Student Project Proposal (SPP)

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Supervision status according to student
Check one of these:
[x] Currently working with (Ongoing project)
[ ] Agreed but not started
[ ] Wish to work with (or unclear of status)
[ ] No preference, help me find one

Cooperative partners (Optional):

Växjö Linnaeus Science Park

Preliminary Title:

Cost-Focused Cloud Tracking

Elevator pitch:

Quick yet accurate Weather prediction is imperative for certain industries to now only survive, but simply exist. An important factor of these is the ability to track, categorize and predict movements of clouds within a given area. Current data is not meant for real-time application on a local area level. The proposal is the construction of a number of 'weather stations' which take atmospheric readings and images of the sky above them to accurately track cloud cover.

Steps/Milestones/Actions

1. Create weather station(s) able to collect and send weather data within expected sensor accuracy.
2. Create/host a server which is able to accept multiple connections from these stations and process and store the incoming data.
3. Undistort the sky images. This is done by obtaining the intrinsic and extrinsic matrices of the stations prior to their deployment.
4. Calculate the LCL (Lifted Condensation Level) via the environmental readings given, according to the method outlined in Romps. D (2017).
5. Identify the clouds in the scene via either statistical analysis or simple object detection.
    a. This also then allows identification of the size of the cloud given the focal length and FOV of the camera module.
6. Set up a weather station at the Växjö Kronoberg Airport.
7. Compare the accuracy of the readings, as well as cloud heights against the data of the Växjö Airport. These are available via the METAR Api, and viewable at https://metar-taf.com/ESMX.

Risks

1. Inability to set up a weather station directly at the airport would mean requiring us to obtain the data in some other way. Due to our proximity to the airport however, weather conditions should remain the same, including cloud cover. When comparing readings then, a simple shift on the time scale during comparisons should be enough to account for the distance between our positions.
2. Inability to properly separate cloud areas from sky areas in images.

The longer story:

Background and Motivations

More location-accurate, real-time weather tracking and prediction is an endeavor with wide-reaching application. These include:

1. The ability of the average person to better prepare for local weather conditions in their day-today.
2. More refined weather condition description, such as duration and area of effect for storage units and warehouses.
3. The ability for solar panel owners to more accurately estimate power output using knowledge of cloud-cover.

These sorts of forecasts are usually made using satellite data. This would be from sources such as the MISR Level 2 Cloud product from NASA, showing cloud-motion vectors accurate to 17.6km [2], or the EUMETSAT MTG 3rd Gen. satellite array with a purported resolution of approx. 1km. [10] This data cannot be used for local weather forecasting however, as cloud-cover obscures the view of the land, as well as cloud-heights and environmental readings for overcast areas being unknowable.

Cloud-height, visibility, humidity are usually measured on the ground via devices such as ceilometers. This however costs an average of approx. USD $ 30,000 [3] and covers approximately 8 km^2 [12]. Ground-based techniques which utilize a visual component usually do so via the use of calibrated camera arrays performing triangulation (B.Lyu, Y.Chen et al 2021)[13], sometimes going further to separate cloud fields from the sky background to describe cloud cover in terms of both horizontal size and velocity vectors(P.Crispel, G.Roberts 2018)[14]. Techniques which do not make use of a visual component utilize environmental readings such as dewpoint and relative humidity to then calculate the Lifted Condensation Level (LCL). This is “the height at which an air parcel would saturate if lifted adiabatically” [9] and can be used as a stand-in for the base-height of a cloud in a given area. This approach may be able to rival ceilometers in accuracy of +-5m depending on the sensor accuracy [9].

A hybrid approach of 3D approximation of cloud positions may be possible with ‘lower-end’ consumer hardware through determination of cloud height via the LCL. 3D reconstruction through camera calibration via the intrinsic/extrinsic distortion matrices are not novel concepts. Many popular image and computer-vision libraries such as OpenCV have methods for finding these properties [15]. The use of a single fixed-point sky-imager to accurately describe the height, position, and velocity vectors of clouds however, is novel.
Implementation of IoT weather stations which transmit sensor data and sky images over either GSM or Wi-Fi to a central server as well is not novel, being done in (Puja Sharma, Shiva Prakash, 2021). The density of information gathered from a single image at hobbyist cost

however, is. The ability to geo-reference ground-based sky images with less data than multi-camera techniques:

1. Enables systems hobbyists to create and use more accurate weather data.
2. Generates a higher density of data per unit cost in deployment of IoT weather monitoring systems on a local level.

Related work

Finding cloud height and positional data through sky imaging is done usually with multi-camera arrays via triangulation [13][14]. In B.Lyu, Y.Chen et al 2021 [13], the main output is multiple cloud height points. Separation of cloud areas from sky is not done, unlike in P.Crispel & G.Roberts 2018 [14] where cloud area separation is done through visible spectrum filtering, similar to Long et al [22], however, using HSV rather than RGB. We similarly propose obtaining cloud height, however, with only a singular camera, and finding a singular cloud base height value directly above the sensor rather than multiple, using atmospheric calculations to derive cloud height estimates as in Romps, D. 2017 [9]. Unlike those mentioned however, this height estimate is used by us in obtaining cloud size through 3D reconstruction, rather than through the scale-invariant feature transform (SIFT) used in B.Lyu, Y.Chen et al 2021 [13] and P.Crispel & G.Roberts 2018 [14]. We also propose finding cloud 'pixels' in sky images with an approach similar to Long et al [22], filtering by the color ratio of pixel groups, though we propose using multiple color spectrums rather than just RGB; namely RGB, HSV and YCbCr, as well as more modern image pre and post-processing techniques. The cost associated with sky imagers has always been high, though there have been attempts in the past to create inexpensive, miniaturized solutions. Dev et al [23] is a popular example, with Jain et al [5][24] dropping costs further in the area of US$300 per unit capturing 4k images using consumer hardware and compact, 3D printed materials. Our solution drops this cost further, though using 1080p images, whilst retaining the small stature.

Knowledge Gap/Challenge/Problem

Both a miniaturization and hybridization of existing techniques of cloud feature description must take place. There now exist ceilometer weather stations with reasonable accuracy such as the MWS-M625 from Intellisense which measures at 19 x 14 x 14 cm fitting many high precision instruments, including a 360 deg high-resolution sky imager [20]. Though inexpensive solutions have been shown such as Dev et al [23] in 2016 in creating whole-sky imagers which cost US$2,500 per unit, as well as Jain et al [5][24] in 2021 and 2022 respectively with costs close to US$300, we believe it possible to drop this further, whilst using less data than either.

The lack of hybridization in related works means that the density of information per image is more sparse than possible if a combination of environmental and visual methods are used.

Knowledge Contribution/Action

We intend to create and test the system which will carry out tests in accuracy and variance. If Accurate enough, by which we mean within expected variance given the precision of the sensors, this will allow local weather tracking devices to be built:

1. For a fraction of the cost.
2. From readily available hobbyist parts.
3. Using open-source software.
4. With a fraction of raw data being transmitted per unit of useful information.

*Empirical Evidence/*Evaluation

To evaluate the accuracy of cloud feature estimation, firstly the sensors within the station must be calibrated for the height.

To supply us with known truthful data, we have been given permission to place a weather station within the Växjö-Kronoberg Airport. After close to a month, we will compare the readings and estimations made by the weather station to that of the airport on-site equipment. Historical data is available for the airport through the METAR API. Ideally, we would place a number of the weather stations at the same location within the airport.

Once the data is collected from the stations, it can be back-tested against the historical data, and the variance between the expected and actual readings is realized. Once this is known, it can be included in further estimation of the cloud height, size, etc.

In creating the undistortion profile for the cameras of the stations, simple tests of accurately measuring objects of known sizes at known distances after calibration can be taken before deployment to ensure accuracy within a decided degree.

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