Automated transient detection and classification in the context of the International Liquid Mirror Telescope

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Abstract

In the era of sky surveys like PTF, ZTF and upcoming Vera Rubin Observatory and ILMT, a plethora of image data will be available. ZTF scans the sky with a field of view of 48 deg^2 and the upcoming Rubin Observatory will have a FoV of 9.6 deg^2 but with much larger aperture. The 4m ILMT will cover a 22' wide strip. Transient detection requires all these imaging data to be processed through a Difference Imaging Algorithm and subsequent identification and classification. The ILMT is also expected to discover several known and unknown astrophysical objects including transients. Here, we propose an image subtraction algorithm and a convolutional neural network based automated transient discovery system which will be integrated in the ILMT transient detection and classification pipeline in the future.

Introduction

- The ILMT is a first telescope dedicated to an optical survey in India[1].
- It will be entirely dedicated to photometric/astrometric direct imaging surveys.
- Owing to its 4m diameter, it will be able to detect relatively faint objects of up to 22 magnitude in a single scan.
- This makes it a promising instrument to discover new bright as well as faint transients occurring in its observation strip.
- The discovery of these transients demands for a dedicated **pipeline** equipped with Image Subtraction and Machine Learning algorithms followed by a transient classifier and an alert stream.
- Fig. 1 illustrates the proposed pipeline through a flowchart.

Image Subtraction

- In order to detect transients as new sources in the sky, we need to subtract a good reference frame of a region of the sky from a science image of that same region[2].
- The first step involves background subtraction from the images and alignment of the science and reference images with respect to each other.
- Then the PSFs of both the images are matched by convolving the reference image with a kernel and the images are subtracted.
- Since the PSFs often don't completely match after convolution, artefacts are left behind in subtracted frames.
- Fig. 2 illustrates image subtractions performed on an ILMT image resulting in detection of an asteroid candidate.

Real/bogus classifier

- A convolutional neural network (CNN) is a neural network based machine learning algorithm that can be used in classification problems where the input data is in form of images
- Running a simple source detector on subtracted frames will result in detections of multiple subtraction artefacts as well.
- So a CNN[3] was trained with an extensive manually labeled dataset of almost equal number of 31 X 31 pixel images of candidates and artefacts to do the classification.
- Data augmentation techniques like rotations, translations etc were used[4].

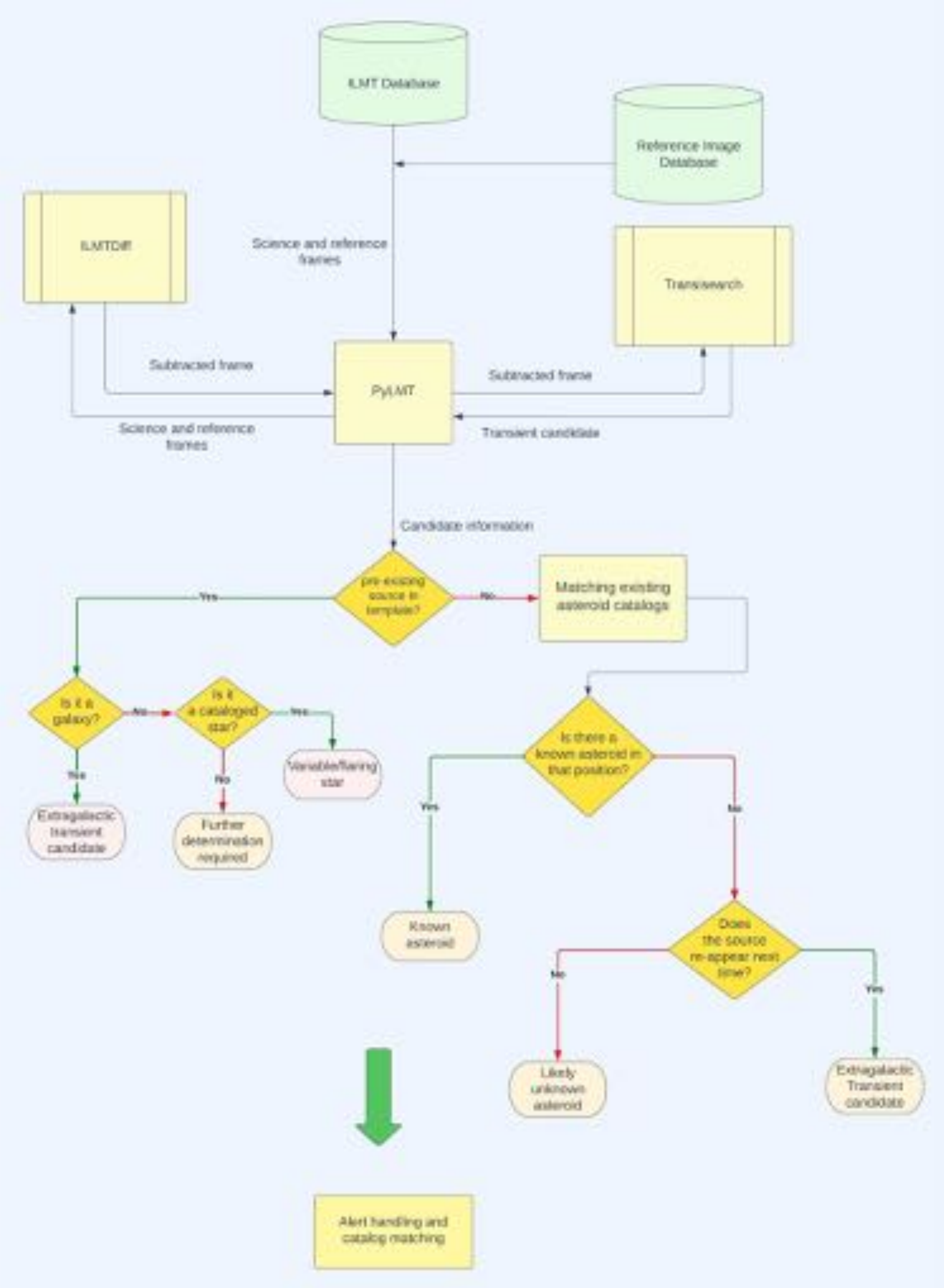

Fig. 1: Flowchart of the proposed pipeline for fast detection and classification of astrophysical transients. The first layer is the python based PyLMT pipeline which performs the image subtraction using ILMTDiff module and transient detection using Transisearch module. The second layer will carry out fast classification of the detections made by the first layer. The third layer will be for alert handling and catalog matching

Fig. 2: Figure illustrating science, reference and difference image of the same region of the sky falling in the ILMT field taken in i band. The science image was taken on 30th October at 4h 31m LST while the reference image was taken on the previous day at the same sidereal time. The CNN based real/bogus classifier successfully identified an asteroid candidate in a region of the field in the difference image which has been highlighted using a golden circle.

The CNN algorithm was applied on an image of 30th October 2022 keeping the frame of 29th October as reference. The test resulted in detection of 39 sources in the subtracted image out of which **33 appeared like asteroid candidates** while the other **6 appeared like variable/flaring star candidates**. There was also 5 false negative and 5 false positive detections. Detection threshold was set at **4 sigma**. One of the asteroid candidates detected by application of CNN on difference image has been highlighted in **Fig.2** with a golden circle

Steps involved in the pipeline

- The proposed transient detection and classification pipeline will operate in a series of steps
- In the first step, the in-house image subtraction algorithms will subtract the reference frame from the science frame.
- The subtracted frames will then be passed on to a CNN based transient detection[5] step which will locate and isolate the transient candidates.
- The first and second steps constitutes the PyLMT transient detection package of the pipeline.
- There will be a third step to further sub-classify the detected sources in the subtracted frame into three classes namely (a) variable or flaring sources eg: variable stars (b) asteroids and (c) extragalactic transients like supernovae
- Finally in the fourth step, the information of the detected sources will be cross verified with existing catalogs and the details will be communicated with the wider scientific community through an alert stream. Fig. 1 illustrates the pipeline using a flowchart.

Preliminary trial

- The PyLMT transient detection algorithm/package was implemented on data acquired from ILMT run in the month of October 2022.
- Implementation of the PyLMT algorithm resulted in detection of several point sources of possibly astrophysical origin in the subtracted frames as illustrated in Fig. 2

Future work

- Based on initial results, we are detecting close to 25 - 30 sources per frame in i' and r' bands while about 6 - 8 transient candidates in g' band.
- So a separate step for a CNN aided subclassification of these detected sources/candidates is needed to further narrow down to our objects of interest.
- A system for catalog matching and alert handling is also needed to be developed.

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