Event Camera Payload Calibration Flight Software

Supervisor: Dr. Sydney Dolan

Background:

The EventSat mission is a 6U CubeSat technology demonstration mission that is focused on evaluating event-based cameras for space situational awareness. Event cameras are bio-inspired, asynchronous sensors that detect changes in pixel brightness, providing data updates at a microsecond temporal resolution. This asynchronous, low latency update has the potential to lead to a significant decrease in overall data and thus power consumption, an attractive quality for satellite platforms with constraints on systems power, processing, and communication bandwidth. Building upon existing work, which has demonstrated the effectiveness of these cameras on ground in conjunction with telescopes, our mission seeks to demonstrate the effectiveness of this class of camera for space-based observation. The EventSat mission payload has two objectives, carefully selected to maximize the impact of this technology demonstration and to address key performance questions about the use of event cameras in orbit. First, the mission seeks to develop a database of space-based event camera observations. Second, the mission will identify resident space objects in the event cameras field of view using the event camera.

This project seeks to develop the associated payload flight software for the initial calibration of the event camera in orbit. In this initial calibration mode, the event camera's capabilities are validated to check for any misalignment or issues with specific pixels before operation begins. The expected outcome of this project is to develop C++ code that will be used in the initial launch and early operations part of the mission. The work itself will involve both writing code and documenting the code structure so that the functions can be called from the onboard computer. This project can be scoped to be a semester thesis or a master's thesis.

Requirements

- Strong programming background, proficiency in C++ and python is a must

Schedule

Below is my best estimate of how the work would progress from this task description, and the first things that you would be tasked to do.

Onboarding Phase: Literature Survey, Build Familiarity with Sony IMX Sensor

- [Software] Work through the example event camera google colab notebooks that I have created at the chair to get a sense of the data
- [Experimental] Successfully implement an event camera calibration in lab downstairs
- [Reading/Writing] Read existing literature on event cameras, event cameras for space, and event cameras overall (see references for some examples)

Next Phase: Initial Software Development

- [Software] – Write C++ code for the initial calibration phase of the payload. Adapt existing code base functions that identify hot pixels, filter noisy data, and print key

payload housekeeping status information into a single calibration protocol. Integrate code with existing drivers to handle event data.

- [Writing] – Write documentation for associated code development for the code functions to be passed onto the OBC team for integration

Final Phase: Fail Mode Calibration Code Development and Documentation

- [Software] Write C++ code for calibration reset mode, a mode definition used to determine the payload status should it enter safe mode. This mode should re-calibrate the software, and feature functions to changes biases of spacececraft.
- [Writing] – Write documentation for associated code development for code functions to

Expected Deliverables

By the end of the masters thesis, the student will have produced.

1. (Most Important) Thesis document, that features:
    - An introduction chapter that discusses event cameras, how event cameras function on a pixel by pixel basis, and the specific research questions asked in this thesis.
    - A methods section, that describes the inputs to the calibration mode (CONOPS), what functions exist in the calibration mode, and the expect outputs
    - A results section, that demonstrates the performance of the calibration mode, computational expense, and timing
    - A conclusions chapter, that highlights the limitations of the work done so far and what you've identified are next steps or open areas of work
2. A Thesis Presentation
    - Captures the most important elements of the thesis document
3. Code in a github repo
    - Documented + tested + ideally a corresponding website or pdf to explain the structure
4. Software architecture and interface diagrams for the calibration mode code you've developed

Supervisor Expectations

General Personal Beliefs on Mentoring in a Research Setting: As a mentor, my goal is to give you tasks that are well-defined, manageable to achieve in an agreed upon timeframe, and aligned with your personal interests and overall professional development. I try very hard to give clear guidance on the things I ask for, and justification for why I am asking at all. This is so you can understand my perspective on your work and the value of every step in the research process, even the cumbersome ones. I hope to earn your trust so that you feel comfortable asking for clarification, and even pushing back on me if you have alternative ideas for how something could be done.

Meeting: I expect to meet with you at least once a week to have a formalized research update on the progress of the masters thesis. In this meeting, we will cover your of progress and key updates, discuss any challenges or resources you need from me, and set goals for what should

be completed by the next meeting. I do not expect that you come to every meeting with results, but I do expect you to be able to clearly articulate what you have been working on, and what has been taking up your time so far. For our research tag-ups, I am presentation agnostic, meaning that you can use powerpoint, canva, a latex file, a word doc, a hand drawing. These meetings are also a great opportunity for you to prepare actual figures and tables of your work, which will be useful when you actually write your thesis so that the thesis writing effort is implicitly 'done' already months in advance.

Physical Location: This project will require to use of the Sony Prophesee IMX 636 sensor. As a result, there will periods during this thesis where it makes the most sense to physically be in the Chair to work on the hardware. During those times, I expect you to physically be here to work. Otherwise, I do not have any strong preference if you find it easier to work at home, or if there are days when you would rather not make the commute. Please just communicate with me if you need a virtual meeting instead of face-to-face when we have a meeting planned.

Vacation: I trust you to manage your time appropriately. If you want to take time off, please do, just give me heads up when it is so I can make sure that there are no important deadlines near your vacation + I do not bother you when you are on break + that you are not stressed about your work on your thesis when you should be relaxing.

General Communication Expectations: Feel free to message me on Teams, by email, or to just physically get my attention when I'm working at my desk. I am a strong proponent of writing expectations down and having clearly articulated, tractable communication, so as a mentorship thing I will often be writing down my specific task requests of you for clarity.

Publishing: Publishing is not guaranteed to anyone that works at the chair. With high-quality work, and a little bit of luck, I believe it will be possible to publish the work done on this thesis if that is an active area of interest to you. If publishing is an important thing that you would like for your career, please let me know and we can identify possible publishing opportunities for you to work towards.

Ethics and LLMs: The process of research means that the fundamental questions we are seeking to answer are unknown. You may have some inherent intuition about what the answer may look like, or what solution may be the best, but the whole reason we pursue research is because we do not know for sure. I am placing a lot of trust in you to perform research ethically, meaning that the data has not been cherry-picked, and that you will explore multiple options to determine what the strengths and weakness of each. Do not manipulate results or data just to have an answer. It is fine to show up to meetings without a result, or if the answer we learn isn't that new or exciting. Similarly, on the research writing front, please do the writing yourself. Services like ChatGPT and other LLMs are nice tools, but ultimately cripple your abilities as a writer, and also hinder me from truly helping you because I'm not critiquing a thought that came from your head, I'm correcting an LLM. You will become a much stronger writer through the masters thesis process if you learn how to write the document yourself, rather than to massage an LLMs outputs into something you think I would like (I likely will not enjoy what the LLM has to say at all). If I ask you to write a formal document, please refrain from the use of LLMs.