Selection of A Computer Vision Algorithm to Track Bed Bug Swarms

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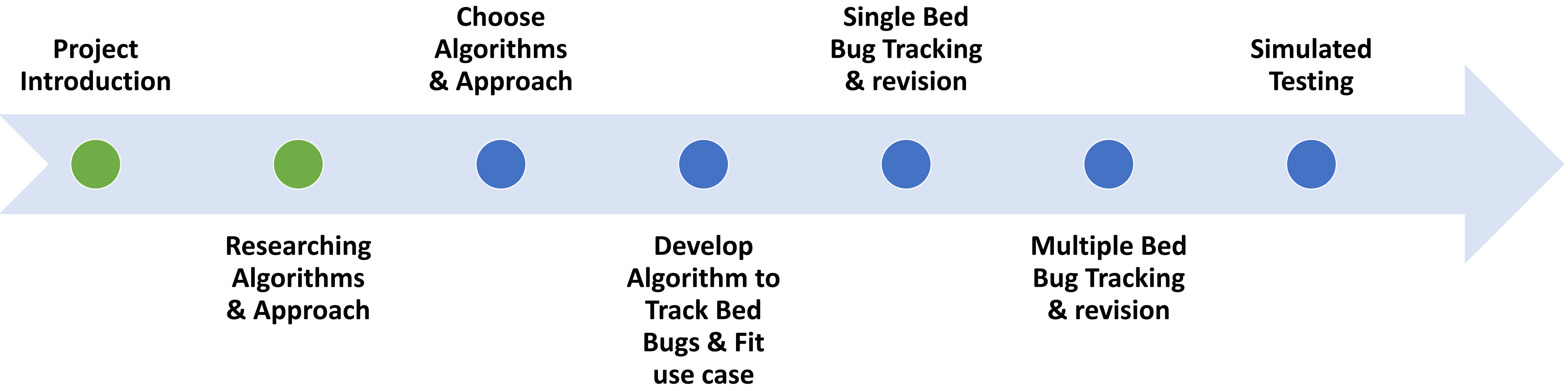
Abstract

Modern aerospace systems require a new approach for swarm consensus that is distributed, operates with localized information, uses simple agents, and is easily deployable and expandable. The overarching goal of our research is to advance our understanding of bed-bug behavior and use this understanding to improve performance of aerospace swarms. The central hypothesis is that if we record bed-bug response to CO2 exposure, then we will be able to improve our understanding of collective decision making because the bed bugs coordinate their response to environmental conditions. Previous research began this work by developing an algorithm capable of tracking a single target bed-bug utilizing computer vision. We seek to continue this research to develop an algorithm capable of tracking the interaction of multiple target bed-bugs at once utilizing computer vision. The research for the improved algorithm will consist of two undergraduate students and will result in the examination of six viable approaches and algorithms for tracking multiple targets utilizing computer vision. This poster is the first step of reviewing potential algorithms for selection for the project. Difficulties with our scenario include the small size of the bed bug, lack of identifying characteristics, and multiple cameras where movement needs to be tracked from one another, all of these challenges pose difficulties with many existing individual approaches.

Setup & Current Approaches

To obtain data from the bed bugs a test bed with multiple cameras was used to track the bed bugs movement. The current approaches taken to track single bed bugs involved Blob Analysis which uses a binary filter and CV algorithms to find the blob of pixels identifying the bed bug. Later the approach changed to Image Difference Tracking which subtracts the previous frame from the current frame to find the difference between the two and uses the area of largest difference as the likely position of the bed bug, and Cropped Image Tracking which given the rough location of the bed bug crops the image to a bounding box around the bug, using this box the center of the bug is found, that position is used to search for the bug in the next frame.

Project Timeline



Pros

- Lucas-Kanade:
  - Fast Calculations
  - Accurate time derivatives
- Kalman Filter:
  - Computationally efficient
  - Noise statistics not fully known
- Mean Shift Algorithm:
  - Good with noisy Data
  - Tracking of non-rigid objects
- KCF:
  - Efficient processing & Minimal Resources
  - Good for tracking Swift Objects
- YOLOv8:
  - High Speed
  - Computationally Efficient
  - Integration with OpenCV

Cons

- Lucas-Kanade:
  - Errors on boundaries of moving objects
  - May be difficult/Fail with small objects
- Kalman Filter:
  - Assumes process & measurement are gaussian and white with linear system dynamics
- Mean Shift Algorithm:
  - Computational Cost
- KCF:
  - Challenges with objects that scale or change size
  - Boundary sensitivity
- YOLOv8:
  - Struggle with small object detection
  - Requires lots of training Data
  - Limited ability to handle occlusion.

Kernelized Correlation Filters (KCF)

This algorithm is a robust method for object tracking in video sequences. It leverages kernel functions to extract and analyze features, allowing it to efficiently learn the spatial relationships between object features and distinguish them from the background. KCF offers advantages such as fast computation, low memory requirements, and competitive results in typical object tracking scenarios. However, it may encounter challenges with varying object scales and objects located near frame boundaries. Despite these limitations, KCF remains a popular choice for real-time object tracking applications.

Mean shift Algorithm

Non-parametric, density-based clustering method for finding regions with high density modes in a dataset. Each pixel is first assigned an initial mean which is itself. Algorithm interactively places a window around that initial mean and calculates the new mean of all points within that window. This process is repeated until the position of the mean no longer changes significantly. The algorithm can also be extended to classify the data points into different clusters based on final positions.

YOLOv8

YOLOv8, a cutting-edge object detection method, works by breaking down an image into smaller parts and quickly figuring out what objects are in each part. Using smart techniques, it's great at spotting objects accurately and fast. With OpenCV's help, it gets even better at understanding images. It's like having a super-smart camera that can instantly recognize things in a picture, making it handy for tasks like identifying objects in videos or images.

Kalman Filter

Mathematical algorithm used commonly to estimate the state of a system based on a series of noisy measurements. Recursive algorithm that uses a combination of predictions and measurements to estimate the state of the system at any point in time. those predictions are then compared to new measurements, and the algorithm uses a process called "update" to refine estimates. Kalman filters can be used to predict the current and future positions of an object, even when it is hidden by obstacles (occlusion).

Lucas-Kanade

Widely used for optical flow estimation which is process of finding pixel wise motions between consecutive images. Based on the assumption that the optical flow in the local neighborhood of pixels in an image is constant. uses the brightness constancy assumption meaning that pixels in the image can move around but their brightness cannot change.

Makes an estimate of the displacement of a neighborhood by looking at changes in pixel intensity. such changes can be explained by the known intensity gradients of the image in that neighborhood. Lucas-Kanade uses least-square estimation to find optical flow of all pixels over the neighborhood

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