Assessment of tomography signals in view of neural network reconstruction

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1. Introduction

- Current tomography methods include Minimum Fisher, Maximum Likelihood and also Neural Networks, which can reproduce the results of the previous methods [1].
- These approaches do not take into account reflections on the vessel walls, which are misinterpreted as direct incidences coming from the plasma.
- The goal is to generate large amounts of training data for neural networks, while at the same time taking into account the previously stated effects.
- An experimental setup has been used to collect a few initial samples. This setup was then represented in a ray-tracing simulation environment [2] in order to be able to generate arbitrary samples.
- The simulation environment has been tuned to data collected from the experimental setup. It takes into account viewing geometries, occlusion, vignetting and reflections.
- This simulation is able to provide the sensor measurements for any desired synthetic plasma profile. It has been configured based on the ISTTOK tomography system.
- Cameras are placed on the top and low field sides of the vessel. Each camera has 16 photodiodes that are sensitive from infrared to soft X rays.

2. Experimental set-up

- Cylindrical cold cathode lamp with 4.1mm in diameter.
- Placed at various radial and poloidal positions inside the vessel.
- Sensor measurements were acquired for a total of 57 positions (Figure 1).

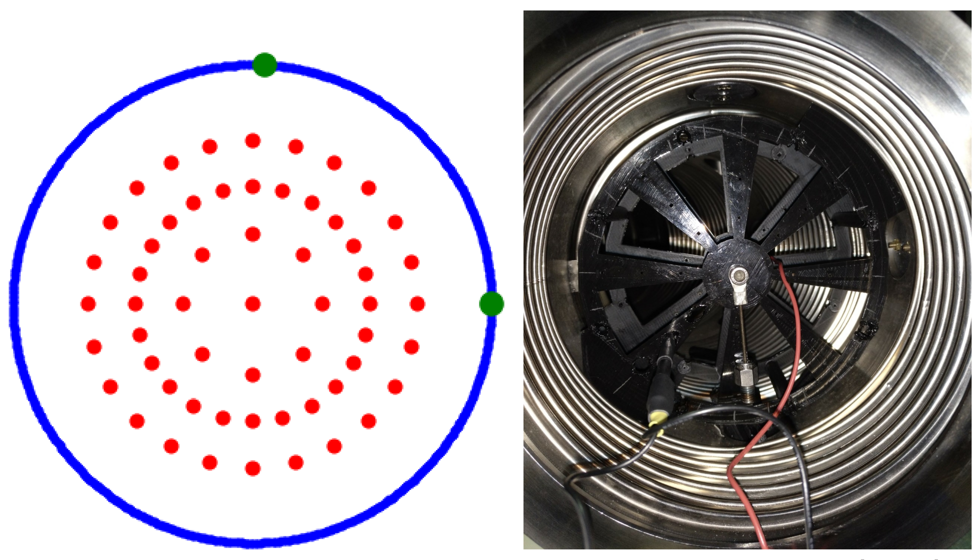

Figure 1: Left: Lamp placement positions (red) and camera's pinholes positions (green).
Right: Lamp support inside vessel replica.

3. Reflection effects

- Two types of reflections that affect sensors measurements: specular and diffuse.
- Specular reflections (Figure 2) are mirror-like and have a specific direction.
- Diffuse reflections affect all possible angles in the same way.

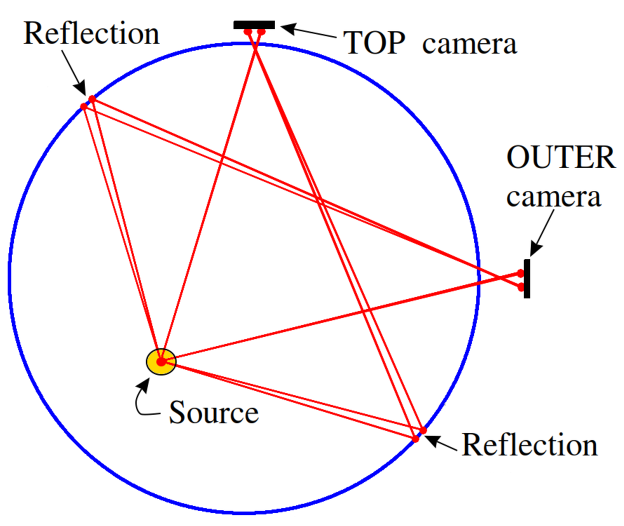

Figure 2: Lamp (yellow) and emitted rays that reach a detector (red).

(%)	Top	Outer
Specular	7.5	8.0
Diffuse	5.9	10.9

Table 1: Fraction of total power received by each camera due to each type of reflection.

4. Tuning of simulation environment

- Using the Python framework Raysect, we have replicated the experimental setup in a ray-tracing simulation environment (Figure 3).
- A 3D model simulates the vessel, cameras, lamp and its support structure (Figure 3).
- Raysect is also able to accurately simulate the reflections on the nickel-based vessel walls.
- To ensure a matching between the experimental data and simulations, we conducted a grid-search to fine-tune the parameters of camera geometries and vessel roughness (Figures 4 and 5).

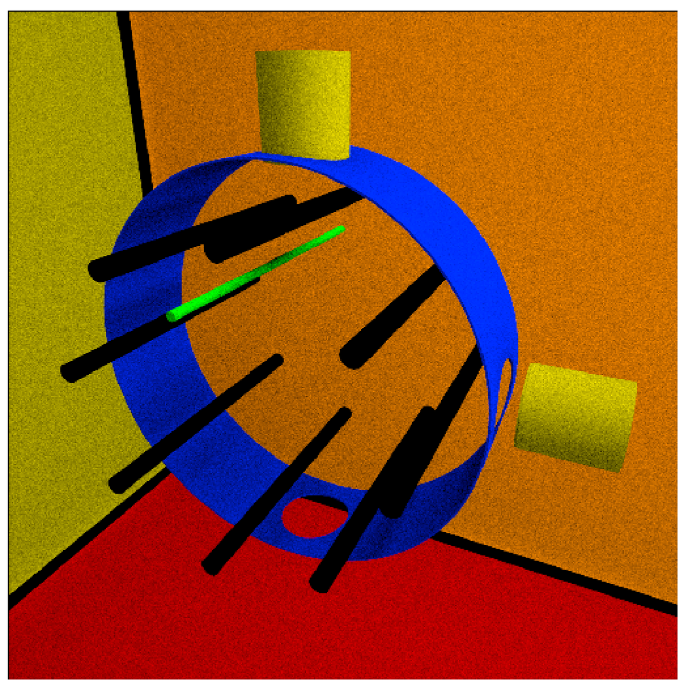

Figure 3: Raysect setup: vessel (blue), cameras (yellow) and lamp (green).

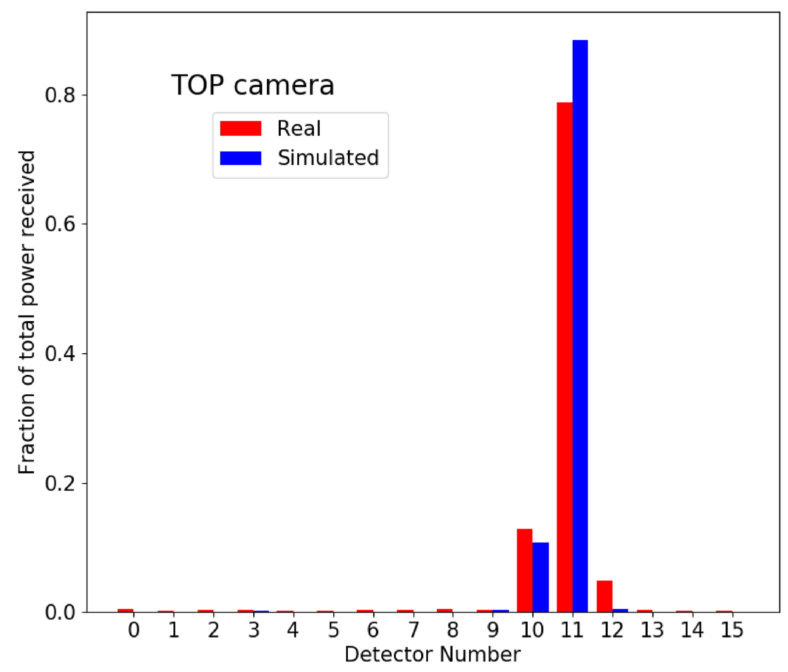

Figure 4: Real and simulated top camera signals for the lamp placed as shows in figure 3.

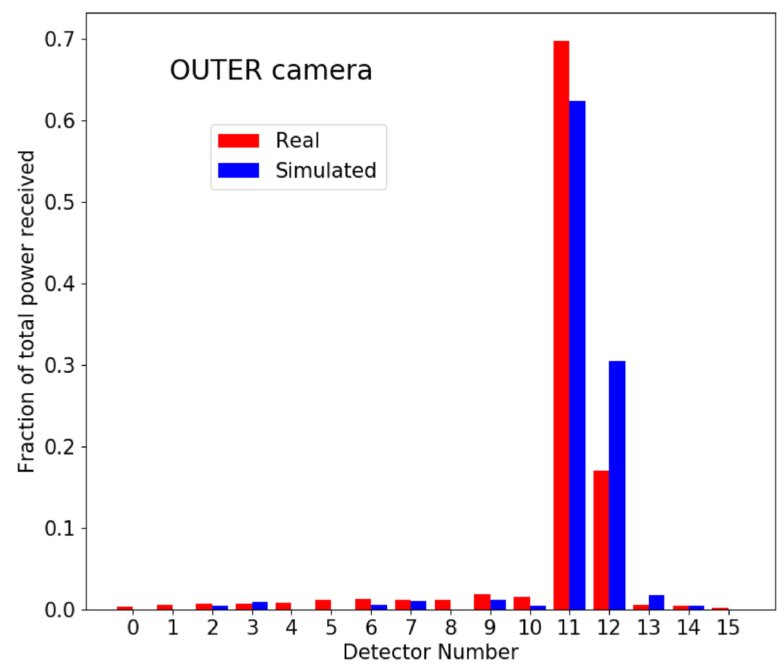

Figure 5: Real and simulated outer camera signals for the lamp placed as shows in figure 3.

5. Synthetic Tomography Signals

- Raysect allows the simulation of synthetic plasma with any desired profile (Figure 6).
- It is possible to compare the sensor signals from the ray-tracing simulation with those obtained through the typical line of sight approach (Figures 7 and 8).
- Using the simulation environment, we can collect the sensor measurements for any given plasma profile.
- A large number of such samples will be used to train a neural network to perform the tomographic reconstructions for ISSTOK.

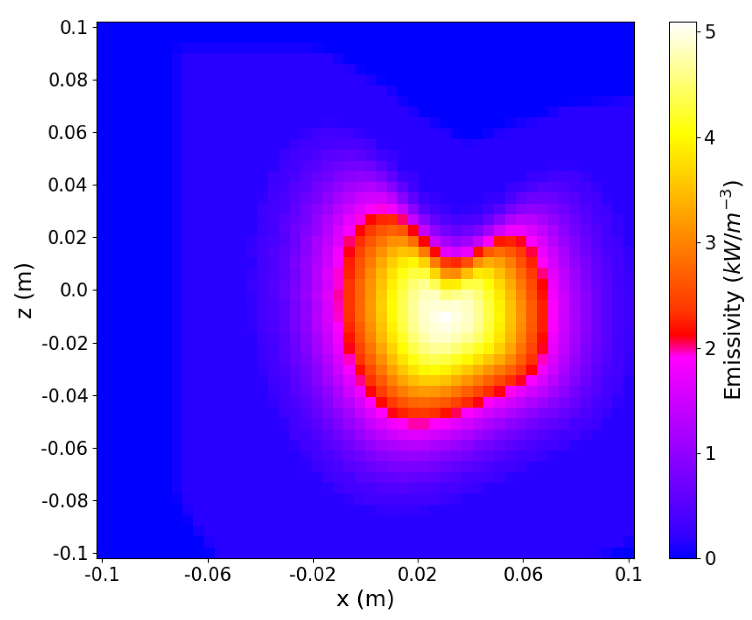

Figure 6: Example of plasma profile.

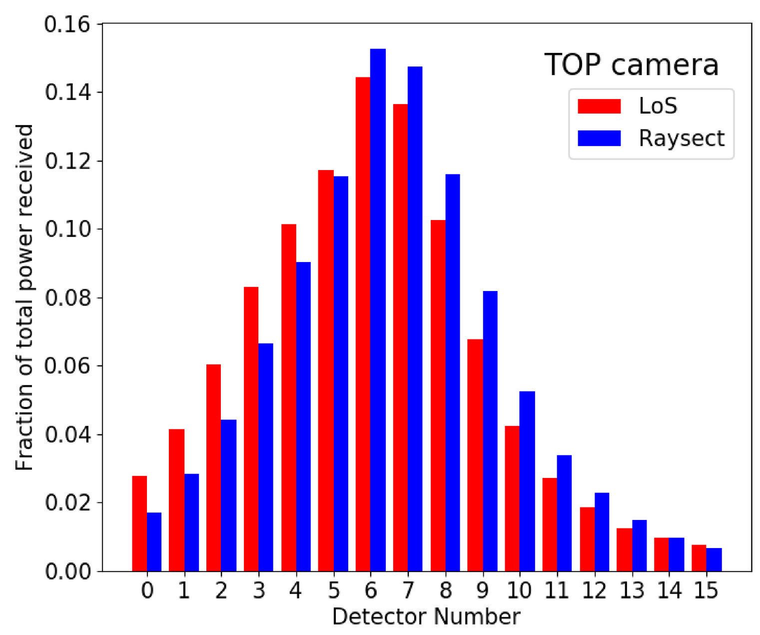

Figure 7: Simulated signals for the top camera.

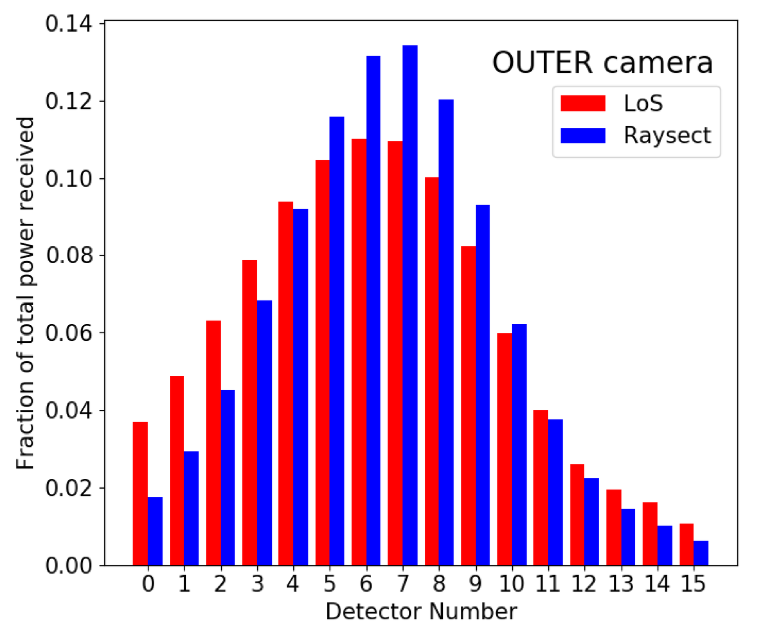

Figure 8: Simulated signals for the outer camera.

FCT Fundação para a Ciência e a Tecnologia

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[1]: Mlynar, J., Craciunescu, T., Ferreira, D. R., et al (2018, August 23). Current Research into Applications of Tomography for Fusion Diagnostics. Jornal of Fusion Energy. https://doi.org/10.1007/s10894-018-0178-x

[2]: Dr Alex Meakins, & Matthew Carr. (2018, August 7). raysect/source: v0.5.2 Release (Version v0.5.2). Zenodo. http://doi.org/10.5281/zenodo.1341376