Coastal Fog Detection Using Visual Sensing

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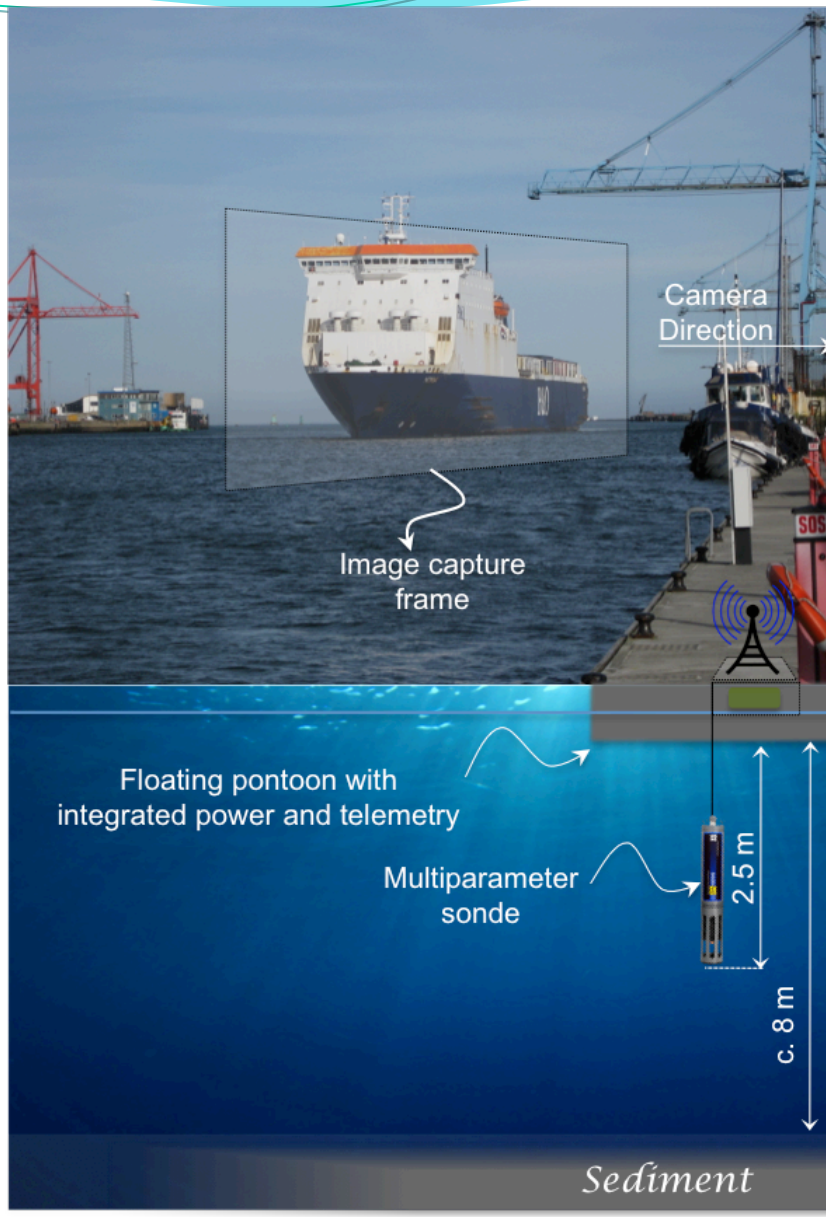
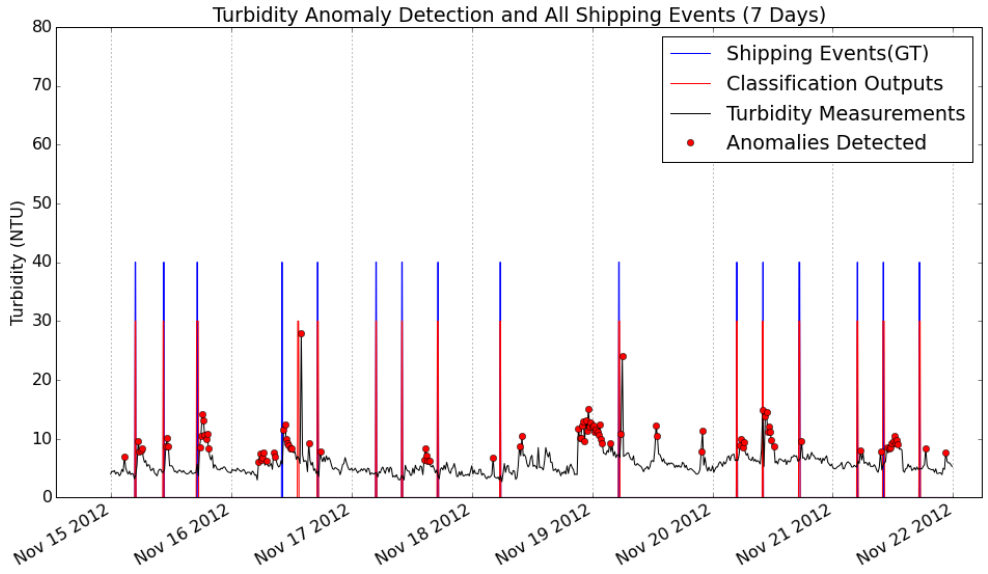
Background


Camera Direction
Image capture frame
Floating pontoon with integrated power and telemetry
Multiparameter sonde
2.5 m
c. 8 m
Sediment


Turbidity Anomaly Detection and All Shipping Events (7 Days)
Shipping Events(GT)
Classification Outputs
Turbidity Measurements
Anomalies Detected
Turbidity (NTU)
0
10
20
30
40
50
60
70
80
Nov 15 2012
Nov 16 2012
Nov 17 2012
Nov 18 2012
Nov 19 2012
Nov 20 2012
Nov 21 2012
Nov 22 2012

Introduction: Fog detection

- International definition of fog consists of a collection of suspended water droplets or ice crystals near the Earth's surface that lead to a reduction of horizontal visibility below 1 km

- **Fog processes are complex**: involve droplet microphysics, aerosol chemistry, radiation, turbulence, large/small-scale dynamics, and surface conditions (e.g., pertaining to the presence of ice, snow, liquid, plants, and various types of soil)

- Satellite observations can be used for fog detection at night time when mid- and high-level clouds are not present because the 3.7-μm channel detects only the infrared radiance as opposed to the sum of the shortwave (SW) and IR radiances during daytime.

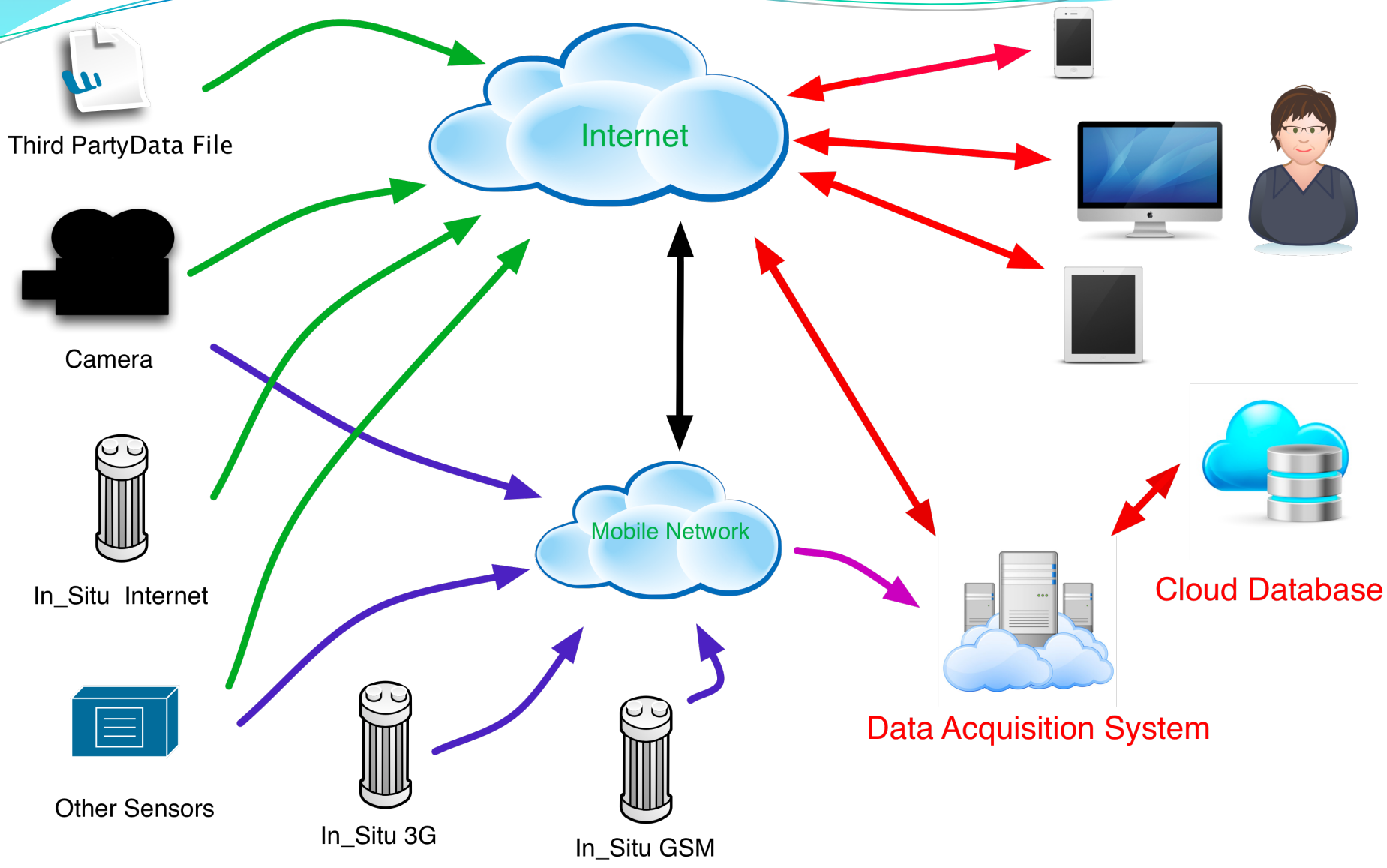
- Fog detection techniques based on polar orbiting satellite systems like NOAA/AVHRR (Advanced Very High Resolution Radiometer) and Terra & Aqua/MODIS (Moderate Resolution Imaging Spectroradiometer) has been widely investigated – now GOES (Geo- stationary Observational Environmental Satellites) and the SEVIRI systems (Spinning Enhanced Visible and Infrared Imager) aboard MSG (Meteosat Second Generation) satellites

Coastal Fog Detection

Why Use Cameras?

- To better evaluate forecasts of fog formation, development, and dissipation, field observations can be used for verification purposes
- The majority of sensors dedicated to measuring visibility distances (diffusiometer, transmissometer) are expensive to operate
- Current difficulties with satellite- based methods in distinguishing between low stratus (LS) layers and ground fog which is based on information about cloud top altitude and geometrical thickness

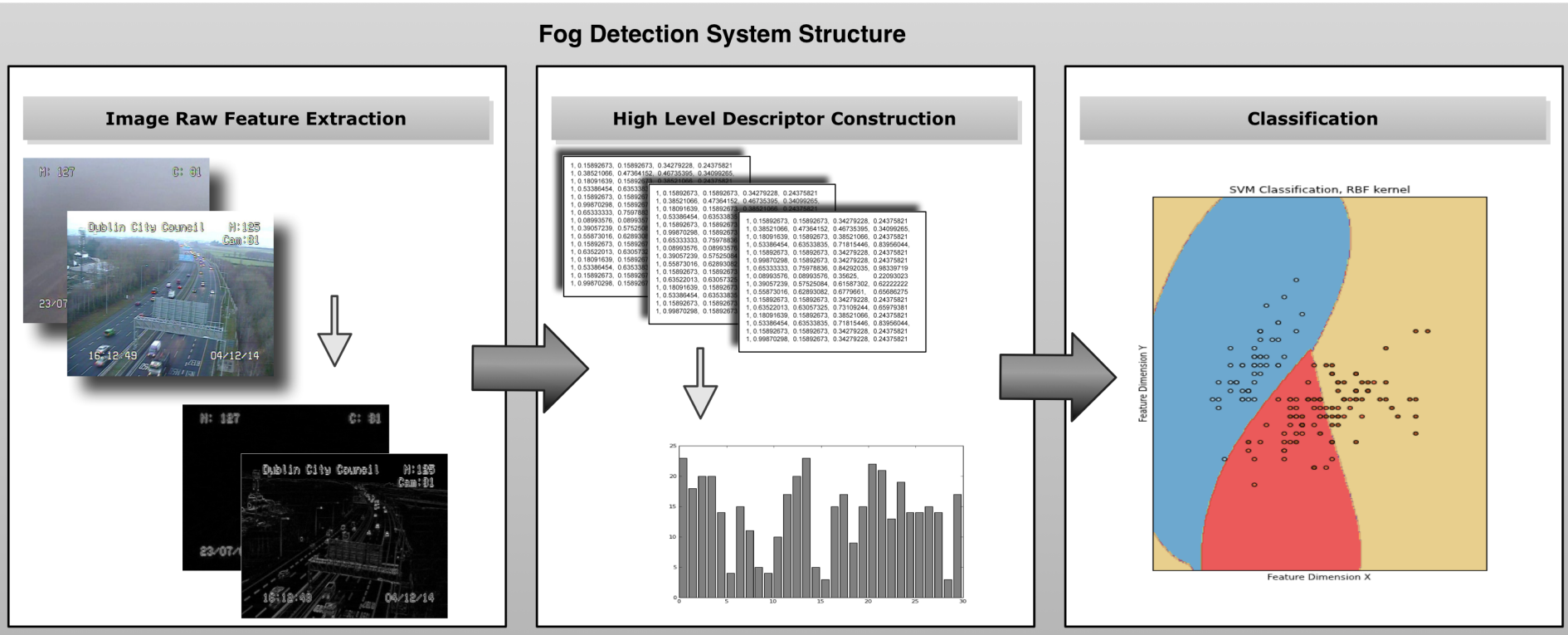
electro-optic camera systems


Third PartyData File
Internet
Camera
In_Situ Internet
Mobile Network
Cloud Database
Data Acquisition System
Other Sensors
In_Situ 3G
In_Situ GSM

Data

Dataset provided by the Irish Meterological Service contains a total of ~400 images captured from six cameras at three weather observing stations (Mace Head, Roches Point and Malin Head) between 31-Nov-2011 and 08-Feb-2015 - these images were annotated as three categories corresponding to either no fog, light fog and heavy fog.

Machine learning strategy



1. **Color and Edge Directivity Descriptor (CEDD)**: - incorporates colour and texture information in a fixed 54 byte histogram per image- low computational power needed for extraction. Its main functionality is image- to-image matching and the intended use is for still- image retrieval, where an image may consist of either a single rectangular frame or arbitrarily shaped, possibly disconnected, regions.

2. **Edge Histogram**: descriptor from the MPEG-7 standard. An image is first divided into 4x4 sub-images and 5 edge types, which include no directional, vertical, horizontal, 45 degree, and 135 degree diagonal edges, extracted from each sub-block. EHD provides primitive information on the edge distribution in the image.

3. **Gabor**: a set of features obtained from passing an image through Gabor filer. Gabor descriptor have been found to be particularly appropriate for texture representation and discrimination.

4. **Fuzzy Colour and Texture Histogram (FCTH)**: FCTH is a low level feature that combines colour and texture information.

5. **Fuzzy Opponent Histogram (FOH)**: a combination of three 1D histograms based on the channels of the opponent colour space. The intensity of an image is represented by channel one and the colour information is represented by the other two channels.

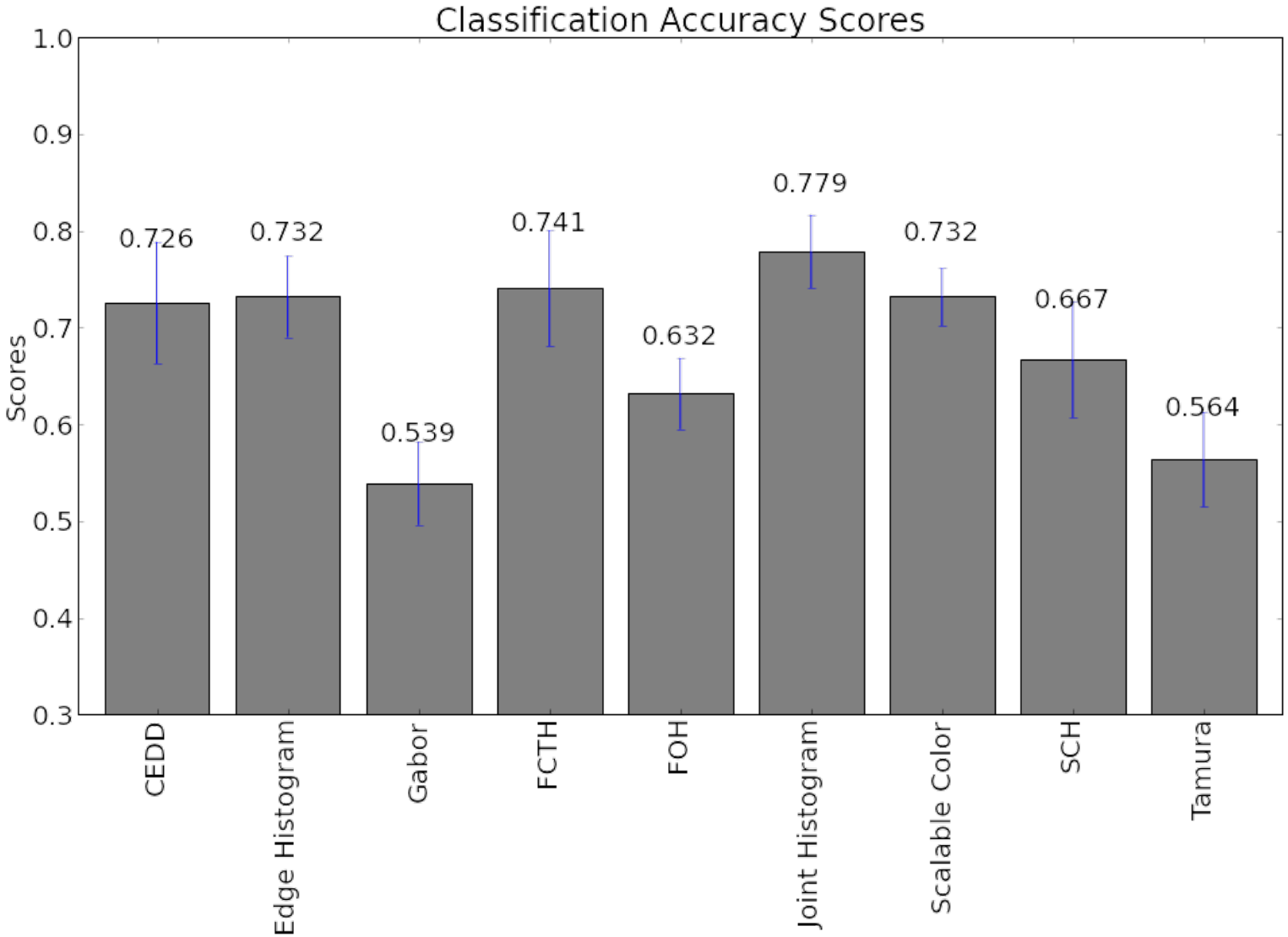
6. **Joint Histogram**: A joint histogram is created by selecting a set of local pixel features and constructing a multidimensional histogram. Each entry in a joint histogram contains the number of pixels in the image that are described by a particular combination of feature values.

7. **Scalable Colour**: another standard MPEG- 7 colour descriptor, which is derived from a colour histogram defined in the HueSaturation-Value (HSV) colour space with fixed colour space quantisation. It uses a Haar transform coefficient encoding, allowing scalable representation of description, as well as complexity scal- ability of feature extraction and matching procedures.

8. **Simple Colour Histogram (SCH)**: represents the global distribution of the composition of colours in an image. The simple colour histogram shows the brightness distribution of each of the three (RGB) colour channels.

9. **Tamura** : a combination of three features corresponding to coarseness, contrast and directionality, taking account of size, shape and the orientation in the texture.

Results


Classification Accuracy Scores
Scores
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.726
0.732
0.539
0.741
0.632
0.779
0.732
0.667
0.564
CEDD
Edge Histogram
Gabor
FCTH
FOH
Joint Histogram
Scalable Color
SCH
Tamura

Hyper-parameter Optimization

Grid search is one of the standard methods of performing hyper-parameter optimisation. Various pairs of (C, γ) values are tried and the one with the highest evaluation accuracy is picked.

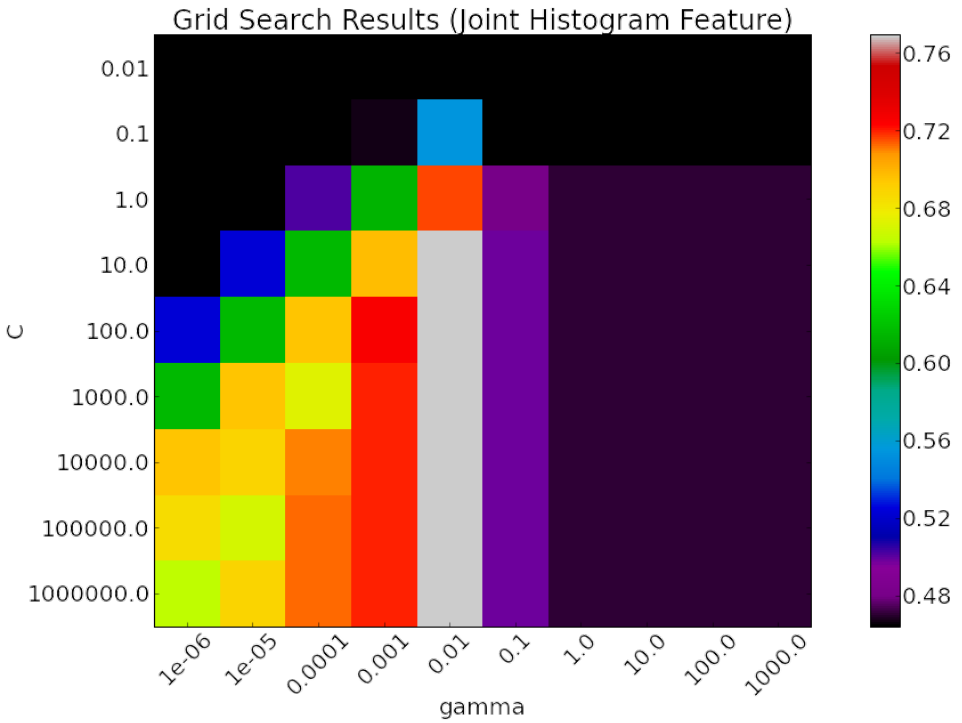


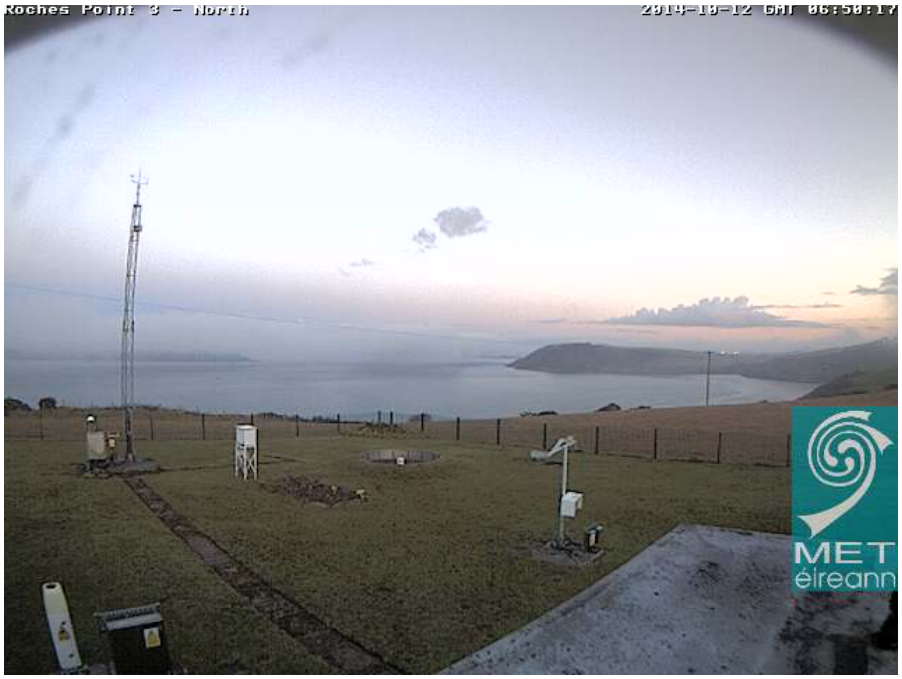
TABLE I. OPTIMAL SET OF C, γ FOR EACH TESTED FEATURE

Feature	C, γ	Feature	C, γ
CEDD	$1e^{1}, 1e^{-2}$	Joint Histogram	$1e^{3}, 1e^{-6}$
Edge Histogram	$1e^{1}, 1e^{-2}$	Scalable Color	$1e^{1}, 1e^{-4}$
Gabor	$1e^{6}, 1e^{-5}$	SCH	$1e^{3}, 1e^{-4}$
FCTH	$1e^{0}, 1e^{-1}$	Tamura	$1e^{1}, 1e^{-5}$
FOH	$1e^{4}, 1e^{-6}$		

To avoid over-fitting, 5 fold cross validation is applied.

Misclassification

Example of incorrectly classified image. Image is annotated as light fog but classified as no fog.



Example of incorrectly classified image. Image is annotated as no fog but classified as light fog.

Conclusions

- Joint Histogram method gives the highest classification accuracy score for initial datatset, closely followed by Fuzzy Colour and Texture Histogram – however issues still with misclassification
- Next steps: aquisition of larger training set (Completed: May 2015)
- Determination of techniques for dynamic platforms – (Gyro-Stabilized) buoy platforms
- Integration of camera detected patterns with other data to provide more comprehensive visibility information

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