Automatic Virtual Soccer Camera

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Motivation

Soccer clubs use video recordings to stream and analyze their matches. However, smaller clubs may lack the resources to hire a camera operator to record their games.

This thesis aims to develop a new, open prototype of an automatic virtual soccer cameraman. Given a static video stream of a soccer match covering the full pitch, **estimate a region of interest** (ROI) for each frame, such that a video composed of these ROIs resembles a video recorded by a human camera operator.

Method (key contribution)

The main contribution of this thesis is a system of 4 main modules that process each frame in a pipeline:

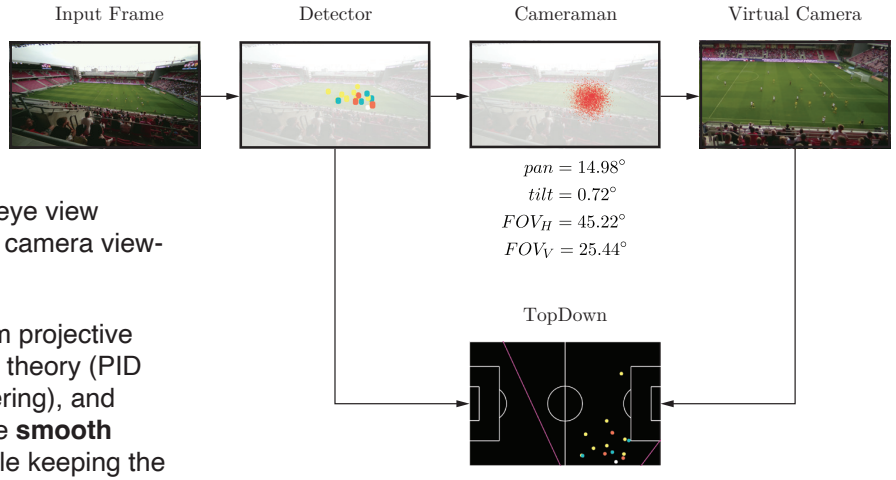
1. The **Detector** module detects the players and the ball.
2. The **Cameraman** module uses the detections to estimate the appropriate pan-tilt-zoom (PTZ) of the virtual camera.
3. The **Virtual Camera** module calculates the ROI (corrected for perspective distortion) and crops out that region from the input frame.
4. The **Top Down** module renders a bird-eye view based on the detections and the virtual camera viewing cone.

The modules utilize various techniques from projective geometry (homography estimation), control theory (PID controller), probability theory (Bayesian filtering), and computer vision (object detection) to ensure **smooth camera movements** with minimal jitter while keeping the **action in frame** throughout all key moments of the match.

Dataset

Our dataset's recording setup (left) and sample frame (right)

With the support of the company Goal Sport Technology, **we recorded an entire soccer match** between FC Spartak Trnava and MŠK Žilina in the Slovak First Football League. For evaluation purposes, the Slovak Football Association kindly provided us with the original broadcast footage from the primary (VAR) camera.



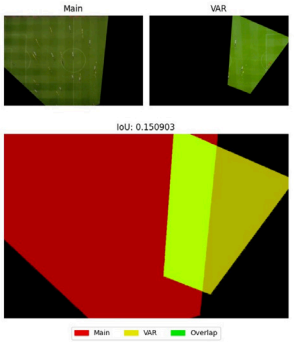
The application pipeline

Evaluation

We introduce **two evaluation methods** for comparing different variants of our system:

1. Full match evaluation

Compares the estimated footage with the footage from the broadcast camera. The metric is the **average intersection over union** (IoU) of the top-down projected estimated (Main) and broadcast (VAR) frames.



Evaluation metric visualization

Algorithm variant	Full match average IoU
Single detector	**0.3548**
Ball detector	0.3472
Imgsz640	0.3402
N1000	**0.3548**

Full match evaluation results

2. Clips Evaluation

Pass/fail manual inspection of 30-second clips of selected match highlights (goals, shots, and counterattacks) to test whether the ball stays in the frame during these events.

Clip	Passed
p0_shot1	✅
p0_shot2	✅
p0_shot3	✅
p0_shot4	✅
p0_zoom	❌
p1_counter1	❌
p1_goal1	✅
p1_goal2	✅
p1_shot1	✅
p1_shot2	❌

Clips evaluation results

SAMPLE VIDEO OUTPUT

FULL THESIS WITH CODE