INTERNSHIPS OPPORTUNITIES AT PROPHESEE
(Paris Office)

Our engineers and programmers invent the future of vision technologies with the most advanced neuromorphic vision system in the world.

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Inspired by the human vision and *built on the foundations of neuromorphic engineering*, PROPHESEE is the revolutionary system that gives metavision to machines, revealing what was invisible to them.
Our vision sensors, inspired by the functioning of the human retina, address the limitations of conventional vision sensors by enabling *real-time detection of the scene's dynamic content* and by acquiring only what is necessary. This is the *event-based approach* to vision.
We're looking for unique talented people who are willing to keep pushing the limits every day.

Care to change the world with us?

Our Technology

Prophesee (formerly Chronocam) designs and produces a new type of cameras that are bio-inspired and thus free themselves from the concept of images. They don't gather information with a fixed *frame-rate* but instead each pixel is captured asynchronously when needed. This is called *event-based* image processing. Therefore the output is extremely sparse and allows a real time treatment of the information at an equivalent frequency of a kHz or more. But since the data coming from the sensor are quite different from the images used in standard vision, Prophesee is also advancing the algorithmic and machine learning side of this new kind of machine vision. It enables its clients to build new applications mainly in automotive, virtual reality and industrial automation.

We offer several internship positions in various fields:

- Software and Tools;
- Signal Processing;
- Visual Odometry;
- Frame-Based and Event-Based Sensor Fusion;
- Machine Learning.

Nota Bene: All subjects here are indicative and *will* be discussed with candidates before acceptation, which may result in changes.

I SOFTWARE AND TOOLS

Prophesee's software team develops tools that are used throughout the company and by clients to operate Prophesee's cameras.

Prerequisites: Good programming skills (C++); Computer Science background;

I.1 GUI for Prophesee Event-Based Camera and Algorithms

Prophesee develops event-based cameras on compute platforms that can embed a server enabling remote streaming and interactions. This allows for very lightweight web-based client GUI to display event-based streams and control the cameras. The server is developed using our C++ event-based device driver API, while the client is web-based using electron and a React back-end.

The goal of this internship is to continue the development of the existing server/client infrastructure to add/update the following required features :

- recording and playing back event-based sequences at different speeds
- live camera settings and feedback
- live basic event filtering

Care will be taken to write automatic User Interface tests for every developed feature.

I.2 GUI for Prophesee Event-Based Camera Recording Offline Edition

event-based recordings contain data encoded in a proprietary format for efficiency, and as such, a custom GUI tool to edit the recordings offline is needed. The same server/client infrastructure as used in the GUI for live event-based cameras can be leveraged to produce a lightweight web-based client. The server is developed using our C++ event-based device driver API, while the client is web-based using electron and a React back-end.

The goal of this internship is to continue the development of the existing server/client infrastructure to add/update the following required features like seeking in a recording, cutting it or exporting it as a video.

Care will be taken to write automatic UI tests for every developed feature.

I.3 Automatic Test Benchs for Event-Based Cameras

Prophesee develops multiple event-based cameras that support a wide range of functionalities to control the event generation, e.g types of events like temperature, trigger or IMUs, event encodings, ROIs, event rate, etc.

To ensure those features are always working with every software release, automatic unit tests and functional tests needs to be put in place.

In this internship, unit tests using the Google test framework in C++ will be written to validate the behavior of the cameras. The infrastructure to run those tests automatically for all supported camera devices and platforms, and to report the results on a nightly basis will also be developed.

II SIGNAL AND EVENT-BASED PROCESSING

Event-based data is quite unique and can be used in innovative ways without requiring overly complicated algorithms and frameworks. These topics are about taking full advantage of the precise time information and the sparse nature of events for various applications.

Prerequisites: Good programming skills (C++); Mathematical and/or Computer Science background; Experience with frame-based Computer Vision or Robotics.

II.1 3D Motion Analysis from Event-based Timestamp Surfaces

Event-based timestamps have been proven to be useful to extract (normal) optical flow from a scene, which itself relates to the 3D motion of a moving camera or moving objects in the scene.

The goal of this internship is to build an algorithm to efficiently estimate the 3D motion of a region, using basic assumptions, for instance object planarity, and evaluate it in the context of applications such as

- instantaneous speed estimation of an object (radar-like);
- motion segmentation of objects in a scene;
- multi-modal object tracking.

II.2 Demonstration of Applications Using Event-Based Structured Light

We are currently developing in Prophesee a new approach to Structured-Light using event-based sensors and laser projectors.

Today we only demonstrate the raw output of the sensor but getting a complete grasp and proof of what the resulting 3D sensor can do requires to build applications based on it like SLAM (Visual Odometry) or 3D object reconstruction.

Feeding back observations from the application into the structured light algorithm (to take better benefit of the way we generate 3D or enhance it) would be a very interesting conclusion to this internship.

II.3 Visible Light Communication (VLC/"LiFi") with an Event-Based sensor

The algorithms we developed for structured light are more generic than what they are used for. Instead of only looping a temporal pattern encoding the location of the point from the projector, we could consider sending more interesting data from an active light source in the camera field of view for communication purposes. We obtain a multichannel VLC system which can locate the source it is receiving by its spatial position in the field of view of the camera. Ideas to explore in this internship:

- What way of encoding data in light pulses would enable the best use of the sensor resources ?
- What bandwidth can we achieve with current sensors ?

- Can we decode is the source if moving in the camera field of view while transmitting ?

Build a demo of event-based VLC for marker detection or IoT applications

II.4 Motion Estimation from Ground Looking Camera for Drift Detection

In applications like autonomous driving, the big players already have solutions they spend a huge amount of work creating and are very often quite happy with, like vehicle positioning from LIDAR and 3D maps.

Their solutions are very good for localization but suffer from a low update frequency and therefore cannot be used for fast control loops.

The topic of this internship is not to build a full positioning system maintaining precision over long distances but to fill in the gap of existing systems, by exploring speed estimation from an event-based sensor looking at the ground.

Leveraging the sensor low latency and high temporal precision, the goal is to detect that the vehicle is maintaining correct ground contact or is drifting.

II.5 Intern Position in the Innovation Team

The mission of Prophesee's Innovation team is to evaluate brand new usages of event-based technology. This involves doing experimentation and pre-studies in very various fields of application with a lot of short iterations depending on prospects feedback.

This internship is about joining this team and working on its day to day topics. For instance, some of the latest topics studied in the team:

- Golf ball tracking during a swing for speed and spin estimation
- High-speed bar-code reading
- Use of event-based sensors as a mouse sensor
- Structured-Light and other active light 3D reconstruction

II.6 Automatic Tuning of an Event-Based sensor - Application to Vibration Monitoring

Prophesee is pushing its technology towards applications in the field of Industrial Automation. To achieve robustness in real-world applications which can be deployed in very different environments, we need to offer a way to control the internal settings of the camera without having the user manually tune them.

This topic by itself is very broad and ill-defined. We propose here to take a particular application of interest as a use case to test what a framework for automatic pixel parameter tuning could be. Some of the goals of such an internship could include:

- Study experimentally the impact of environmental conditions (temperature, light levels, ...) on the vibration demo
- Derive online KPIs translating the quality of the sensor data to achieve applicative goals
- Explore how pixel parameters can be changed to recover performances when moving away from standard "good" conditions

Develop an automatic loop control of the pixel parameters using the developed KPIs.

II.7 Event-based Compression

Raw Event-based videos can be very dense and memory intensive. The goal of the internship is to find data-structures and algorithms to efficiently compress the events binary representation. The format must be significantly smaller, and fast to parse. Space-Partitioning Trees, Predictive-Coding, entropy coding are some of the topics that can be explored for this internship. Final Result is a demonstration of fast parsing and memory reduction.

III SLAM (Visual Odometry)

Prophesee uses event-based cameras in Simultaneous Localization And Mapping targeting both Augmented and Virtual Reality applications. These subjects explore different venues to improve some of Prophesee's existing approaches.

Prerequisites: Good programming skills (Python/C++); Mathematical and/or Computer Science background; Knowledge of Embedded software development, in 3D geometry, rigid-body mechanics or SLAM is a plus.

III.1 Incremental Smoothing and Mapping with event-based Camera

Efficiently maintaining the long-term relationships between poses and maps during the iterative optimizations is crucial. As demonstrated by Kaess *et al.* it is possible to maintain these relationships in realtime.

The goal of this internship is to adapt the Incremental Smoothing and Mapping algorithm to event-based cameras and implement a first real-time demo.

III.2 Stereo Semi-Dense SLAM with event-based Camera

Prophesee developed a Stereo Event-based visual odometry and we demonstrated that it is possible to perform real time localization using sparse 3D point clouds. The first prototype is working well in several situations but it requires to be robustified and improved.

The goal of the internship is to port the current solutions adopted for monocular pose tracking in the stereo event-based, integrating the IMU and developing a new real-time demo.

III.3 Feature-Based Embedded Visual odometry in High-Speed robotics applications with event-based Camera

Features are the corner stone of many computer vision applications. In Event-Based solutions they are very important because they have the capability to represent in a compact way the geometric information of the perceived scene. To exploit this solution, in Prophesee we developed a first monocular feature based visual odometry.

The main challenge of this internship is to optimize the current solution and improve both the accuracy and the robustness of the visual odometry.

IV FRAME-BASED AND EVENT-BASED SENSOR FUSION

Frame-Based and Event-Based cameras often produce complementary information: current versions of event-based cameras capture really well fast moving objects, while frame-based ones give good information for slow-moving objects. This topic consists in algorithms designed to take advantage of both sensors in a single algorithm.

Prerequisites: Good programming skills (Python/C++); Mathematical and/or Computer Science background; Experience with frame-based Computer Vision and Deep Learning.

IV.1 Frame - Event Camera Stereo

In this internship we want to explore the use of a synchronized pair of event and frame cameras to compute depth.

The internship will be divided in:

- Photo-metric and geometry study and modelization
- Learn from simulation a matching cost between frame and event camera
- Augment the training data with noise, blur, dynamic range differences, saturation to robustify the solution.

IV.2 Frame - Event Camera Fusion for Image Enhancement

The goal of this internship is to use an event camera synchronized with a frame camera to improve image quality. Some possible topics to cover are denoising, HDR, super-resolution.

The project will be divided in two stages:

- In a first phase we will model mathematically the chosen problem, evaluate the challenges and establish Key Performance Metrics (KPIs).
- In a second phase, according to the results obtained from the first phase, we will model the entire solution or part of it using a machine learning model.

V MACHINE LEARNING

Today Machine Learning is omnipresent in Computer Vision and event-based is no exception to that. These internships deal with adapting models to the specificity of event-based data or handling cases where Prophesee's cameras have a particular edge.

Prerequisites: Good programming skills (Python or C++); Mathematical and/or Computer Science background, experience with Deep learning frameworks; Knowledge of Deep learning, CNN, optimization algorithms. Interest in 3D geometry and/or rigid-body mechanics is a plus.

V.1 Training Deep Spiking Neural Networks for Event-based Cameras

The output of an Event Camera is an extremely high temporal resolution, sparse and asynchronous signal. Thanks to these properties, event cameras outperform conventional frame-based cameras in terms of latency, power consumption and data rate.

However, conventional hardware used to process the output of an event camera (such as CPU and GPU in a Von Neumann architecture) has been designed and optimized to process synchronous and dense blocks of memory. As a consequence, many advantages of event cameras, such as latency and low power consumption, are lost when processing their output on conventional platforms. By contrast, neuromorphic architectures process event data as an asynchronous stream of data in a power efficient manner and preserve the temporal resolution of the input.

The goal of this project is to explore and design algorithms suited for event-based data and neuromorphic hardware. The most promising class of such algorithms is called Spiking Neural Network (SNNs).

V.2 Unsupervised Depth from Events

In Computer Vision is it possible to find many solutions based on Unsupervised CNN to estimate depth from a single frame (an overview can be found here) and, recently, new solutions are emerging from the Event-Based community (i.e. the work of Gallego et al.). The goal of

this internship is to continue the exploration of these methods, focusing on real-time solutions and real-case applications.

V.3 Event-Based feature tracking in Speed Invariant Time Surfaces

During CVPR 2019 we presented a paper where we demonstrated that is possible to estimate stable features from an event-stream. The goal of this internship is to implement a machine-learning solution to improve the robustness of feature tracking for SLAM and pose estimation problems.

About Prophesee

Prophesee (formerly Chronocam) is the inventor of the world's most advanced neuromorphic vision systems.
Prophesee's patented technology breakthrough introduces a new computer vision paradigm based on how the human eye and brain work to dramatically improve the efficiency and intelligence of vision sensing and processing.
The company's event-based method selects only the most useful and relevant elements of a scene, drastically reducing the power, latency and data processing requirements imposed by traditional frame-based systems.
Prophesee's sensors and camera systems open vast new potential in areas such as autonomous vehicles, industrial automation, IoT, security and surveillance, and AR/VR. Its solutions improve safety, reliability efficiency and user experiences across a broad range of use models. Prophesee was founded within iBionext Start-up Studio (Paris) in 2014 by Ryad Benosman, Bernard Gilly, Christoph Posch and Luca Verre. The quartet brings a strong combination of experience in image sensing, neuromorphic computing, VLSI design, entrepreneurship and business development.
Prophesee is based in Passage de l'innovation in Paris, with local offices in China, Japan and USA, is driven by a team of 75 visionary and global engineers, holds more than 50 international patents and is backed by leading international investors including 360 Capital Partners, Supernova Invest, iBionext, Intel Capital, Renault Group, and Robert Bosch Venture Capital. More information can be found at www.prophesee.ai.