# Automatic Mapping of Finish Line Videos for the Objective Analysis of Sprint Behavior

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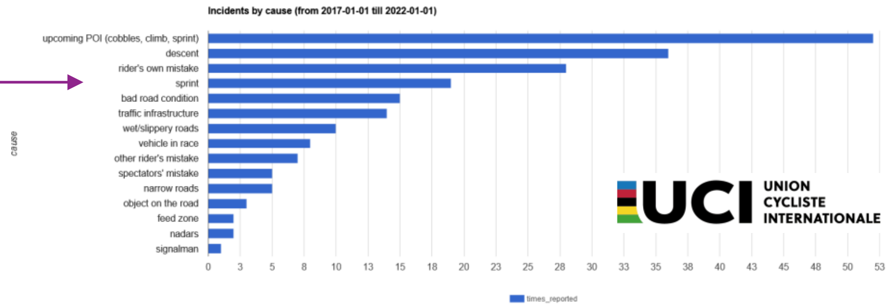
# Outline

- Context and problem description
- Goals/objectives
- Sprint video dataset
- Sprint map generation
- Rider detection/tracking
- Spatio-temporal sprint data
- Demonstrator/applications
- Conclusions / Q&A

# Context and problem description

- **Sprints** sometimes are marred by **crashes and dangerous riding behavior**, impacting the sprint result of some of the riders.




- Having tools to <u>**objectively**</u> **study sprint incidents** and visualize them in an **easily consumable** way can **facilitate the work of race jury** and improve safety in future races (e.g. by making riders more aware about the impacts of their riding behavior).

- <u>**Objective analysis**</u> can help the UCI to become <u>**more consistent**</u> in its <u>**judging of violations of rule 2.3.036**</u> : "*riders shall be strictly forbidden to deviate from the lane they selected when launching into the sprint and, in so doing, endangering others*".

# Goals/objectives

Assist race jury by i) **flagging outliers (~ abnormal sprint behavior)** and ii) **finding similar historical sprints** + jury decisions

=> **data-driven second opinion**

=> improve the interpretation of rule 2.3.036

**HOW?**

**Mapping bird's eye view video images** onto a **sprint map** => generate **spatio-temporal data of rider positions**

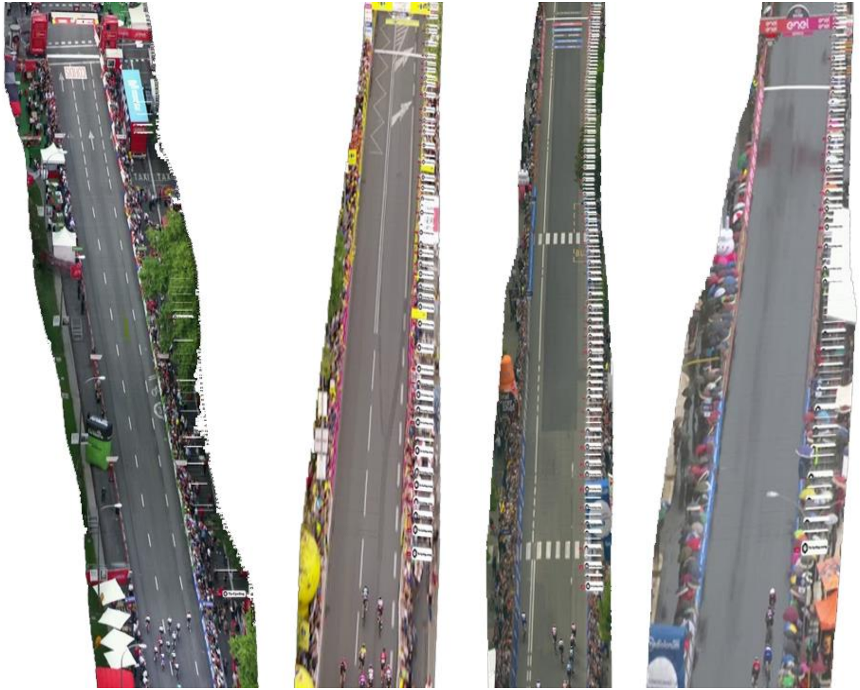
# Bird’s eye view sprint video dataset

- Challenging World Tour races dataset of **approx. 100 bird’s eye view finishing line videos of the past five years**

  => since 2021 – UCI VAR logs heli footage of last 3km

- Covers **majority of finish line types** -> generic solution

- **Sprints with different characteristics**:
  - rural/urban environments
  - different zoom levels
  - varying weather/lighting conditions
  - with/without spectators



*Sprint map examples from our dataset*

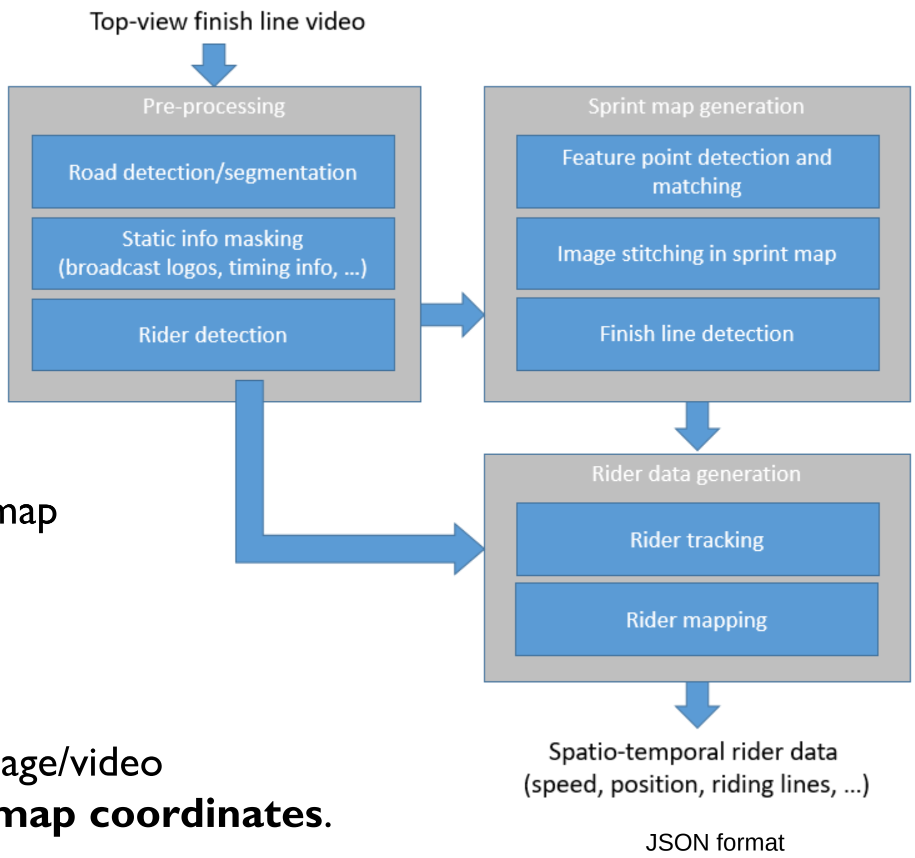
# Sprint map generation

- Detectron2 based **road/rider detection**
  https://github.com/facebookresearch/detectron2

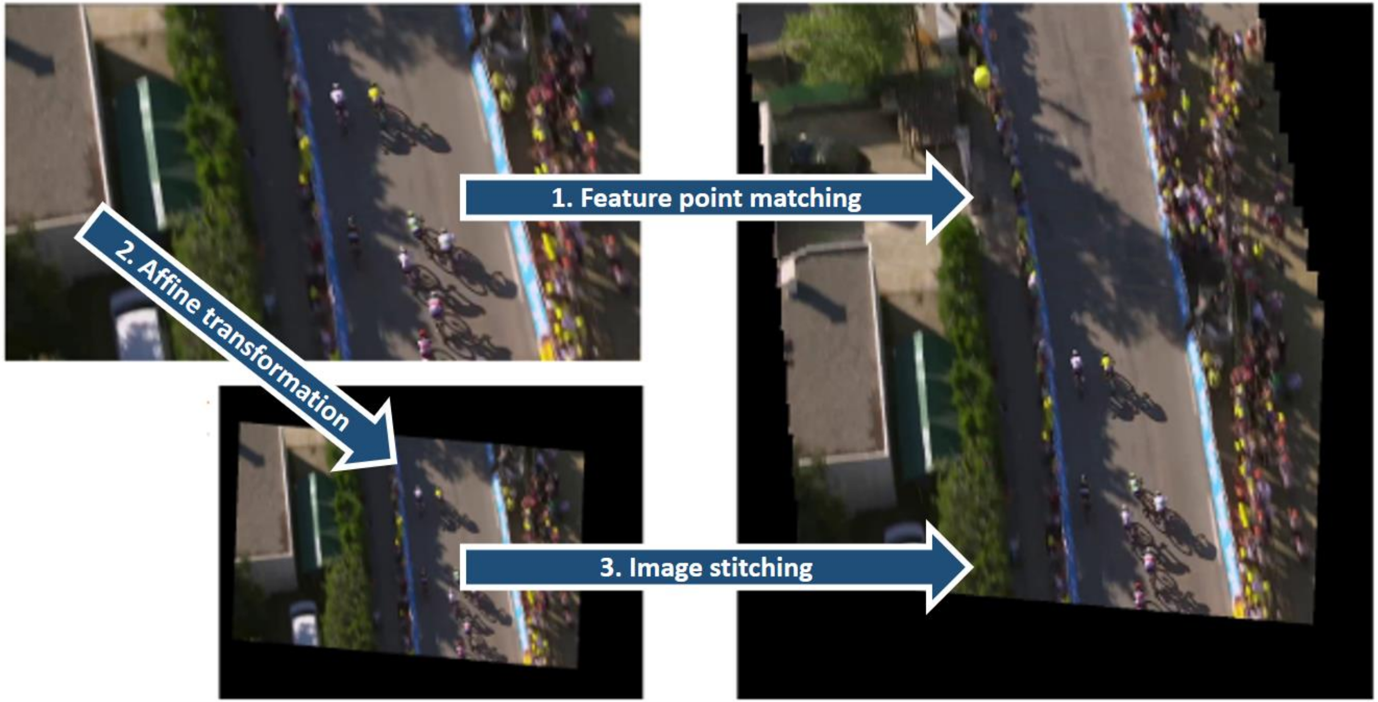
- BG subtraction for **static info masking**

- **Feature matching** between image & sprint map
  SIFT (best performance/accuracy) + RANSAC
  => estimate the **geometric transformation parameters**
  to **stitch the image to the sprint map**

- Using the same transformation parameters, image/video rider positions can be transformed to **sprint map coordinates**.



# Sprint map generation



# Road/rider detection

- **Trained** on a dataset of **annotated images** with **road surface & rider** segmentations. Image labeling -> **VGG image annotator -** https://www.robots.ox.ac.uk/~vgg/software/via/

- Pre-trained **mask_rcnn_R_50_FPN_3x model** -> trains fast and has best speed/accuracy ratio. Learning rate set to 0.0025 for both classes and amount of iterations was set to 10000 and 15000 for rider and road objects respectively. **Segmentation precision for both classes is above 0.9**

- Currently, the **center of the bounding box is used as rider position** - future work will focus on optimizing this.



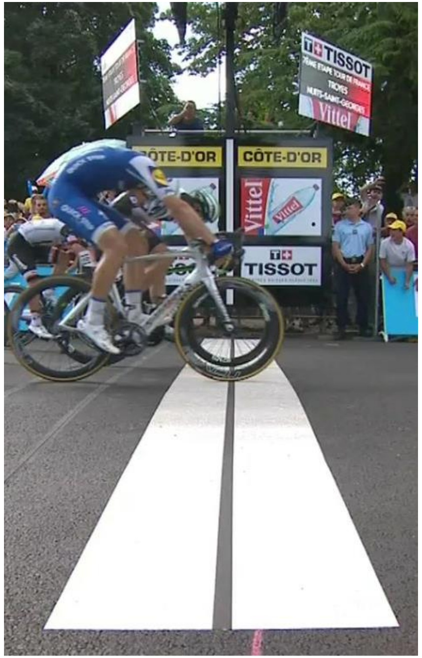
| Type | #training images | #test images | #training labels | #test labels |
|---|---|---|---|---|
| Rider | 432 | 95 | 2139 | 357 |
| Road surface | 432 | 95 | 432 | 95 |

# Rider tracking and speed prediction

- Riders are **tracked across consecutive video frames** using the **SORTalgorithm** which uses the position of a rider in the past frames to **estimate the new position** in the current frame. Based on the estimated and detected positions, each rider is **associated with its correct ID**.

- For **speed prediction**, the **pixel per meter ratio of the sprint map** needs to be known. Based on the **finish line detection** - and more specifically **its width -** we can calculate this ratio.

- Finish line detection also allow us to **link the rider detections to the stage results** and **identify which rider corresponds to which ID/line**.




*Finish line width is fixed in World Tour races as a 4cm black line enclosed within two white bands of 34cm each – as defined by UCI*

# Spatio-temporal sprint data


```
[{"Metadata": {"Name": "Giro", "Year": "2019", "Stage": "3", "City": "Orbetello" ,
"left_border": [[688, 5650], [757, 5130], [851, 4628], [920, 4147], [997, 3620], ...
"right_border":[[1087, 5757], [1124, 5410], [1184, 4950], [1230, 4537], ....
"finishlinewidth":15 ,"pos_finish":[[1691, 377], [1967, 382]]}},
{"fps": 30.037128712871286, "fps_scaled": 3,
"1": {"positions": [{"id": 8.0, "position": [1904, 223]}, {"id": 7.0, "position": [178
"2": {"positions": [{"id": 10.0, "position": [1837, 221]}, {"id": 9.0, "position": [18
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# Evaluation

- Decent objective evaluation is needed to correctly measure the accuracy of the proposed methodology (*-> future work*).

- Currently **exploring several strategies**:
  - analyzing the smoothness of the generated riding lines
  - evaluate/study the speed curves
  - comparisons with Strava sprint results
  - matching with satellite images
  - *… any suggestions/ideas?*

*Comparison of sprint map and satellite image for 2021 Oxiclean Classic Brugge - De Panne.*

## **DEMO: objective sprint analysis**
## of race cycling finish zones


Practical applications:

- Objective evaluation of sprint lane deviation
- Sprint performance analysis
- Storytelling, querying, …

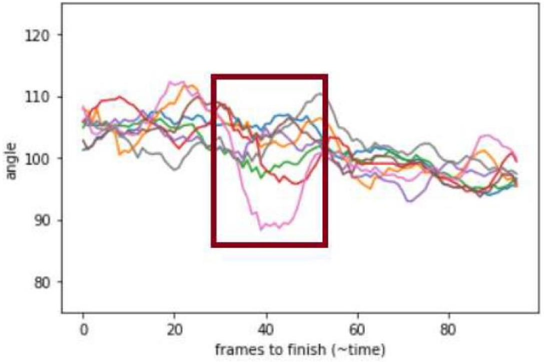
# Applications - objective evaluation of sprint lane deviation

## Example: Giro d'Italia – Stage 3 (Orbetello)

**Goal: flag riders that change direction and in doing so block the predicted future position of those that are just behind them.**

Giro d'Italia - Stage 3 (Orbetello)

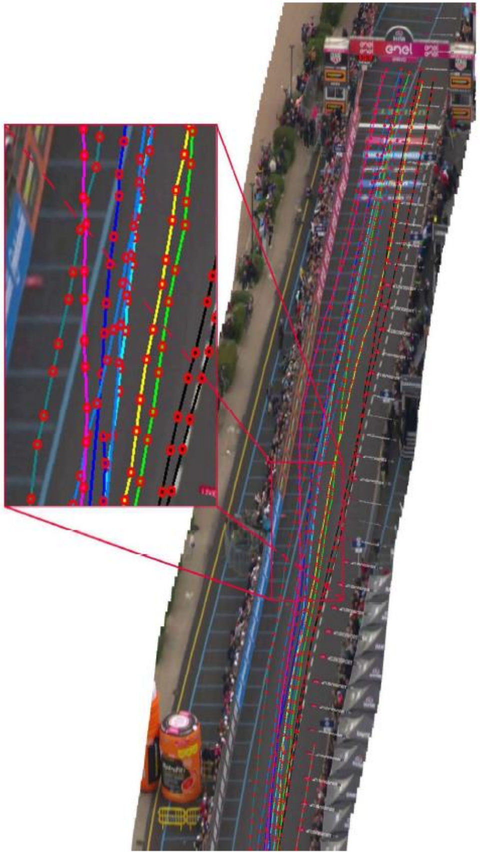
Viviani's dangerous riding behavior impacts several riders that are just behind him.




Riding angles of Giro 2020 stage 3. An abrupt change can be detected at 50 frames (~measuring points) from the finish.

⬇

Distance to the predicted position of a rider behind him (= Viviani) was close to zero, after deviating from his line,



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# Applications – sprint performance analysis

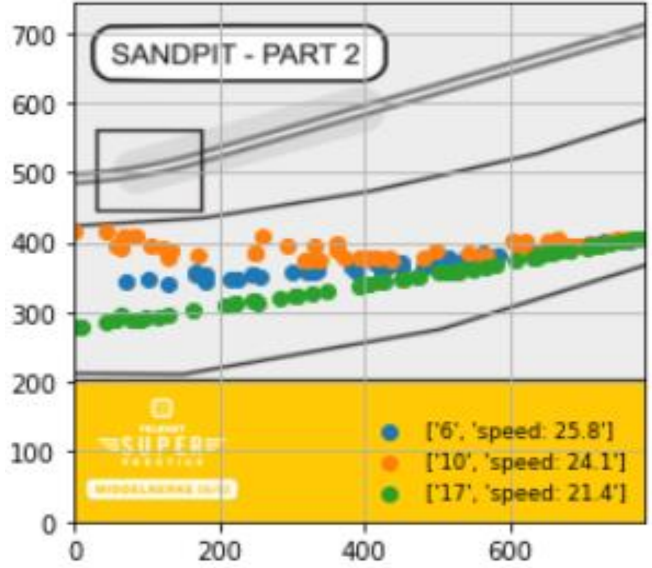
To assess sprint performance, we **transform the data into numerous variables**:

- race position in all frames
- final result of each rider
- velocities and accelerations (=> relative values to allow for a comparison of sprints on different terrains)
- position variables, such as the position on the road with respect to barriers

Apply different ML techniques to **explore whether there are patterns in the bunch sprints**. Here, the main goal is to **find similarities between winners.** In particular, we will investigate which of the aforementioned variables have the greatest impact on the performance.

# Applications – storytelling
## DAIQUIRI imec icon project

Line choice and analysis is **also useful in other sports/disciplines** (e.g. in cyclocross)

# Conclusions

- In this work, we presented a first step towards objective analysis of sprint behavior.

- Preliminary results show that it performs best on a continuous stream of bird's eye view video images shot at constant speed, fixed angle and with no zooming effects.

  These instructions can, for example, be given to the broadcast helicopter/VAR to include it into their race coverage/logging protocols.

- Other possible improvements, such as optimizing the rider's segmentation/localization and improving our evaluation mechanisms, are currently investigated and will be reported in future work.

# Other IDLab Cycling Research @ Flanders 2021



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# QUESTIONS?

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