A CNN adapted to time series for the classification of Supernovae

Anthony BRUNEL[1,2], Johanna PASQUET[3], Jérôme PASQUET[1,2]
Nancy RODRIGUEZ[1,2], Frédéric COMBY[1,2], Dominique FOUCHEZ[3],
Marc CHAUMONT[1,4]
LIRMM[1], Univ Montpellier[2], CPPM[3], Univ Nîmes[4]

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Outline

Introduction

The cosmology

Science that studies the structure, origin and evolution of the universe

The challenge

Analyze / Detect huge amounts of data

Figure: Sky image simulation as LSST will see.

The Supernovæ

Set of phenomena resulting from **the explosion of a star** (various types: Ia, Ib, Ic, II ...)

Supernova

Supernova Ia: The standard candle

- A white dwarf accretes the matter of a companion star, and ends up exploding.

  Supernova Ia video Video credit: ESO; Downloaded from: http://www.eso.org

- Always identical explosion (intrinsic brightness)
  Luminosity observed on Earth $\Rightarrow$ deduction of distance

Supernova not Ia

- Explosion after core collapse

Identification of celestial objects

Identification methods

- Spectroscopic identification
  - Study the spectrum of the object
- Photometric identification
  - Identify the star using different filters

Photometry vs. spectroscopy

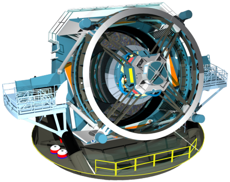
- Spectroscopy = accurate, object must be bright, expensive
- Photometry = less accurate but less expensive

$\Rightarrow$ LSST will provide photometric data

Large Synoptic Survey Telescope (LSST)

LSST

- Operational from 2022
- 10-year observation project
- Will survey the visible sky twice a week
- Will provide 15 Tera of data each night
- More than 10 million supernovae will be discovered



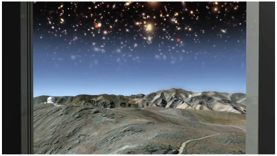
LSST Video Video credit: Guillaume Doyen; Downloaded from:

http://astrospace-page.blogspot.com

Light Curves

Light Curves

- Evolution of luminous flux over time



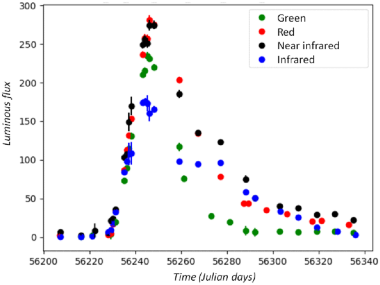


Figure: Example of supernova Ia simulated

Light Curves

Problems

- Irregular temporal sampling
- Variable duration
- Extremely *sparse* (more than 70% of 0)

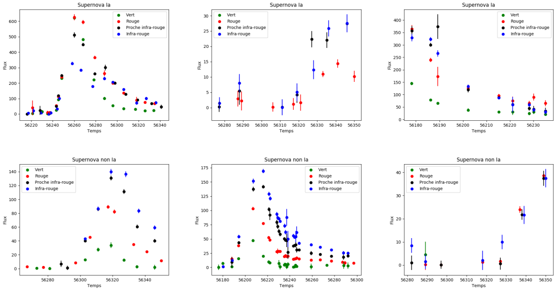


Figure: Example of supernovae light curves Ia and not Ia

Outline

The data

Simulated data

- Simulated data with SNANA software and corresponding to that of the Dark Energy Survey
- Simulations generated to be as realistic as possible

Some numbers

- Curves of light: 5 000
- Supernovæ Ia: 2 500
- Supernovæ not Ia: 2 500
- Sparse: More than 70% of zeros

Representation of input data

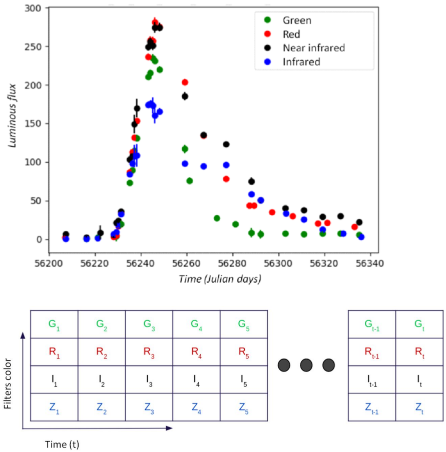


Figure: Representation of light curves in matrix form

Outline

CNN Network Architecture

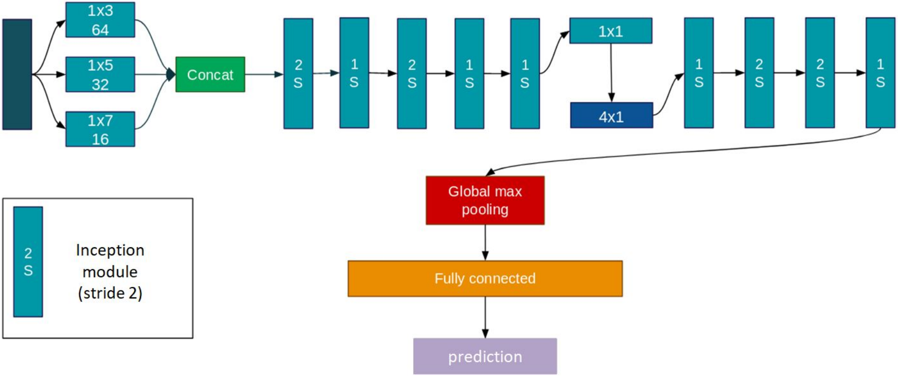


Figure: Convolutional neural network

The CNN is donwloadable there:
https://github.com/Anzzy30/SupernovaeClassification

Plan

Base and Hyper-parameters

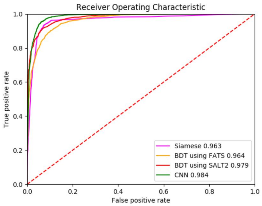
Learning Base / Test Base

- **4-Fold** cross-validation
- **3 750 light curves** for the **learning**
- **1 250 light curves** for the **test**
- **Virtual increase** by crop from 40% to 80% of light curves. Reduces over-fitting and improves results

- *4500 iterations, dropout of 0.4 on the fully connected, learning rate with exponential decay from* 10^{-2} *to* 5×10^{-4}*, Adam optimizer, cross entropy loss, weight intialized with Xavier approach, batch of size 128 ...*
- Learning with a NVIDIA GTX 1080

Results

Model	Training set	AUC	Accuracy
CNN	3750	**0.984**	**94.6**
SALT2	3750	0.979	92.3
FATS	3750	0.964	90.1
Siamese	3750	0.963	93.0



$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN}$$

[Lochner et al. 2016] SALT2: Boosted decision tree (BDT) using SALT2 features (Spectral Adaptive Light curve Template 2)

[Nun et al. 2015] FATS: Boosted decision tree (BDT) using FATS (Feature Analysis for Time Series)

Analysis

- Better than the state-of-the-art ("features + classifier")
- Deep network performance can easily be improved
- Increasing the number of examples (not shown here) improves the results of deep learning
- Results of the RNN slightly lower than the CNN (not shown here)

Improvements

- Virtual increase by noise addition
- Improvement of performance by using Ensemble, transfer learning, multi-class, use of redshift
- Extension: Better manage sparsity
- Extension: Manage the low number of samples
- Extension: Manage the mismatch between celestial objects near and far
- Extension: Manage the cadence mismatch (sparsity)

Second resubmission step: "PELICAN: deeP architecturE for the LIght Curve ANalysis" Johanna Pasquet, Jérôme Pasquet, Marc Chaumont and Dominique Fouchez. Astronomy & Astrophysics 2019

Outline

Conclusion and perspectives

Objectives

- Binary classification of supernovae Ia and not Ia
- Manage locks due to LSST data

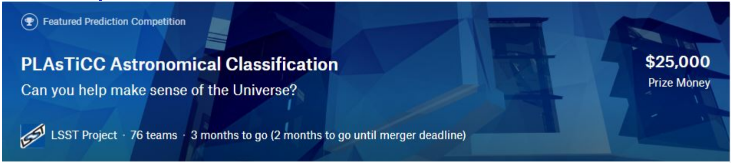
Contributions

- Two state-of-the-art networks
- CNN or triplet loss approaches are possible

Perspectives

- Second resubmission step: "PELICAN: deeP architecturE for the LIght Curve ANalysis" Johanna Pasquet, Jérôme Pasquet, Marc Chaumont and Dominique Fouchez. Astronomy & Astrophysics 2019
- Kaggle

Kaggle Competition: Astronomical Classification Challenge



- The Large Synoptic Survey Telescope (LSST) is about to revolutionize the field, discovering 10 to 100 times more astronomical sources that vary in the night sky than we've ever known.
- The **Photometric LSST Astronomical Time-Series Classification Challenge (PLAsTiCC)** asks Kagglers to help **prepare to classify** the data from this new survey.
- $25,000 in total prizes
- Timeline:
  - September 28, 2018 - Lauch
  - December 10, 2018 - Entry deadline and Team Merger deadline
  - December 17, 2018 - Final submission deadline.
  - January 15, 2019 - LSST Workshop entry deadline.
  - February 15, 2019 - LSST Workshop announcement.

https://www.kaggle.com/c/PLAsTiCC-2018