Preamble

The “Solaris” network of robotic telescopes offers considerable opportunities for development and deployment of small astronomical instruments. Additionally, this is supported by a recent opening of a laboratory at CAMK Toruń fully equipped to carry out small instrumentation projects. Telescopes of our network are capable of observing satellites and space debris on all orbits (LEO-GEO). The project may encompass contributions to development of instruments enhancing the capabilities of our telescopes to observe and characterize resident space objects (RSO, this involves lab work), undertaking observing campaigns to detect, monitor and catalogue RSOs (this includes writing pieces of software, data reduction).

Instrumentation projects

Instrument design

Design and evaluation of instruments for astronomical observatories

- Intern will participate in the design, assembly and testing of astronomical instruments
- Intern will learn/develop practical skills in:
    - Working with 3D CAD software
    - Defining and verifying requirements for instrument design
    - Instrument simulation techniques
    - Component integration
    - Instrument commissioning and deployment

Embedded systems and observatory support

Design of embedded components for astronomical observatories (Solaris network)

- Intern will participate in the design process of embedded components for astronomical observatories
- Intern will learn/develop practical skills in:
    - Communication interfaces
    - Astronomical observatory maintenance and day-to-day operation
    - Mechatronics
    - Network management

Vision systems and satellite tracking

Work with real-time vision systems

- Intern will work with vision systems capable of real-time image processing for astronomical purposes (observatory sensor systems) and satellite observing
- Intern will learn/develop practical skills in:
    - Working with embedded vision systems
    - Component selection and integration
    - Image processing techniques
    - Managing and operation of distributed systems
    - Orbital mechanics and satellite tracking

Software Projects

Data analysis and reduction (Python/C#)

Development and analysis of pipeline for reduction of raw observational data

- Intern will develop existing pipeline, modularize it and verify scientific data generated
- Intern will learn/develop practical skills in:
  - Converting existing codebase into full-fledged library
  - Libraries for numerical analysis
  - Converting raw sensor data into scientific data
  - Best practices and design patterns
  - Basics of scientific data pipeline

Implementation of selected pipeline components in Tensorflow

- Intern will implement selected subset of reduction and processing pipeline in Tensorflow, verify correctness with existing pipeline and benchmark performance of implemented solution
- Intern will learn/develop practical skills in:
  - Libraries for numerical analysis and basics of scientific data pipeline
  - Converting raw sensor data into scientific data
  - Best practices and design patterns
  - Knowledge of Tensorflow framework
  - Performing performance analysis of implemented projects

Scientific data visualization (JS/Unity)

Visualization of sky in a web component (Three.js / Cesium)

- Intern will develop sky visualization using selected technology and developing existing solution based on Three.js
  - As a bonus intern will compare implemented solution with solution implemented in Cesium.js
- Intern will learn/develop practical skills in:
  - Knowledge of celestial mechanics
  - Web technologies and visualization of simulation-generated data
  - Environments for webapp development (VS Code + npm + TypeScript)
  - Best practices and design patterns
- Reference projects:
  - http://stellarium.org/
  - http://slowe.github.io/VirtualSky

Development of desktop FITS viewer using web technologies (Electron, Three.js)

- Intern will develop a multiplatform modern desktop app based on Electron allowing for viewing different kinds of data stored in FITS files format
  - As a bonus task intern may be asked to integrate developed solution with existing services (catalogues, external storages)
- Intern will learn/develop practical skills in:
  - Knowledge of most popular data format in astronomy – FITS
  - Web technologies and developing rich desktop user interfaces in Electron

    - Visualization of scientific data in browser environment
    - Best practices and design patterns
    - Environments for webapp development (VS Code + npm + TypeScript)
- Reference projects:
    - DS9 – http://ds9.si.edu/site/Home.html
    - ImageJ - https://imagej.nih.gov/ij/
    - List of apps created in Electron - https://electronjs.org/

3D visualization of astronomical equipment and state (Unity/Electron, Three.js)

- Intern will develop a multiplatform modern desktop app based on Electron allowing for visualization of astronomical equipment based on their state as reported by sensors attached to real sensors
- Intern will learn/develop practical skills in:
    - Knowledge of astronomical equipment and it's functionality
    - Web technologies
    - Developing rich desktop user interfaces in Electron
    - Visualization of scientific data in browser environment
    - Best practices and design patterns
    - Environments for webapp development (VS Code + npm + TypeScript)

Observations and sensor validation (Python/C#)

Observations using Solaris-Panoptes network

- Intern will prepare and execute observation campaign for given topic (SST, binary star systems, TESS, eclipse timing) gather the data and compile results as a draft for scientific paper
- Intern will learn/develop practical skills in:
    - Creating agent for planning and execution of optical obsevations
    - Reduction of data for photometry and astrometry
    - Usage of existing toolset for management of global telescope network
    - Analysis of astrometric and photometric data
    - Writing scientific papers
- - Following skills will be especially welcome:
    - Familiarity with LaTeX and Markdown

Astrodynamics – modeling of artificial Earth satellites and space debris

- Intern will develop and test tool for modelling orbits of Earth satellites and space debris for later use in detection of potential collisions and presentation as web service
- Intern will learn/develop practical skills in:
    - Astrodynamics of Earth satellites and influence of atmosphere and Sun on Earth satellites
    - Analysis of astrometric data and preparation of orbital tracklets and initial orbit determination
    - Development of microservices for performing necessary computation
    - Visualization of computed results
- Following skills will be especially welcome:
    - Knowledge of optimization techniques
    - Good algorithmic and/or mathematic background

Finding satellites and celestial bodies on astronomical images

- Intern will develop solution for finding celestial bodies and satellites in astronomical images using real observational data with focus on precise determination of location of astronomical objects and objects with low SNR in particular
- Intern will learn/develop practical skills in:
    - Basics of image processing and computer vision
    - Algorithms for edge detection in images (Sobel, Canny, Scharr)
    - Complex image transforms: Radon transform
    - Converting prepared codebase into full-fledged libraries
- Following skills will be especially welcome:
    - Knowledge of optimization techniques
    - Good algorithmic and/or mathematic background

Observation planning (Python/C#)

Development of inteligent observation agent – bot capable of using given scientific target and feedback from observation network after each observation to dynamically adapt global strategy and parameters for specific observation fields and observations (targets for TESS, Solaris projects)

- Intern will develop generator of synthetic training data. Intern will also develop and test bot using a) simple ruleset for conducting observations and conditions under which they should be modified b) library using heuristics, AI or machine learning for autonomous adaptation of observation plan aiming for optimization of data quality and available observation time. Solution will be tested using simulator and real data.
- Intern will learn/develop practical skills in:
    - Observation planning and optimization
    - Solving issue of optimal planning with limited resources
    - Creation of autonomous bots
    - Using heuristics tools, machine learning, AI for solving problems with strong chaotic components
- Following skills will be especially welcome:
    - Knowledge of heuristics tools, machine learning and AI
    - Knowledge of software for bot creation

Our offer

- Rich and engaging scientific projects in the Polish Academy of Sciences
- Work on real scientific data
- Access to state of the art astronomical equipment and lab environment
- Access to expert knowledge and leading Polish scientists
- Options for extended collaboration on selected projects
- Team collaboration
- Hands-on experience with modern programming techniques
- Licencing work on permissive licence (BSD, MIT, Apache)

Expectations (project dependant)

- Basic knowledge of Windows/Linux operating systems
- Programming skill in Python/C#/JS (depending on the projects)
    - Knowledge of C# is especially appreciated

    - Experience in vision systems highly appreciated
    - Experience in CAD highly appreciated
- Background in astrophysics, physics, engineering
- Manual skills and good feel of mechanics