POLITECNICO DI MILANO

# PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 39th cycle

## PNRR 117 Research Field: DATA-DRIVEN TECHNIQUES FOR ROBUST TRAIL DETECTION IN WIDE-FOV TELESCOPES IMAGES FOR SPACE SURVEILLANCE

| Monthly net income of PhDscholarship (max 36 months) |
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| **€ 1400.0**<br>In case of a change of the welfare rates during the three-year period, the amount could be modified. |

| Context of the research activity | |
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| **Motivation and objectives of the research in this field** | Fast-moving objects in optical astronomical images (such as debris in High-LEO orbits) are acquired as trails, that may reach the length of hundreds of pixels. The number of photons arriving from the source, and therefore the collected signal of the object, is shared by the trailed pixels. In the case of faint objects, the SNR on the single pixel belonging to the trail is too low to be detected by standard techniques. Dedicated algorithms can be used to perform the detection. They can exploit the intensity of the pixels included in the trail to detect the target by thresholding; edge detection techniques can be leveraged as well to convolute a predefined kernel to the image to highlight the desired features. This kind of deterministic method can also integrate the signal of all the trailed pixels, thus improving detection sensitivity, but can be at the same time computationally expensive, requiring a not negligible processing time. Moreover, according to the type of target, some fine-tuning on the method parameters and robustness are left to the operator, involving a case-by-case analysis and implying a significant increase in workload with high acquisition volumes. On the other hand, as the human eye is capable of quickly recognising the presence of the pattern of the trail, even in the case of very faint ones, AI could be efficiently employed to detect faint trails in astronomical images. Several works from the literature show that the neural network architectures developed for computer vision tasks can be exploited for this application as well, relieving the tuning and |

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| | adjustments involved with the traditional methods. The fundamental step is the presence of a labelled and structured dataset that is close enough to reality. Not only can tracklets be detected and located in the image, but also their shape can be extracted and provided as a set of coordinates to perform astrometric reduction and provide a first estimate of the centroid in angular coordinates and of the direction and length of the trail. This processing technique can represent the first step of a wider measurements processing pipeline, typical of sensor networks data management. The intended use of the processed data is an initial or refined orbit determination to retrieve or update information on elements of a maintained Resident Space Objects catalogue. |
| **Methods and techniques that will be developed and used to carry out the research** | Starting from astronomical images in FITS format, the objective of the research will be to develop a technology able to detect trails with any possible length (from a few tens of pixels up to a few thousand pixels), irrespective of the trail direction, with an SNR on the single pixel down to 0.8-1. This technology can be applied to the network of very wide-FoV Flyeye telescopes (to be deployed). The first step is the development of a reliable image generator to mimic the physical and processing features of the Flyeye telescopes, implying close interaction with the producer. In this way, a reference dataset can be generated and easily labelled without giving up on the high numbers of samples required for effective neural network training. Real data will be included as well as part of the dataset and data augmentation techniques as well as hybrid datasets creation can be investigated to understand how sensitive the model is to its composition and how close simulated images are to the real ones from the model’s point of view. Once the dataset is obtained, several state-of-the-art neural network architectures can be employed to perform training. Both object detection-aimed ones, like You Only Look Once (YOLO), or models devoted to segmentation, such as U-Net, can be exploited to extract progressively more detailed features from the image. Because of the specific application to wide-FoV telescopes, the model design will focus on the support of multiple tracklet detection and on the sensitivity to low |

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| | Signal-to-Noise Ratio (SNR) trails, trying to highlight the target features as much as possible in every phase of the process. Image pre-processing can address compression to decrease computational cost and inference times while improving detection with effective equalization and edge detection filtering steps. A detection strategy or cooperation between multiple sensors can be foreseen to increase the quality and diversity of the dataset for the same purpose. Validation for the methodology will be shaped by operational scenarios involving real images from the sensor on which the tool is based, granting in this way the consistency of the achieved results. |
| **Educational objectives** | This research involves the knowledge of the current state of Space Situational Awareness (SSA) services and their capabilities, thus leading to the training of a professional figure able to interact in such an international context effectively. The practical implementation of the earlier mentioned analysis must pass through a literature review of the current state of the art of these strategies and methods, thus improving the candidate's scientific knowledge. This will contribute to training a highly qualified researcher who can tackle current space-related issues to contribute to the enhancement of the space sector. The candidate will gain profound knowledge about the concepts related to the fields of astrodynamics, machine learning, image processing, mathematical modelling, and computer programming. Soft skills in writing reports, searching bibliographic resources, preparing progress meetings, and presenting work advancements will also be achieved. |
| **Job opportunities** | Nowadays, numerous companies, national agencies, and universities are directing their efforts towards enhancing image processing techniques, particularly in the context of space traffic monitoring and promoting sustainable space utilization. Profound theoretical and practical expertise in the subjects explored within this research will greatly enhance the candidate's attractiveness within the space community. The research will develop in collaboration with OHB company. This will be a great source of networking for the candidate. For this purpose, the program is |

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| | fostering industrial and academic excellence in the field, which will need the long-term support of experienced professionals. |
| **Composition of the research group** | 0 Full Professors<br>2 Associated Professors<br>2 Assistant Professors<br>9 PhD Students |
| **Name of the research directors** | Prof. Pierluigi Di Lizia |

| **Contacts** |
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| **Additional support - Financial aid per PhD student per year (gross amount)** | |
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| **Housing - Foreign Students** | -- |
| **Housing - Out-of-town residents (more than 80Km out of Milano)** | -- |

| **Scholarship Increase for a period abroad** | |
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| **Amount monthly** | 700.0 € |
| **By number of months** | 6 |

| **National Operational Program for Research and Innovation** | |
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| **Company where the candidate will attend the stage (name and brief description)** | OHB Italia |
| **By number of months at the company** | 6 |
| **Institution or company where the candidate will spend the period abroad (name and brief description)** | University of Arizona (US) |
| **By number of months abroad** | 6 |

| **Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information** |
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| The PhD candidate will receive a desk, possibly through a hot-desking procedure, and a personal computer, if needed. Apart from the compulsory ones, the PhD candidate will have the opportunity to follow additional courses and receive economic support to attend summer schools and participate in conferences. There will be the possibility of paid teaching assistantship. |