Low-cost fast mobile object detection for robotic soccer
Intelligent robots to win from Humans
• If we want to win in 2050, we need adaptive intelligent soccer robots.

Bring the A.I. revolution to RoboCup
• State-of-the-art object detection algorithms bring immediate benefits

Low-cost fast mobile object detection for robotic soccer
• Why? Detect objects fast (and fast objects) on soccer field, based on local compute, affordable for teams

"By the middle of the 21st century, a team of fully autonomous humanoid robot soccer players shall win a soccer game, complying with the official rules of FIFA, against the winner of the most recent World Cup"
The results
YOLO V5

Ultralytics’ YOLOv5 "You Only Look Once" model family
• 5th generation of YOLO real-time object detection (June 2020)
• based on convolutional neural networks
• state-of-the-art, very fast, targeted at mobile devices
• easy to use, It's as easy as running a single pip install
• Pytorch framework

YoloV5-small tested in context of high FPS inference on mobile devices
• 15 MB footprint (90 percent smaller than YOLOV4 and 15x faster training)
• Fastest possible inference (2.4 ms on cloud GPU) without significant quality loss
Continuous digital feedback loop

1. Data collection
2. Train YoloV5 model
3. Deploy ONNX model
4. Optimized mobile Inference engine: Nvidia TensorRT

Based on Tesla best practice
Data collection

Collected 1000 images from perspective of our robot camera
- Image size 672*376
- Image format JPG (batch converter PGN to JPG made available on github)
- Credits to ASML for making their data available for QuickStart

Annotated images on labellmg (free)
- Annotation VOC XML format (universal standard)
- Conversion SW to YOLO text file format (made available on github)

Labels:
- ball
- robot
- goalpost
- human

VDL Robotsports dataset made available on:
- [https://github.com/Charelvanhoof/robocup_vdl](https://github.com/Charelvanhoof/robocup_vdl)
- [https://www.kaggle.com/charel/robocup-images](https://www.kaggle.com/charel/robocup-images)
YoloV5 Training in the cloud

Training in the cloud
- Google Colab cloud GPU (Jupyter Notebook)
- Free of charge
- Many ML libraries pre-installed

Neural network architecture
- Yolo (You Only Look Once) V5 small
- Model Summary: 283 layers, 7,074,330 parameters
- Transfer learning

Only 2 hours training
- 300 epochs

Amazing recall/precision
Some more results

Partially shielded ball

Different ball colors

Follow the ball

Different lighting conditions
Deploy model

ONNX: Open Neural Network Exchange
- Open standard for representing machine learning networks
- Supported by all major machine learning frameworks (e.g. Tensorflow, Pytorch, MXnet)
- Provides interoperability between AI libraries

TensorRT: AI Inference Framework
- Supported by most modern NVIDIA graphics platforms (e.g. graphics cards, Jetson)
- Takes a neural network, produces an inference engine optimized for the specific edge device
- Multiple precision levels supported (e.g. INT8, FP16, FP32)

Our code (2000 lines) will be made available on Github
NVIDIA JETSON NANO
- Quad-core ARM processor, up to 4GB RAM
- Integrated GPU with 128 CUDA cores
- 5-10W power usage
- Developer kits starting at $69. VDL Robotsports used the $99 version. Third-party industrial kits available for a variety of applications

STEREOLABS ZED 2 (OPTIONAL)
- Used by VDL Robotsports for future features (depth estimation)
- Stereo depth estimation using two high-resolution cameras
- Based on NVIDIA CUDA technology
- Integrated IMU and compass
- $400
**Conclusion**

**Low-cost fast mobile object detection for robotic soccer**

**Novelty**
- State-of-the-art A.I. @25 fps on low cost mobile HW (~ 50 ms latency)

**Interest for the league**
- Amazing real-time precision/recall of objects on the soccer field
  - e.g. for the ball: shielded, different colors, different lighting conditions
  - 2 hours training -> train on game location with new images during set-up day

**Complexity**
- YoloV5 training in Google cloud -> ONNX exchange standard -> tensorRT Nvidia GPU network optimization for low cost HW (countless hours, 2000 lines of code)

**Relevancy for the league**
- Acceleration possibility: amazing object detection for all teams
- Affordable for all
- Base on open standards: ONNX, VOC XML

**Demonstrated experimental results**
- practical results, from sceptical AI questions to usable object detection on soccer robots

**Published results**
- Check it out: [https://github.com/Charelvanhoof/robocup_vdl](https://github.com/Charelvanhoof/robocup_vdl), [https://www.kaggle.com/charel/robocup-images](https://www.kaggle.com/charel/robocup-images), ONNX/TensorRT will be made available on github

Mounted on our new robot