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# Automatic detection of defects on wide field images of deep space

Prerelease presentation

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# Contents

- IAP and TERAPIX
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A wide horizontal band with a background of a starry night sky, showing numerous bright stars and a nebula with orange and red hues.

# IAP et TERAPIX



# *Institut d'Astrophysique de Paris*



- Fundamental research laboratory
- Two units
  - UMR 7095, astrophysicists (INSU)
  - FRE 2435, theoretical physicists (CNRS)
- 4.2 millions euros annual budget
- Staff
  - 53 scientists
  - 37 engineers, technicians and administrative staff
  - 26 associated scientists
  - 11 postdoctoral fellows
  - 24 doctoral students
  - 110 visitors a year
- 160 publications a year





# TERAPIX

- Traitement Elementaire, Reduction et Analyse des PIXels de megacam
- 5 engineers and 3 astronomers
- Main tasks:
  - to develop image processing and pipeline software for MegaCam;
  - to develop and provide tools for handling of large CCD images;
  - to operate the final reduction pipeline to produce calibrated images and catalogues of MegaCam images over the next 5 years;
  - to provide technical assistance and Terapix computing facilities to MegaCam users.



# TERAPIX tools

- Snoopix
  - Download via http or ftp
  - 3.6Mb/s France/Canada
- DataTransfer
  - Cluster of 9 computers
  - Dispatch data
  - Manage transfers
- Spica
  - Produce calibrated data
  - Web interface
- QualityFITS
  - Image evaluation
  - Webpages generation
- Panorapix
  - FITS file visualisation





A wide horizontal band of a starry night sky, showing numerous bright and dim stars of various colors (white, yellow, orange, red) against a dark background. The stars are scattered across the width of the band, with some appearing as bright points and others as smaller, fainter specks.

Scientific  
context



# Scientific data

- Canada-France-Hawaiï Telescope Legacy Survey



- 3.6 meters telescope
- wide field panoramic CCD camera, MegaCam
- 3 surveys
  - The CFHT-LS "shallow", 1300 square degrees, focused on the Trans-Neptunian and Kuiper Belt observations.
  - The CFHT-LS "wide", covering 170 square degrees, focused on large-scale structure of the Universe.
  - The CFHT-LS "deep", covering four uncorrelated 1 square degree patches (i.e., one MegaCam field) for detection of supernovae

- 50Tb of data over 5 years

- FITS and MEF formats (astrophysics)





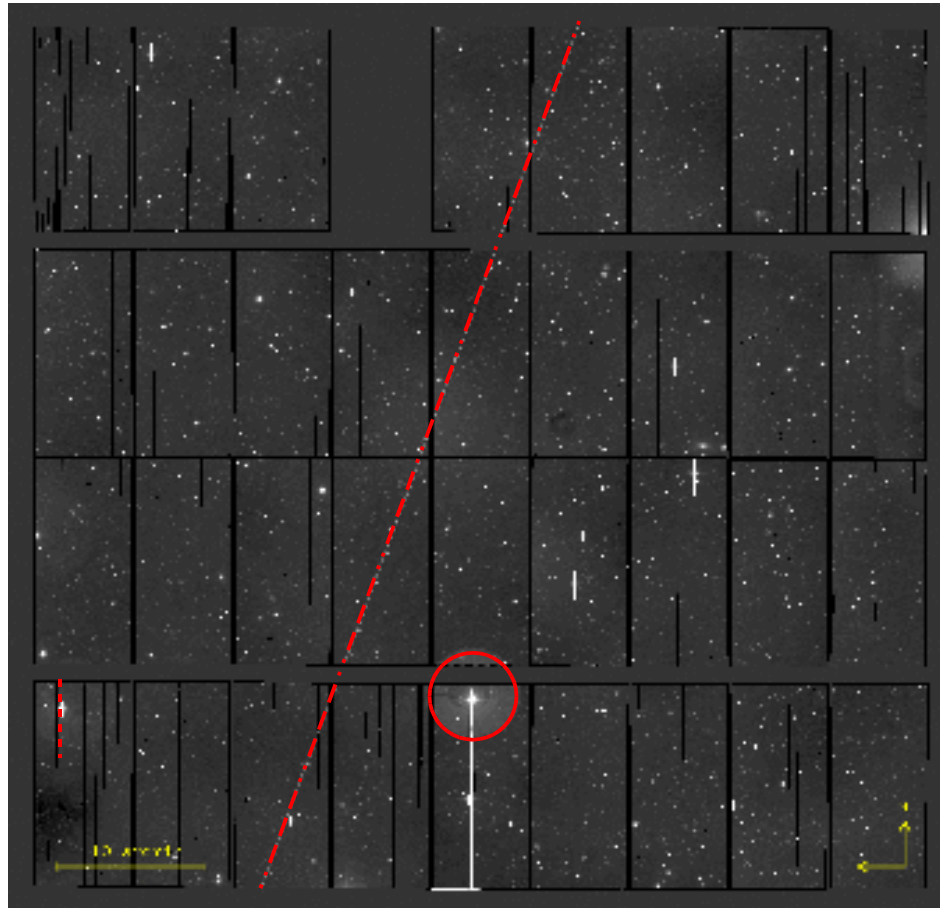
# Scientific goals

- Photometry
  - Measurement of the light intensities
- Astrometry
  - measurement of the position and motion of celestial bodies
- Study of large-scale structure of the cosmos
- Study of the curvature of the universe



# Optical defects

- Halos
- Satellite Trails
- Diffraction spikes





# Project aims

- Create masks of pixels corresponding to optical defects
- Currently done manually
  - *Increase treatment speed*
  - *Save astronomers time for more useful tasks*



# Constraints

- Amounts of data
  - 2112x4644 pixels on each CCD
  - 36 CCD for each mosaic/image
  - About  $3 \cdot 10^8$  pixels for each image
  - *Dimensionality reduction*
- Speed constraints: an image each 5 minutes
  - About  $1 \cdot 10^6$  pixels per second
  - *Fast and robust method*
- Autonomous computing
  - No human intervention during mask computation
  - *Supervised learning machine*
  - *Defect simulator*

A background image of a starry night sky with numerous bright stars and a nebula in shades of orange and red.

# Advanced techniques



# Chosen solution

- FITS File management (cfitsio library)
- Dimensionality reduction
  - Rebinning
  - Background subtraction and dynamic reduction
  - Principal Components Analysis
- Defect simulator
- Supervised machine learning
  - Training
  - Computing






# Rebinning

$p(0,0)$	$p(0,1)$	$p(0,j)$	$p(0,N)$
$p(1,0)$	$p(1,1)$	$p(1,j)$	$p(1,N)$
$p(i,0)$	$p(i,1)$	$p(i,j)$	$p(i,N)$
$p(N,0)$	$p(N,1)$	$p(N,j)$	$p(N,N)$

$$\frac{1}{N \times N} \sum_{i=0}^N \sum_{j=0}^N p(i,j)$$

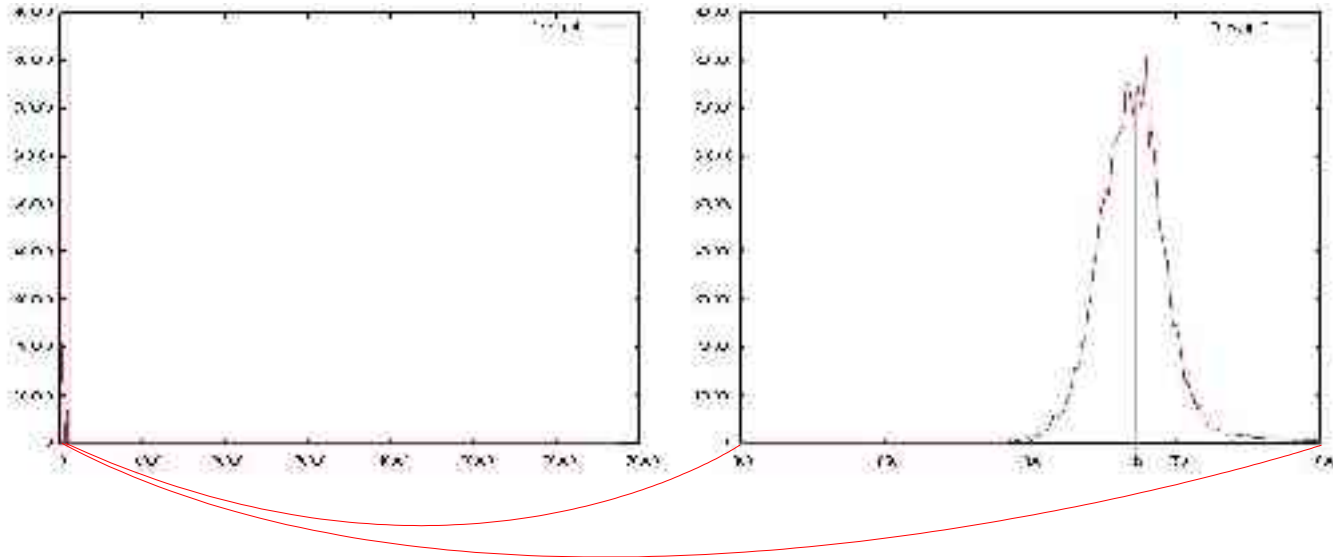


$r(0,0)$

- Reduction by  $N \times N$
- Optional step



# Dynamic reduction



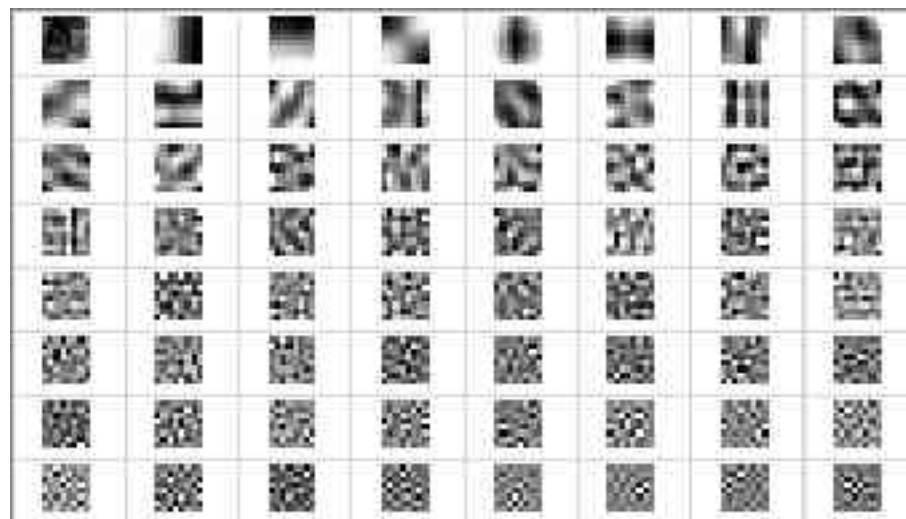
- Background computation and subtraction
- Transfer function

$$z(y) = \frac{y}{|y|} \ln \left( 1 + \frac{|y|}{?} \right)$$



# PCA

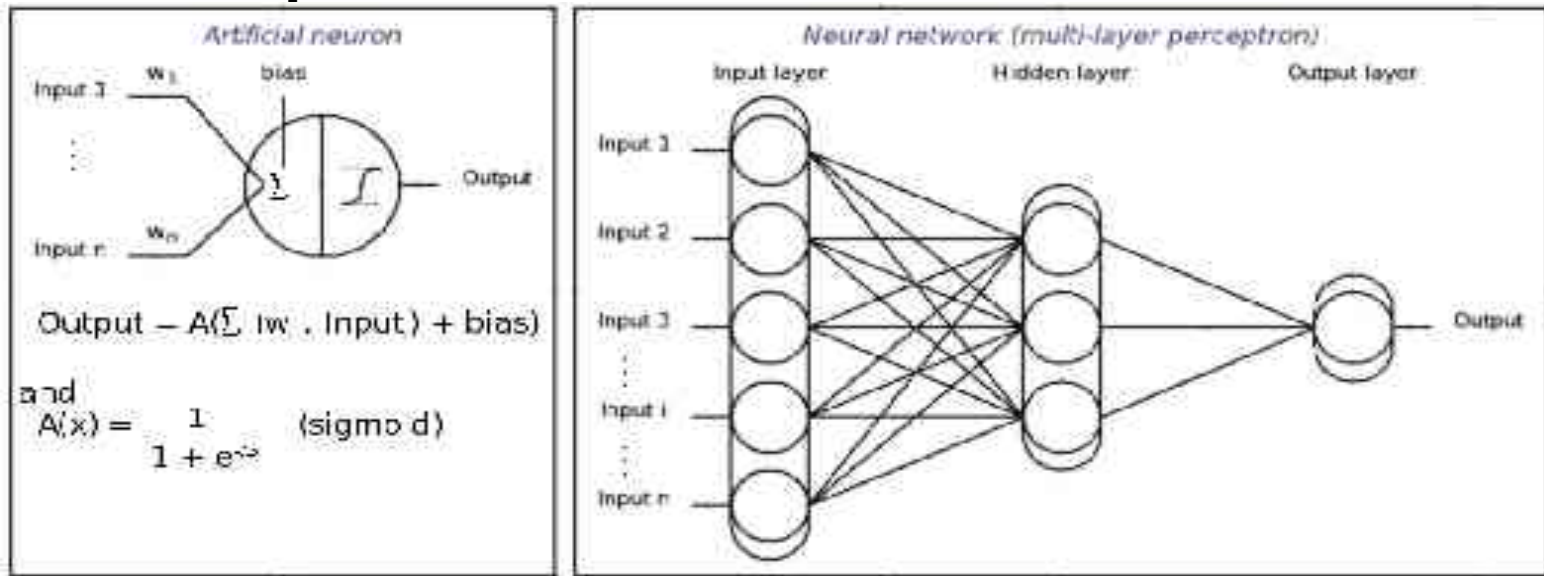
- Principal Components Analysis
- 





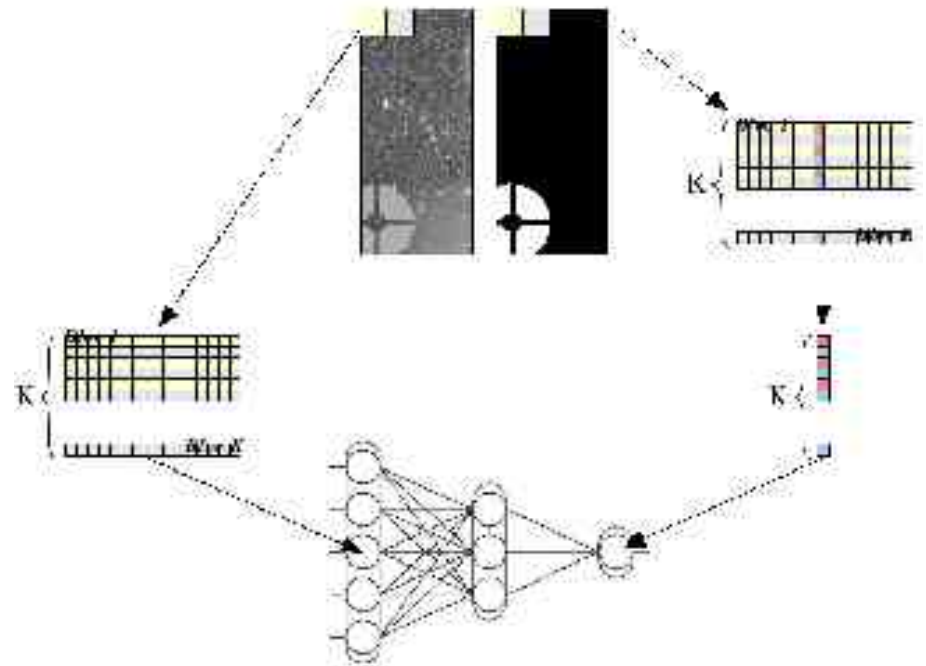
# Neural networks

- Three layers MLP (Multi-Layer Perceptron)



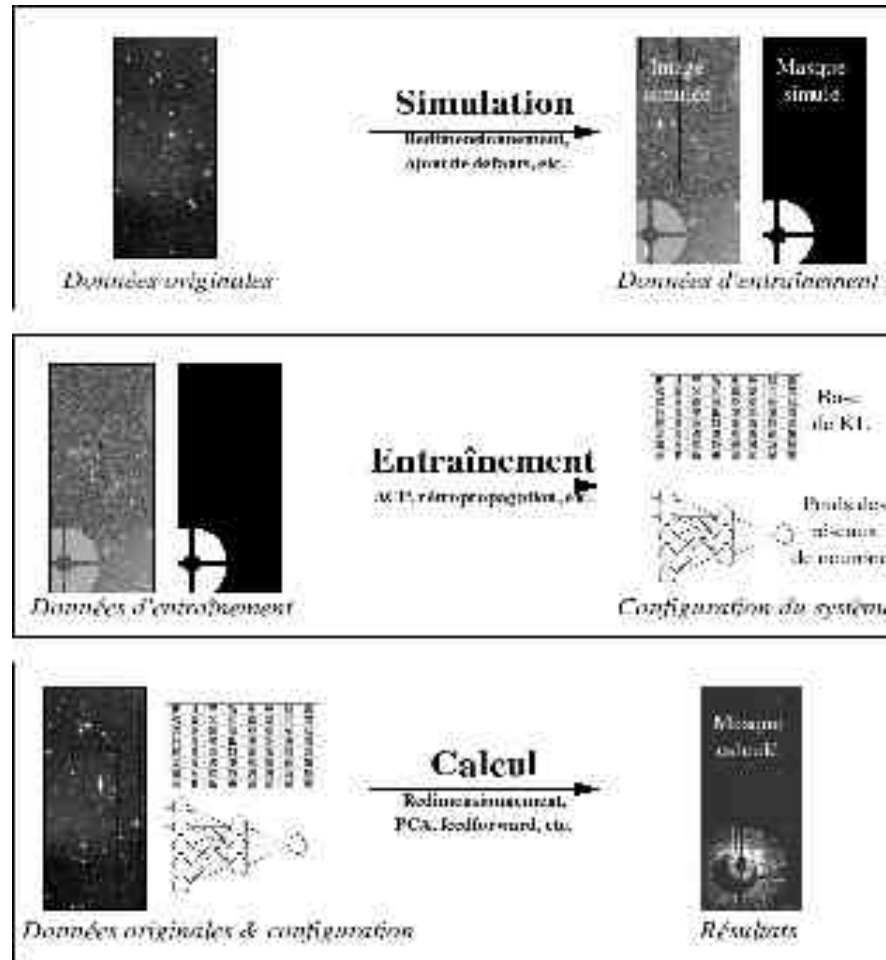


# Input and output





# Global process





A background image of a star field with a gradient from light to dark and a nebula on the right side.

Results



# Estimations and speed

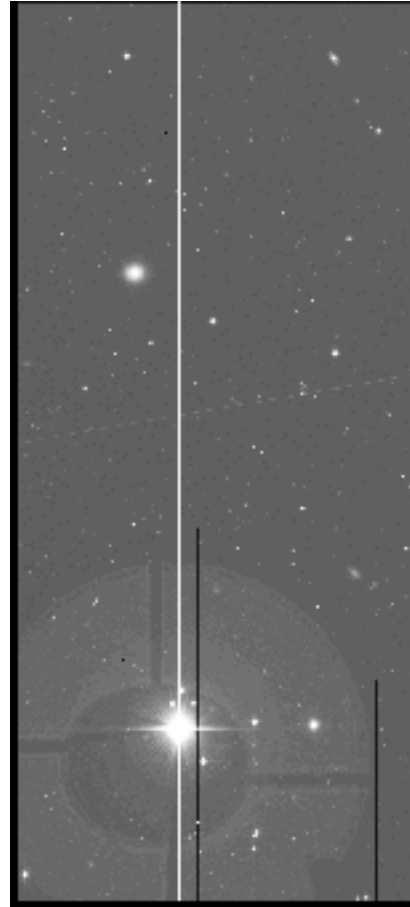
- Training
  - Blocs: 8x8 pixels
  - 352 152 blocs
  - 16 PC
- Computing
  - Blocs: 8x8 pixels
  - 22 068 288 blocs
  - 16 PC
- Quality
  - Quadratic error: 0.027

	Simulating	Training	Computing	PCA
36 CCD (2112x4644) MEF file Halos	< 1 min	-	~4 min	~ 1 min
36 CCD (528x1161) MEF file Halos	-	~1 hour	~4 min	~ 1 min
36 CCD (2112x4644) MEF file Satellite trails	< 1 min	-	~4 min	~ 1 min
36 CCD (528x1161) MEF file Satellite Trails	-	~5 min	~4 min	~ 1 min



# Masks

- Halo example
  - Rebin 4x4
  - 16 PC on 64
  - Network
    - 16 input nodes
    - 8 hidden nodes
    - 1 output node



A wide horizontal band of a starry space background, showing numerous bright stars of various colors (white, yellow, orange, red) against a dark, reddish-brown nebula.

Conclusion



# Future

- Todo list
  - Debug
  - Optimisation
  - Defects simulators
  - Networks training and configuration (mostly)
- First release in July 2004



# Traineeship

- Participation to a scientific conference
- Neural network successful application
- Personal improvement in astrophysics
- New techniques development
- Discover of a research laboratory
- Complementary work
- *Positive experience*





# Credits

- Thanks
  - Emmanuel Bertin
  - Yannick Mellier
  - Valérie Bona
  - TERAPIX team
  - IAP staff
- Websites
  - <http://terapix.iap.fr>
  - <http://www.iap.fr>
  - <http://www.cfht.hawaii.edu/>