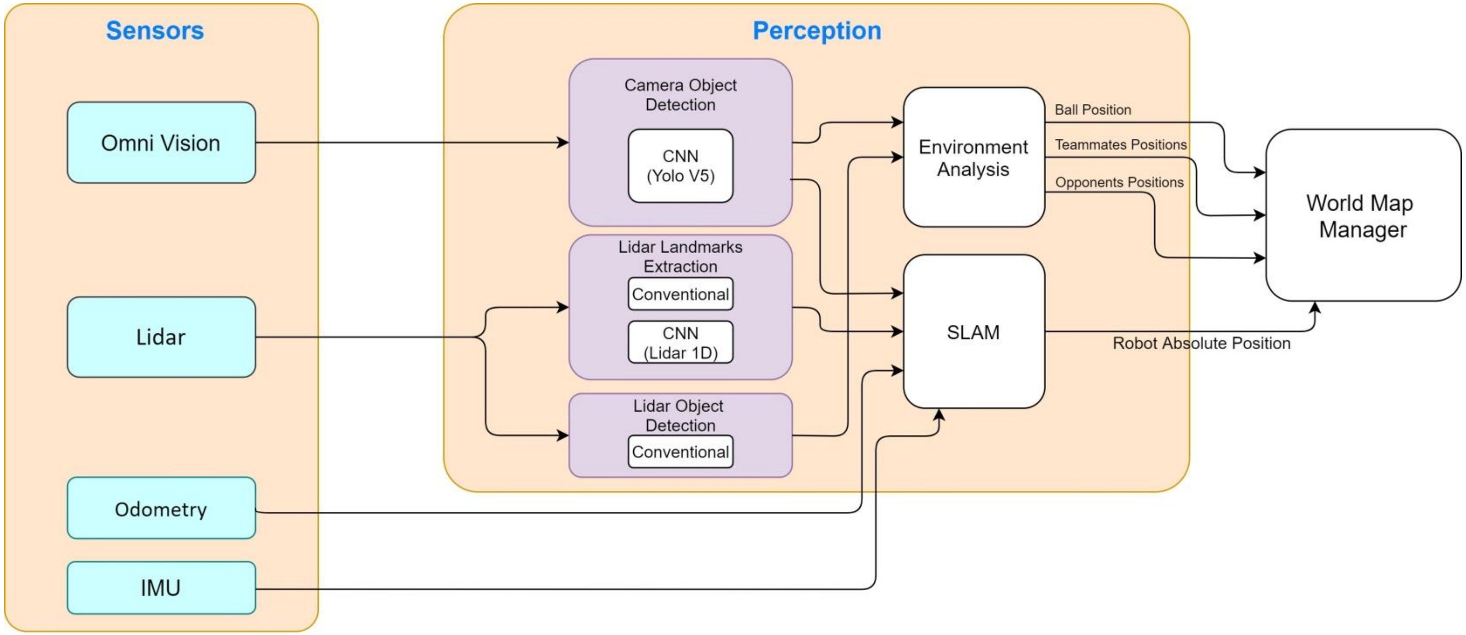
- How perception is implemented in the brain ?
  - Vision preprocessing
    - Close to CNN
  - Identification and posture : Who/What ?
    - Cortex ventral pathway
    - Mainly based on vision
  - Positioning : Where ?
    - Cortex dorsal pathway
    - Coupling « sensors »
      - Vision / Streovision
      - Acoustic perception
- Key bioinspired ideas
  - Complementary perception organs
  - Parallel processings



## How to implement advanced perception in robots ?

- Combining multiple sensors and processings is a key
  - Lidar : precision (angular and radial), but 1D
  - Camera : 2D, color but no radial precision
  - SLAM for sensor fusion
- **Processing efficiency is important : several task in parallel**



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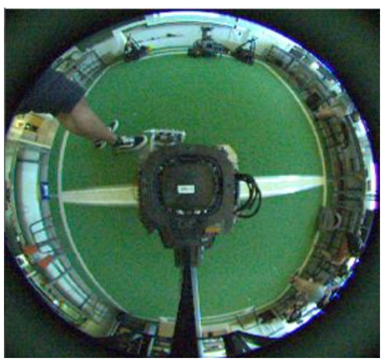
## Playing with humans : improving embedded perception

- Who / What ? Omnidirectional camera + deep learning
  - **Contribution : a new technical choice**
    - 185° fisheye pointed vertically to the ground.
    - No more problem of misalignment of camera and mirror.
      - No need for hardware calibration
    - Excellent optical quality.



- Image transformed to panorama
  - Require a software autocalibration (instead of hardware calibration)
    - Finding fisheye center to have a straight panorama image.

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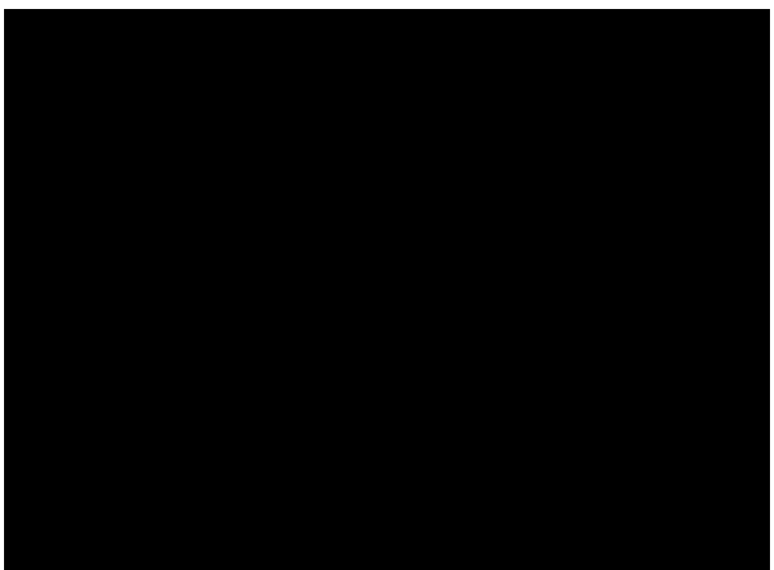
## Playing with humans : improving embedded perception

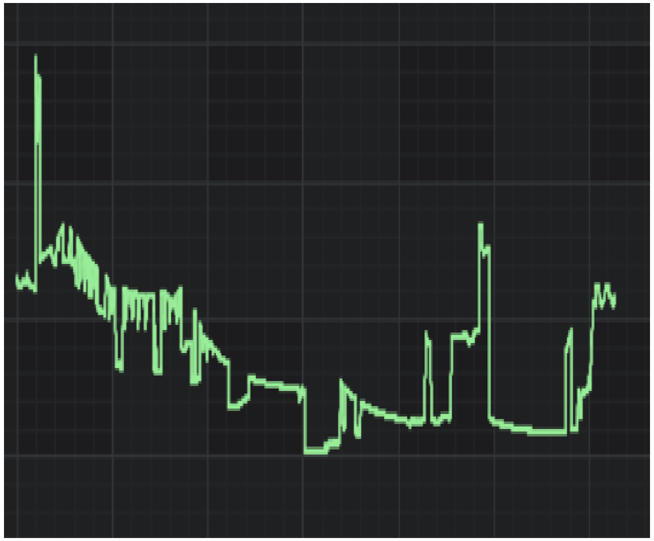
- Who / What ? Omnidirectional camera + deep learning
  - Followed by image segmentation using CNN
    - Well-known Yolo V5 algorithm on standard cameras.
    - Doesn’t work on fisheye images directly
      - CNN are rotation sensitive
  - **Contribution : first time applied to unwarped spherical images**
    - Requires an extended training set
      - Nubot TS + fisheye panorama samples

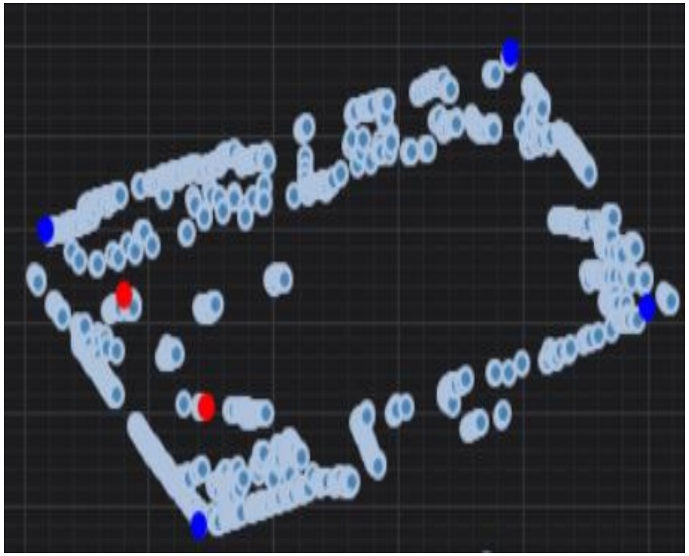
- Who / What ? Omnidirectional camera + deep learning
  - Experimental performances :
    - Detection of 4 classes : goal / robots / balls / humans
      - AUC : 87%
    - Latency : nearly real time
      - 34-40ms (Yolo V5 large model) : 25 fps
      - 10-15ms (small model) : more than 60 fps
    - GPU : 6% (GTX 1060) - CPU : 20% (mainly for fisheye to panorama)
  - Pros :
    - Able to segment complex scenes
    - Able to distinguish human/robots color ( an idea : shirt could be enlarge in the future for easier analysis, like in real soccer)
    - Excellent angular resolution
  - Cons :
    - Poor radial resolution
    - Computationally expensive

- Where ? Lidar : the perfect complement to omni-camera
  - Excellent radial resolution all around the robot : 1 cm
    - Impossible with omnicamera
    - 360° difficult with stereovision.
  - Allow landmarks extraction with precision
    - Example : room corners
      - Limited to simple situations using geometric methods



- Where ? Lidar : the perfect complement to omni-camera
  - **Contribution : a low-computational cost 1D Lidar deep learning algorithm**
  - Finding landmarks in a scene (for further SLAM). Here :
    - Goal posts
    - Room / stadium corners.
  - Can be found by 2D image analysis using CNN : computationally expensive

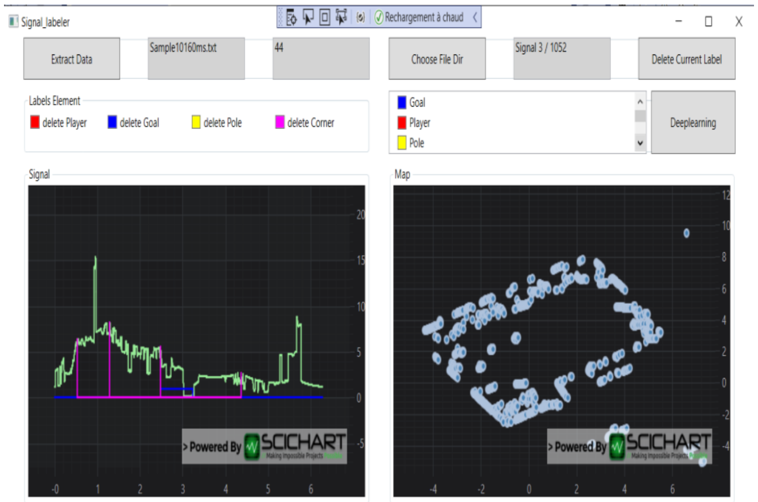




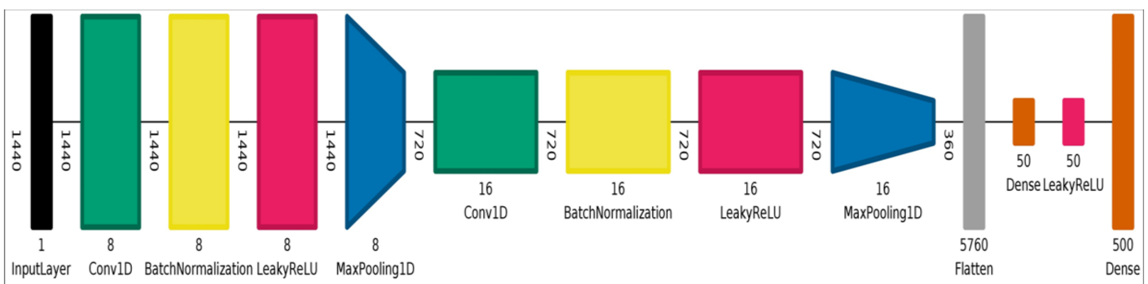
# RoboCup MSL - Scientific challenge 2021

## Playing with humans : improving embedded perception

- Where ? Lidar : the perfect complement to omni-camera
  - **Contribution : a low-computational cost 1D lidar deep learning algorithm**
    - Dedicated labelling software
    - Using a custom 2 layers CNN
    - Optimized for :
      - Object angle and distance
      - Classification




$$
\begin{aligned}
Loss = & \lambda_\theta \sum_{i=0}^{C_x} 1_i^{obj} (\theta_i - \hat{\theta}_i)^2 + (d_i - \hat{d}_i)^2 \\
& + \lambda_{\mathrm{Pr}_1} \sum_{i=0}^{C_x} 1_i^{obj} (Pr_i - \hat{Pr}_i)^2 \\
& + \lambda_{\mathrm{Pr}_2} \sum_{i=0}^{C_x} 1_i^{noobj} (Pr_i - \hat{Pr}_i)^2 \\
& + \sum_{i=0}^{C_x} 1_i^{obj} \sum_{c \in classes} (c_i - \hat{c}_i)^2
\end{aligned}
$$



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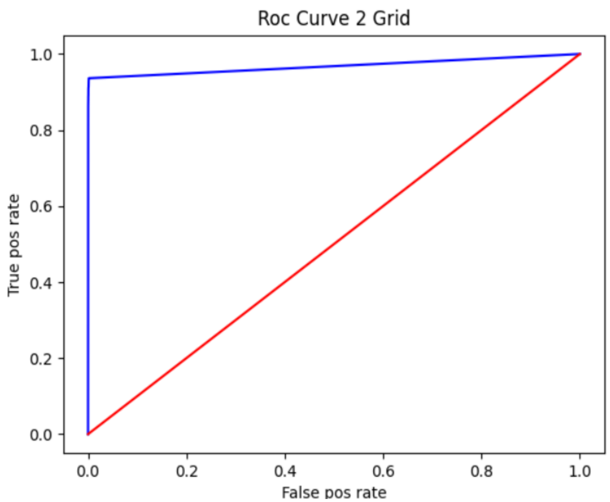
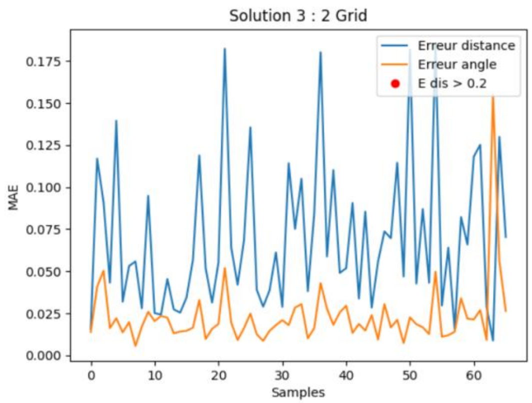
## Playing with humans : improving embedded percepton

- Where ? Lidar : the perfect complement to omni-camera
  - Results for detection of posts / balls / robots / humans
    - **AUC  85% : good detection**
    - **Allow an efficient positioning**
  - Efficiency :
    - Angular error stddev : 0.025 rad (1.5°)
    - Radial error stddev : <10 cm
    - **Low computation time : <1ms**
      - -> low latency
      - Allow several processings in parallel



- Final perception step : merging data in a single world map
  - Implementing standard EKF SLAM :
    - Simulataneous localisation and mapping (SLAM)
    - Based on Extended Kalman Filter
    - **Require to have reliable landmarks**

    - Will be presented next year ☺

# Playing with humans : improving embedded perception

- Bio-inspired combination of sensors and efficient processings is the key :
  - Contribution 1 : **an omni camera with software calibration only**
  - Contribution 2 : **an application of Yolo V5 to unwarped spherical images (Who/What ?)**
  - **Contribution 3** : **a low-computational cost 1D lidar deep learning algorithm (Who/What ? Where ? Low-Power)**

- **Shared on GitHub : https://github.com/iutgeiitoulon/RoboCup2020**

*Recent team publications related to RoboCup MSL or robots multi-agent perception:*


- *Article : 2020 Applied Physics : Distributed Adaptive Neural Network Control Applied to a Formation Tracking of a Group of Low-Cost Underwater Drones in Hazardous Environments – H. A. Pham et al.*
- *Article : 2020 Applied Physics : Optimisation of Energy Transfer in Reluctance Coil Guns: Application to Soccer Ball Launchers – V. Gies et al.*
- *Article : 2019 Actuators : Modeling and Optimization of an Indirect Coil Gun for Launching Non-Magnetic Projectiles –V. Gies et al.*
- *Conf : 2019 RoboCup Symposium : Modelling and Optimisation of a RoboCup MSL coilgun*
- *Conf : 2020 Mechatronics 4.0 conference : Mechatronics Iterative Design for Robots Multi-agent Integration – T. Soriano et al.*

# Thanks for your attention
# Questions ?