



## European Ph.D. defense

Communauté  
d'Agglomération de  
**La Rochelle**

# Segmentation and indexation of complex objects in comic book images

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Introduction

Documents

Contributions

Experiments

Conclusion

UNIVERSITÉ

La Rochelle

- Comic books
- Comics project at L3i



Thinking about the scenario. Image credits:  
Wissam Shekhani, 2010

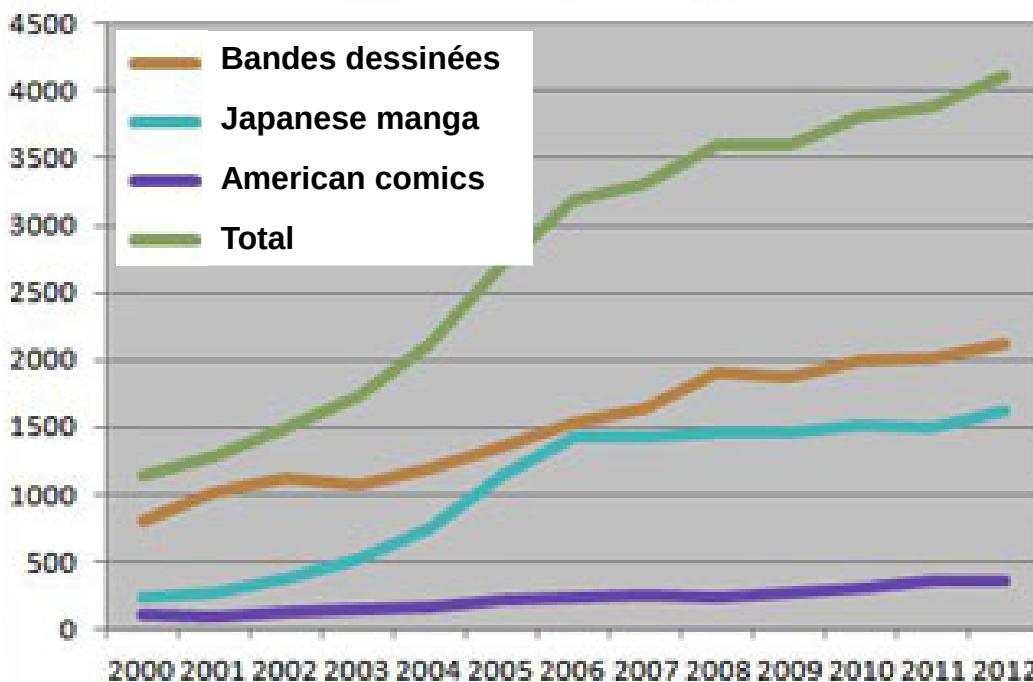
# Comic books

## Introduction

*“a visual medium used to express ideas via images, often combined with text or visual information”*

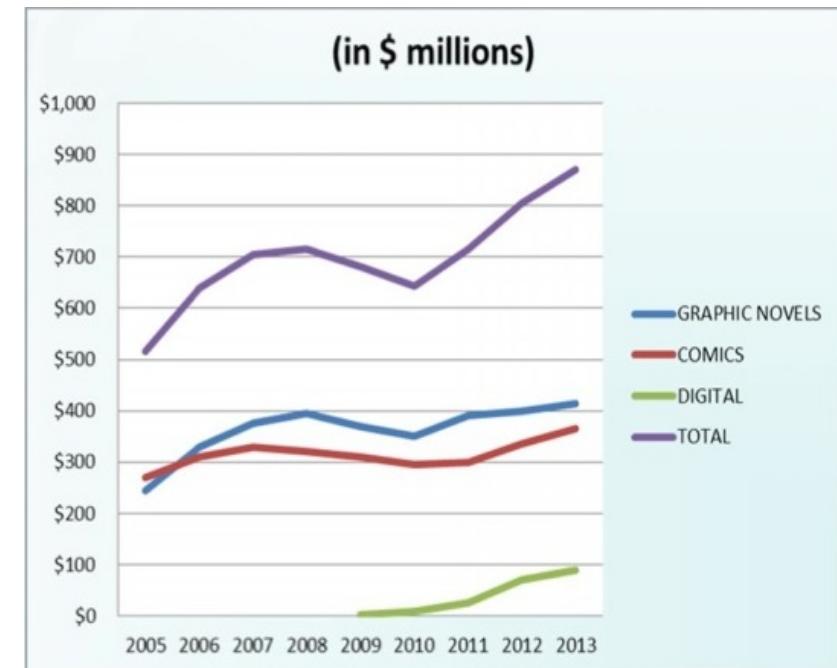
Wikipédia, 2014

One of the most **popular** and **familiar** forms of **graphic content**



Francophone comics production

Infographie (c) L'Agence BD d'après les chiffres de Gilles Ratier/ACBD.



Comics market in the US

Milton Griepp's White Paper, ICv2 Conference 2014

- Objectives
  - Add value to paper-based comics using the new technologies
  - Answer to a real need from librarians, advertisers and readers
- Direct applications
  - Text/image search, reflowable documents, augmented reading and translation assistance
- Research axes
  - Document image analysis: extracting content of digitized comic books
  - Knowledge representation: understanding the semantic of the content
- Participants
  - 2 Ph.D. students, 1 engineer, 1 post doc and 6 professors
- Initial public funding
  - CPER 2007-2013 (State-Region Project Contract)

# Comics project (eBDthèque)

## Introduction

- Objectives
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- Document production to interpretation
- Application to comic books



Pencil drawing. Image credits: Le cycle des bulles, Christophe Rigaud, 2012

# Production to interpretation

# Document analysis

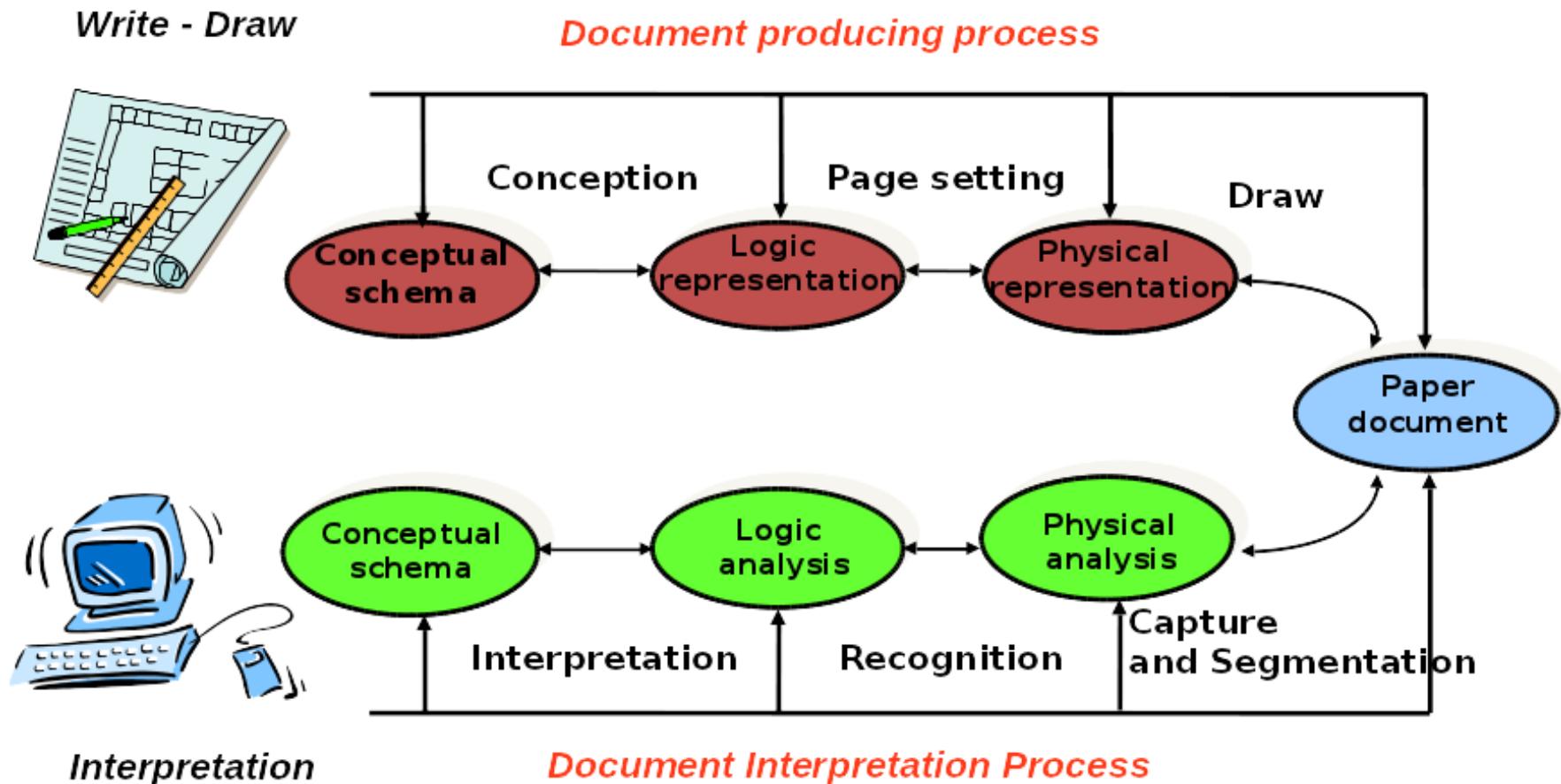


Image source: Handbook of Document Image Processing and Recognition. Springer, 2014

# Application to comic books

## Document analysis

- Challenges:
  - Recent field of research with a **largely unknown**
  - **Semi-structured** and **free-form** document mixing text and graphics

- Production process
  - 1) Synopsis and scenario
  - 2) Pencil drawing
  - 3) Inking
  - 4) Flattening and colouring
  - 5) Lettering and sound effects

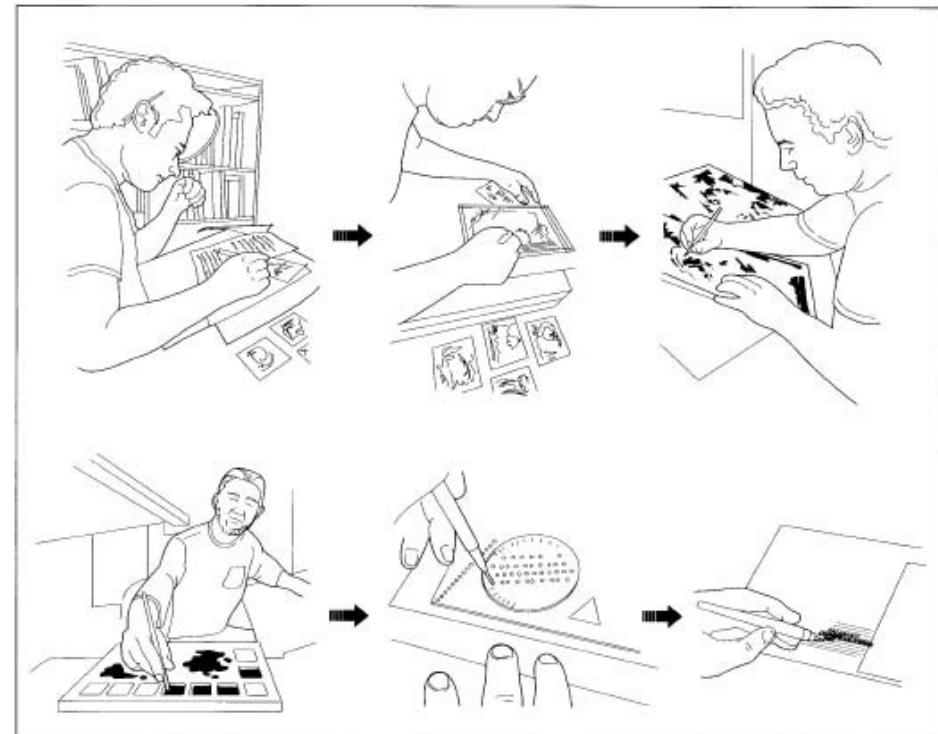


Image source:  
<http://www.madehow.com/Volume-6/Comic-Book.html>

- Introduction
- Content-driven approach
- Knowledge-driven approach



Inking. Image credits: Le cycle des bulles,  
Christophe Rigaud, 2012

- **Introduction**
- Content-driven approach
- Knowledge-driven approach

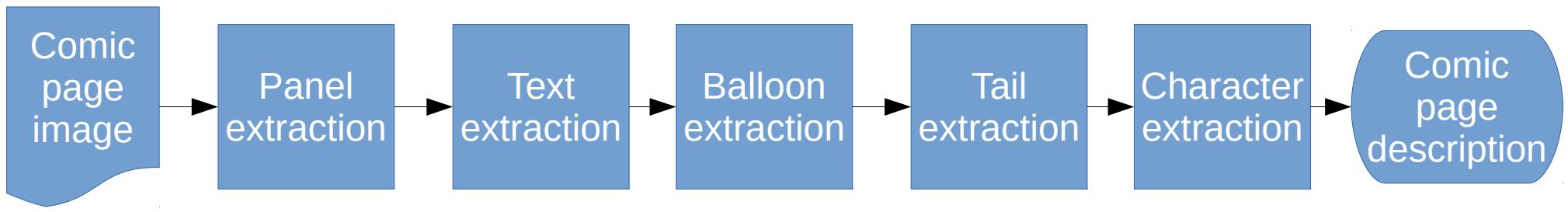


Inking. Image credits: Le cycle des bulles,  
Christophe Rigaud, 2012

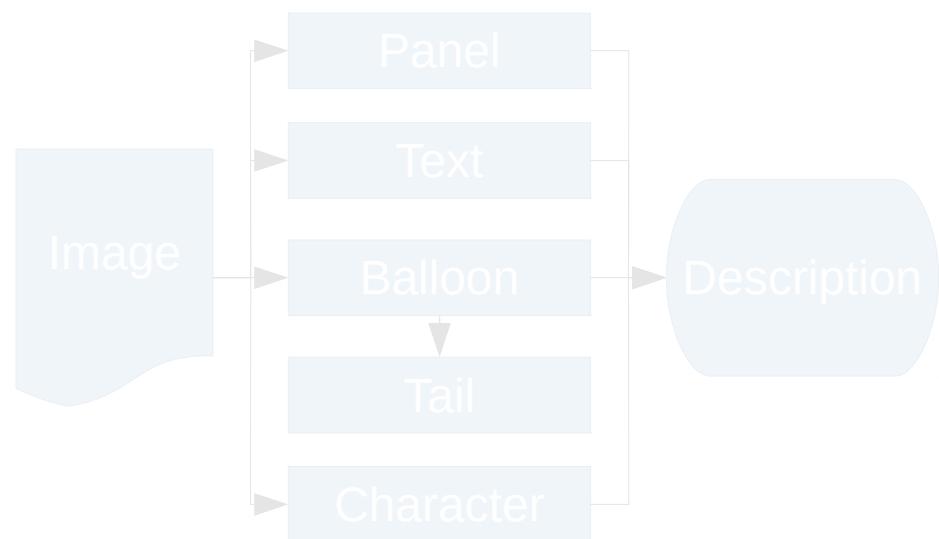
# Introduction

# Contributions

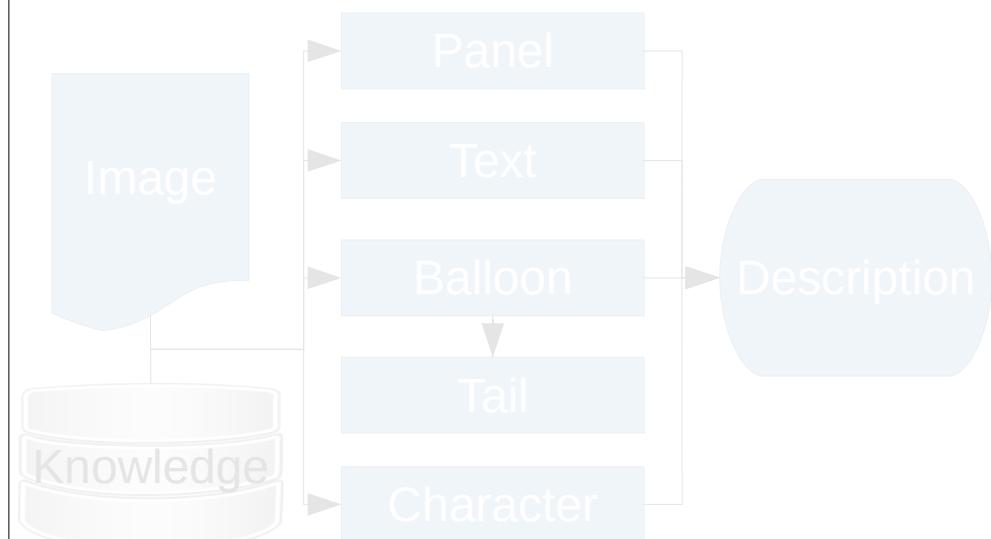
## Content-driven (sequential)



## Content-driven (independent)



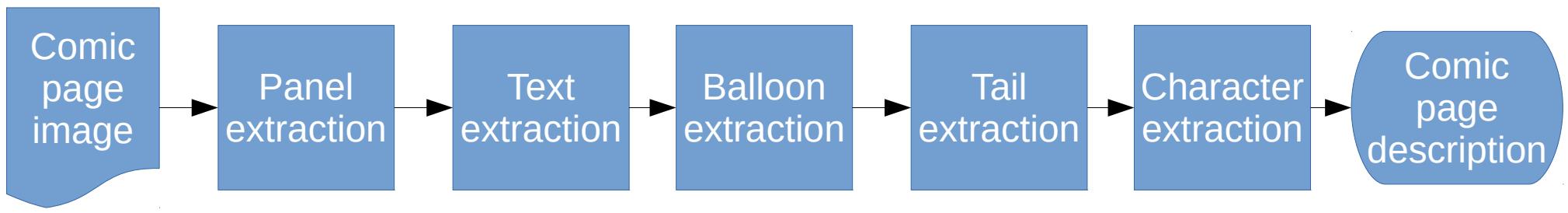
## Knowledge-driven (independent)



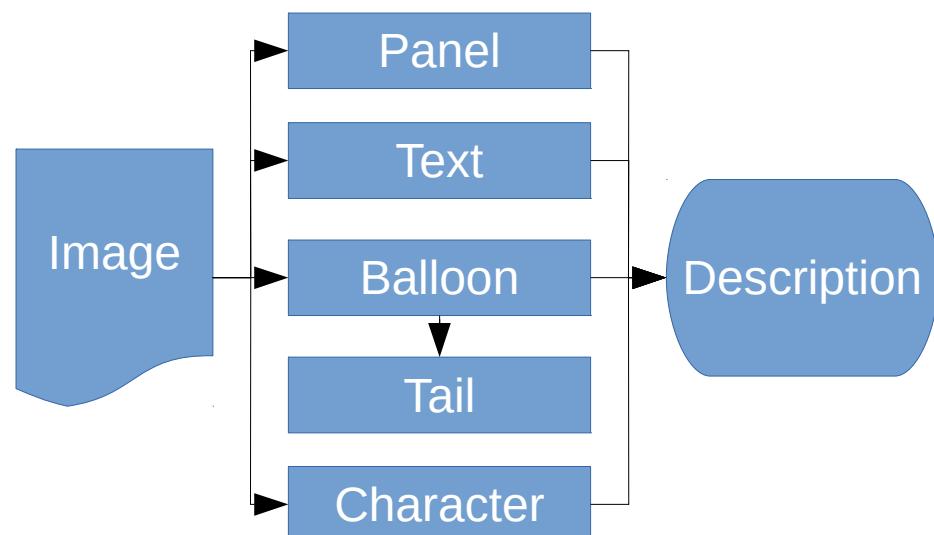
# Introduction

# Contributions

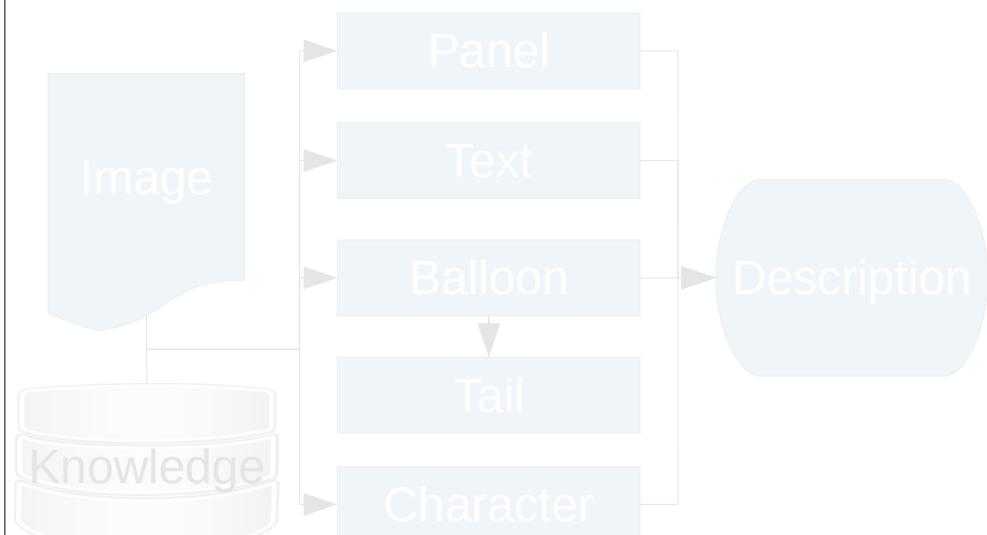
## Content-driven (sequential)



## Content-driven (independent)



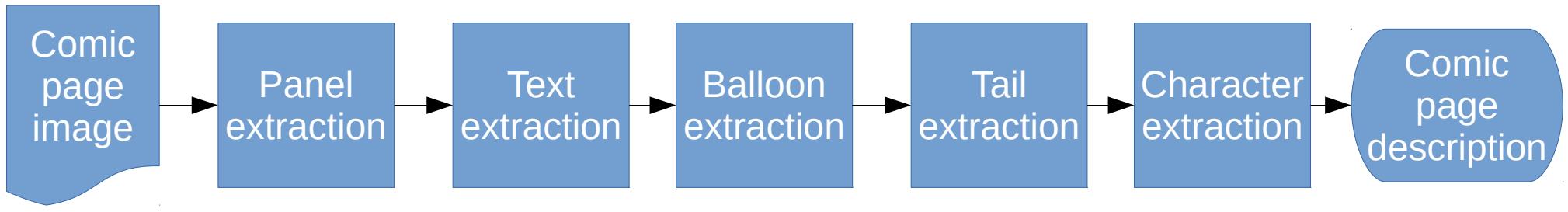
## Knowledge-driven (independent)



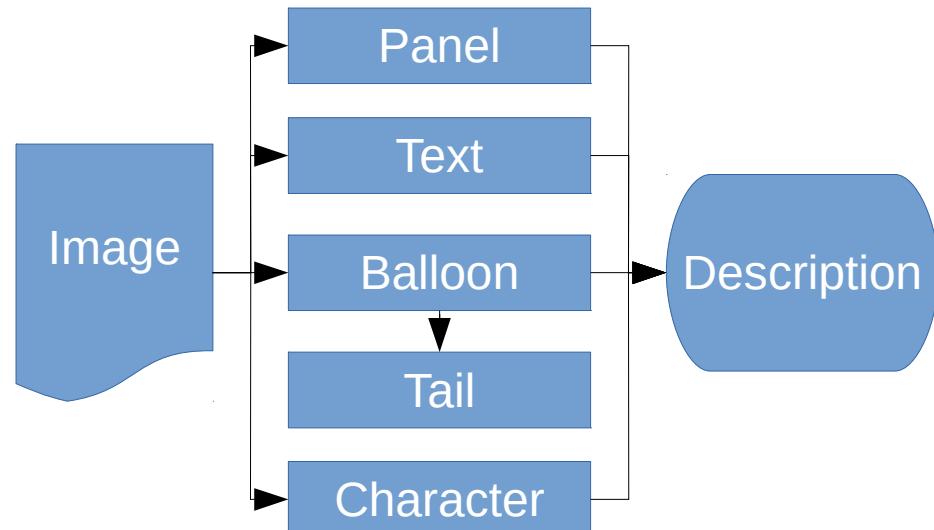
# Introduction

# Contributions

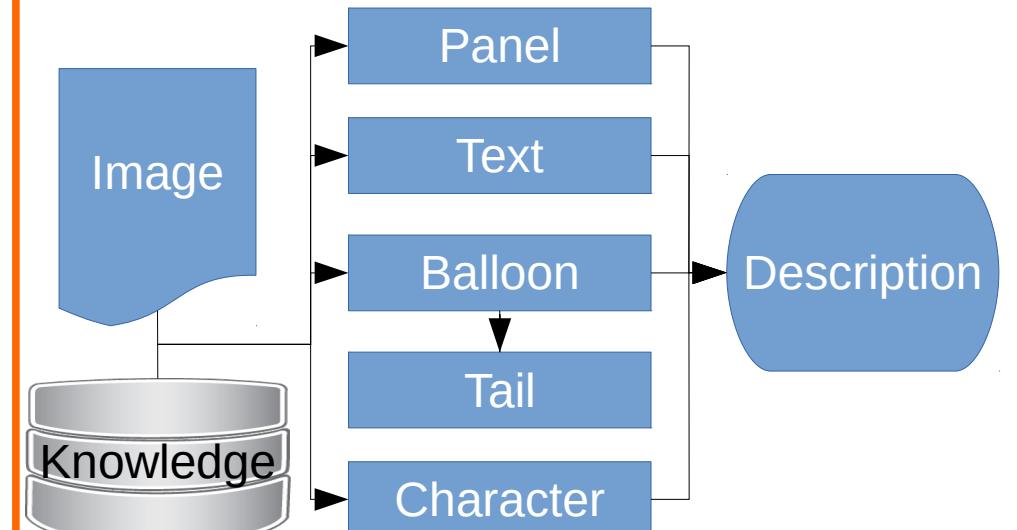
## Content-driven (sequential)



## Content-driven (independent)



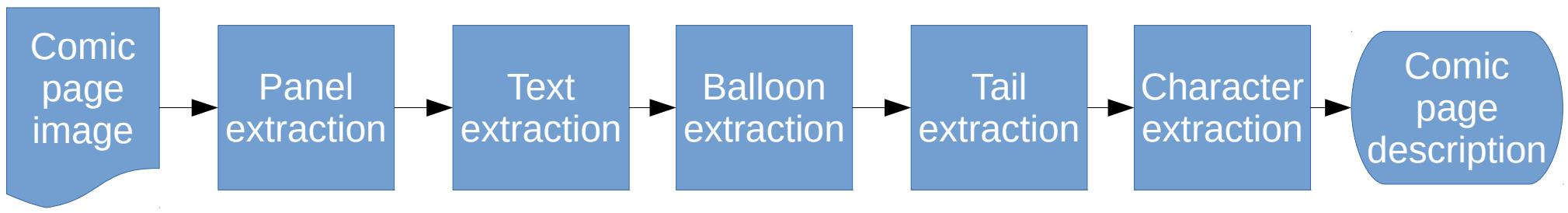
## Knowledge-driven (independent)



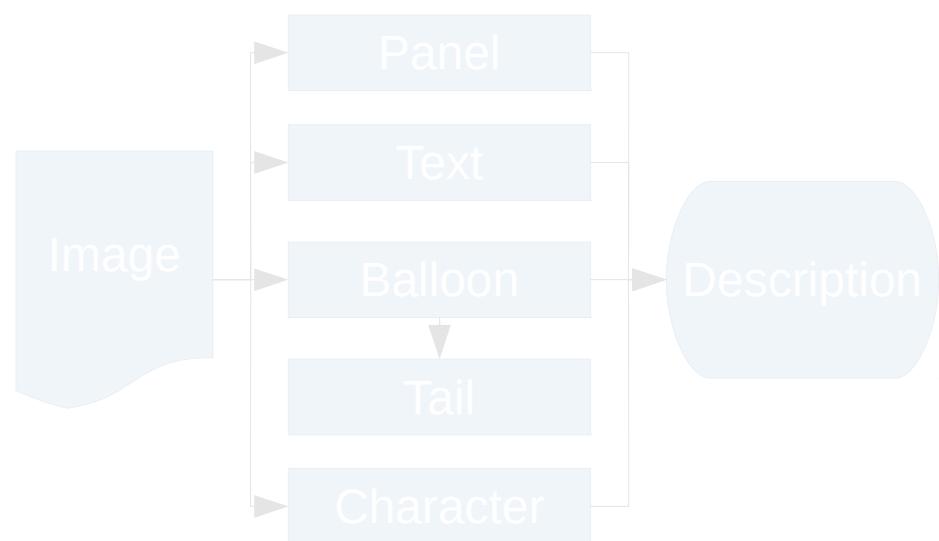
# Introduction

# Contributions

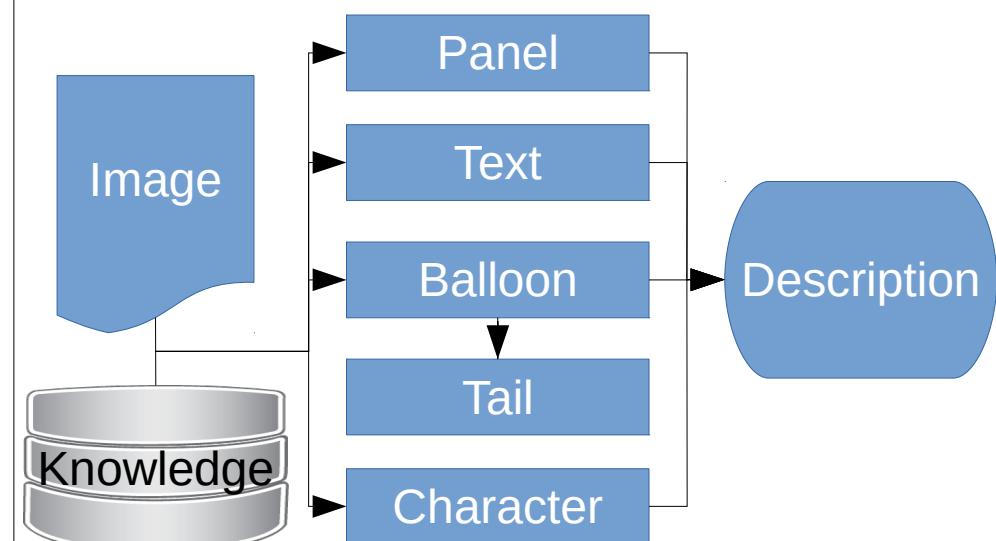
## Content-driven (sequential)



## Content-driven (independent)



## Knowledge-driven (independent)



- Introduction
- Content-driven approach
  - Panel & text extraction
  - Balloon extraction
  - Tail extraction
  - Comic character extraction
  - Conclusion
- Knowledge-driven approach

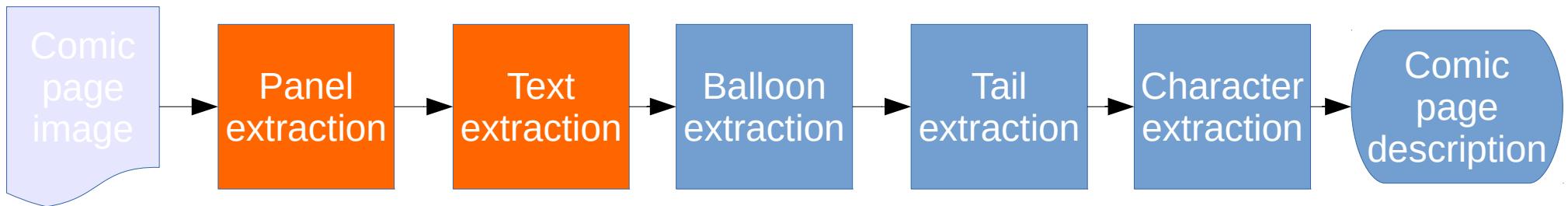


Gray-scale Image credits: Le cycle des bulles,  
Christophe Rigaud, 2012

# Panel and text extraction

Contributions  
Content-driven approach

- Processing sequence



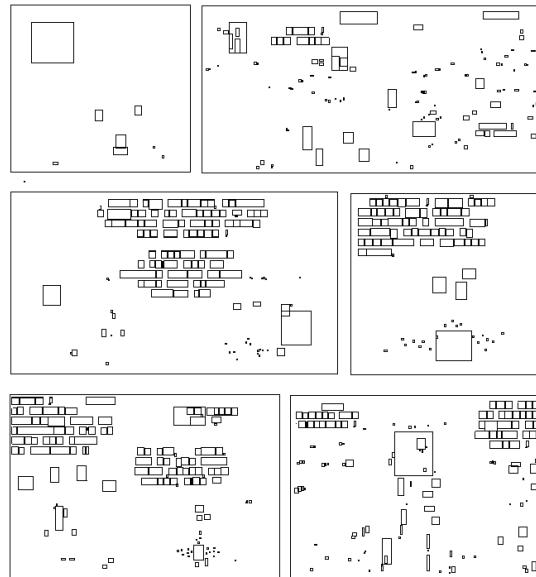
- Literature
  - Panel, balloon, text extraction [Ho2012, Arai2010]
  - TODO M. Stommel, L. Merhej, and M. Müller Segmentation-free detection of comic panels. In LNCS 2012.
  - Text only extraction [Li2013]
- Contribution
  - Simultaneous panel and text extraction

# Panel and text extraction

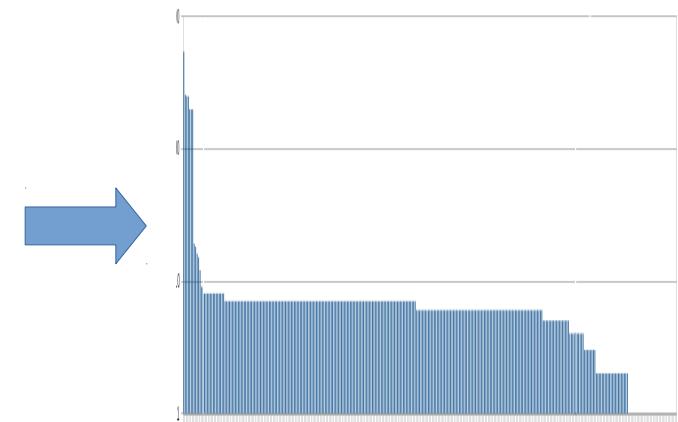
Contributions  
Content-driven approach



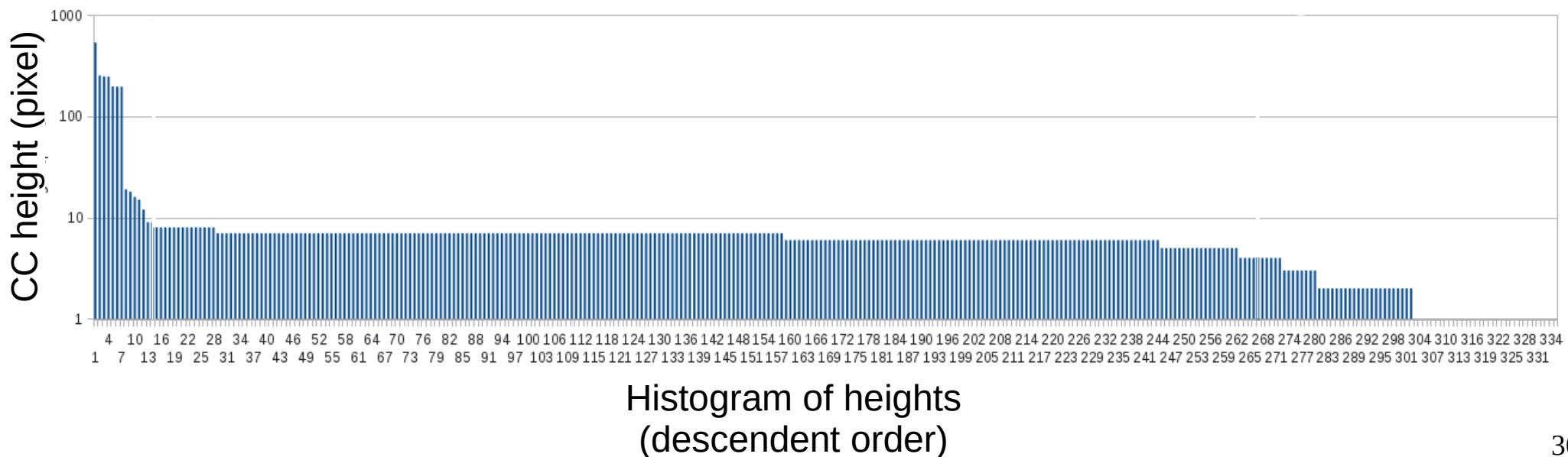
Binary image



Connected-component (CC) bounding boxes



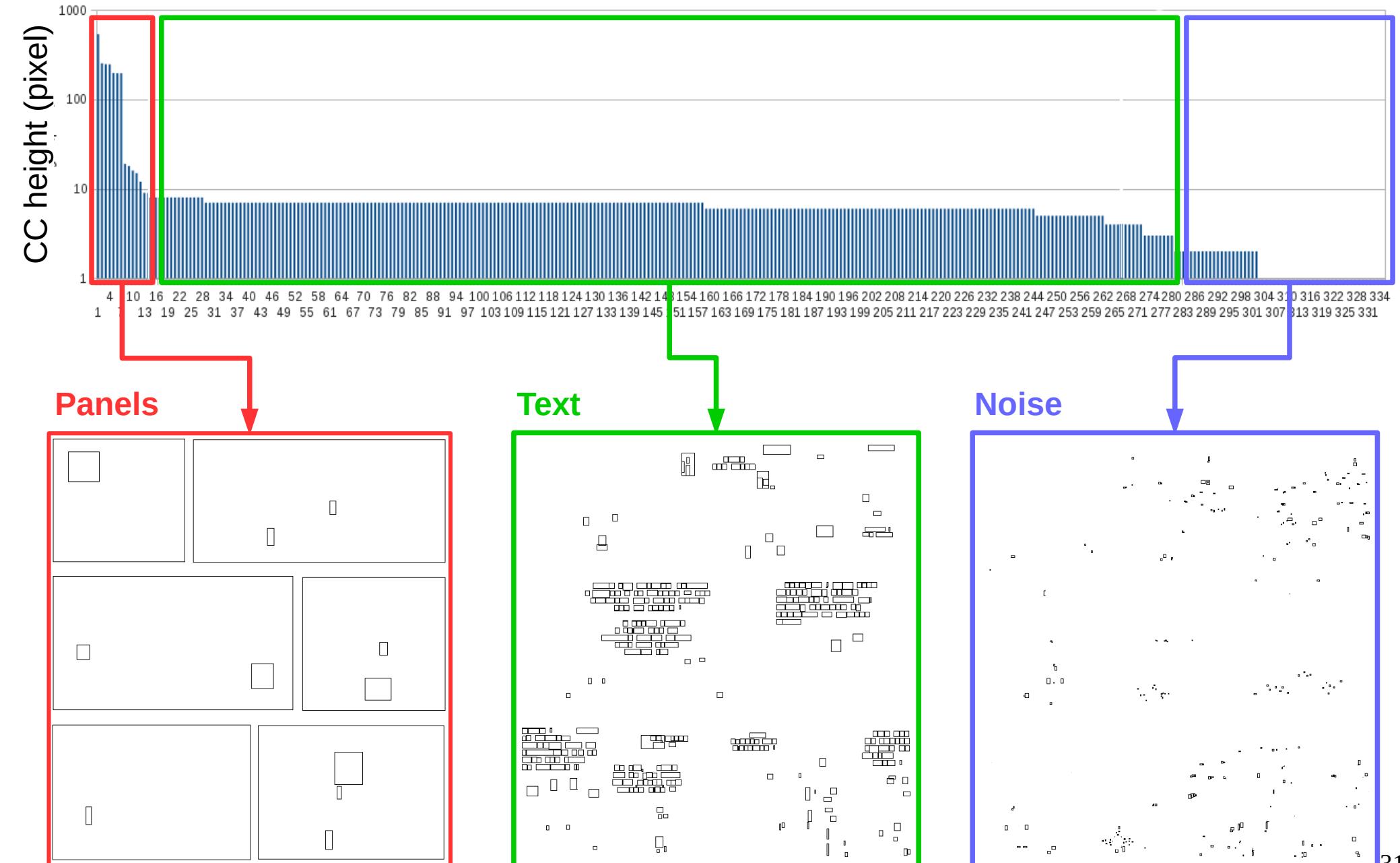
Histogram of heights of CC



# Panel and text extraction

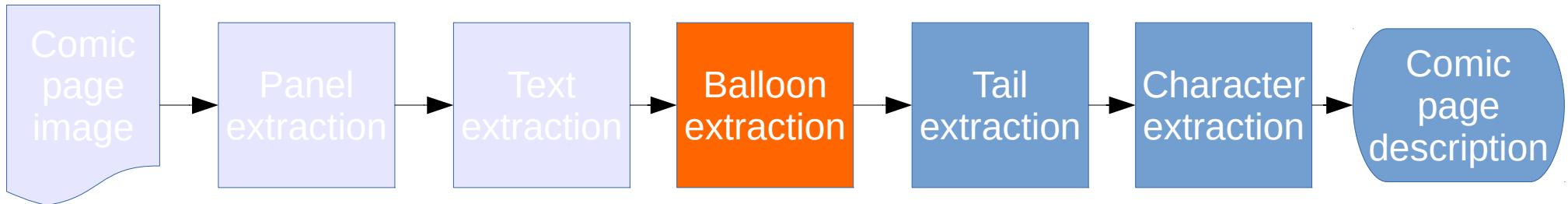
Contributions  
Content-driven approach

K-means clustering ( $k=3$ )

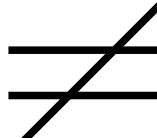


# Balloon extraction

Contributions  
Content-driven approach



Regular balloon

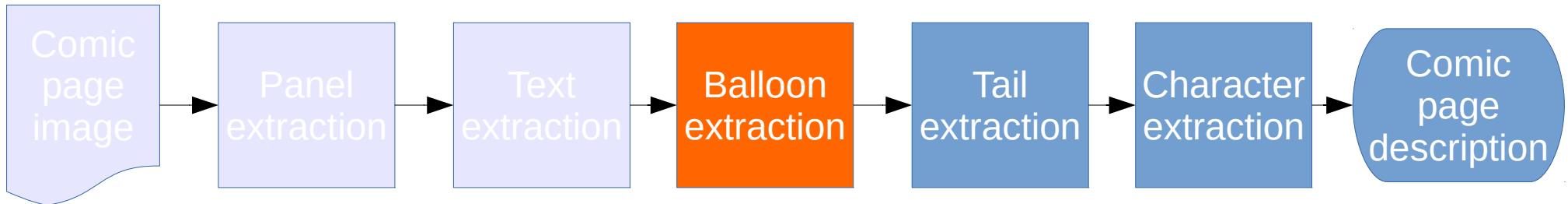


Implicit balloon

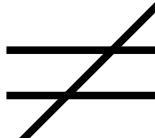
- Literature
  - Top-down approaches: extract white blobs and then text inside
  - Limited to regular balloons
- Contribution
  - Bottom-up approaches: extract text and then surrounding balloons
  - Appropriate for regular and implicit balloons

# Balloon extraction

Contributions  
Content-driven approach



Regular balloon



Implicit balloon

- Literature

- Top-down approaches: extract white blobs and then text inside [Arai2010]
- Limited to regular balloons

- Contribution

- Bottom-up approaches: extract text and then surrounding balloons
- Improvement of regular and a first approach for implicit balloon extractions

# Balloon extraction: regular

Contributions  
Content driven approach

- Assumptions
  - Panels and text block positions are known
  - Balloons contain text
  - Text is fully contained and centred in balloons
- Proposition → structural analysis
  - Extract closed contours that includes centred text

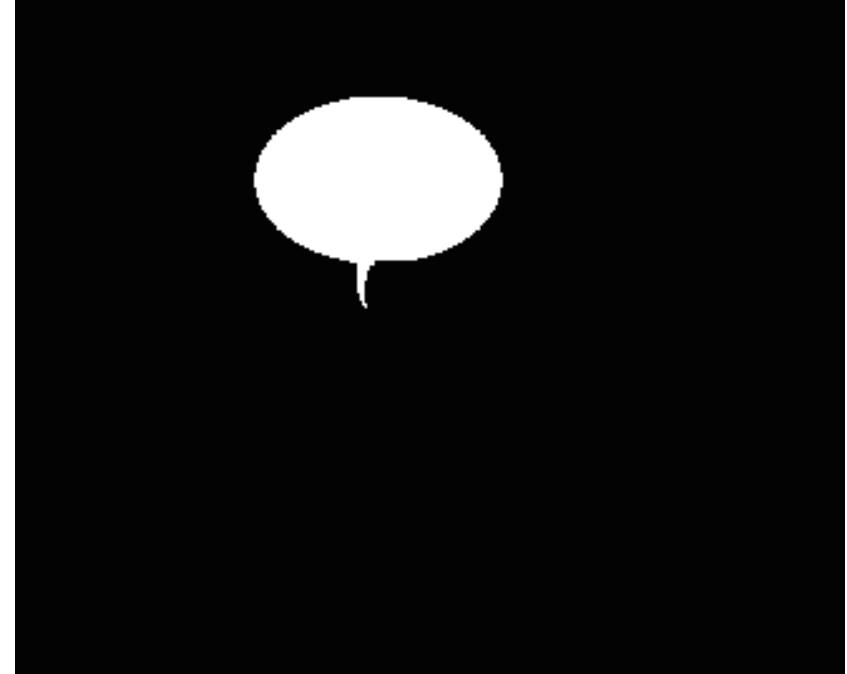
# Balloon extraction: regular

Contributions  
Content-driven approach

- Assumptions
  - Panels and text block positions are known
  - Balloons contain text
  - Text is fully contained and centred in balloons
- Proposition → structural analysis
  - Extract closed contours that includes centred text



Original image



Expected result

# Balloon extraction: regular

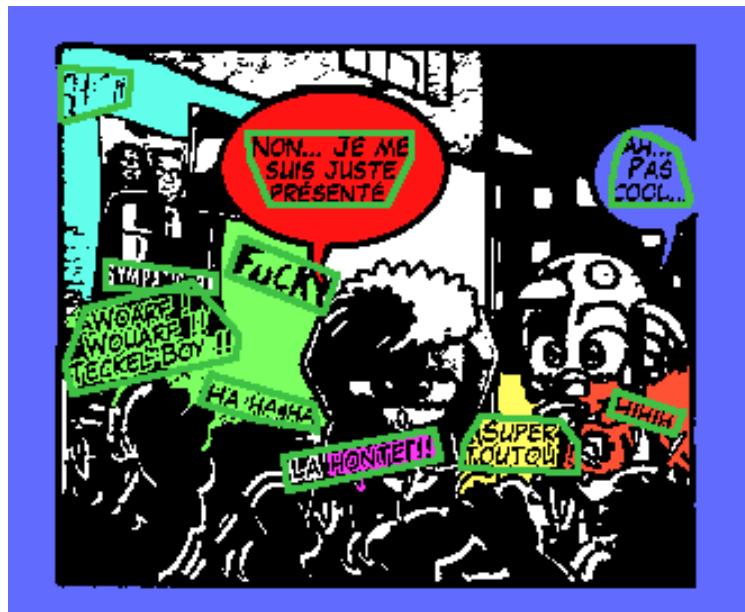
Contributions  
Content driven approach



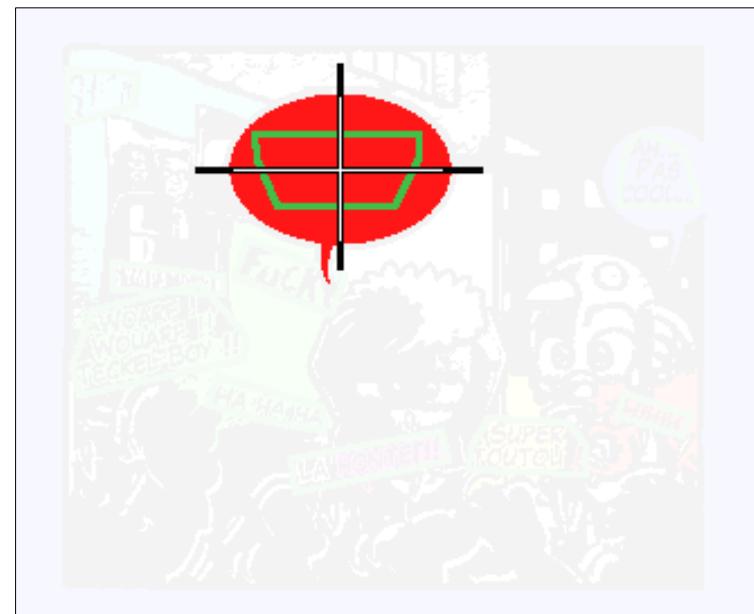
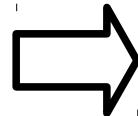
Original image



Text block positions (green)



Regions including text blocks (coloured)



Regions including aligned text block

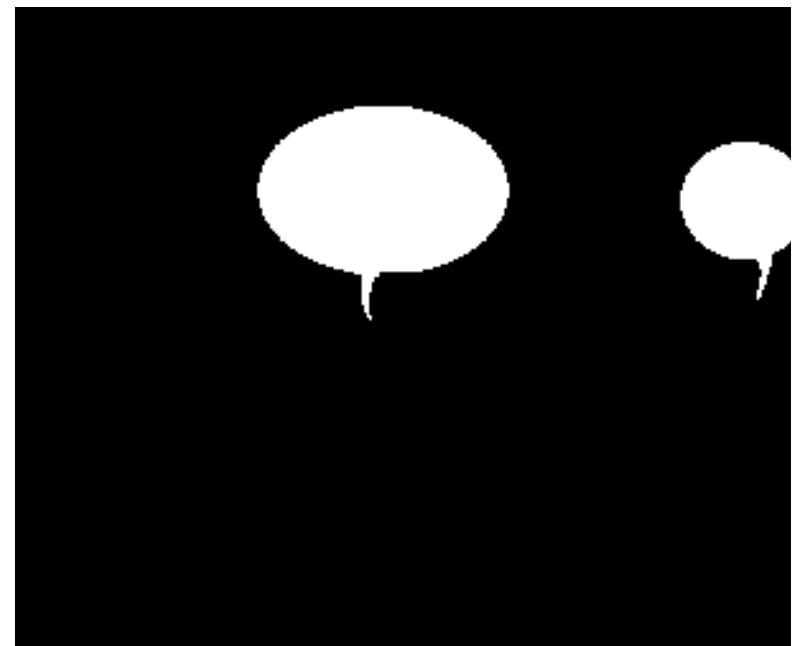
# Balloon extraction: implicit

Contributions  
Content-driven approach

- Prerequisites
  - Text block positions are known
  - Implicit balloons contain text
- Observation
  - Text is fully included and centred in balloons
- Proposition
  - Extract implicit balloons from text regions by inflating a deformable contour
  - Adaptation of active contour model (snake)



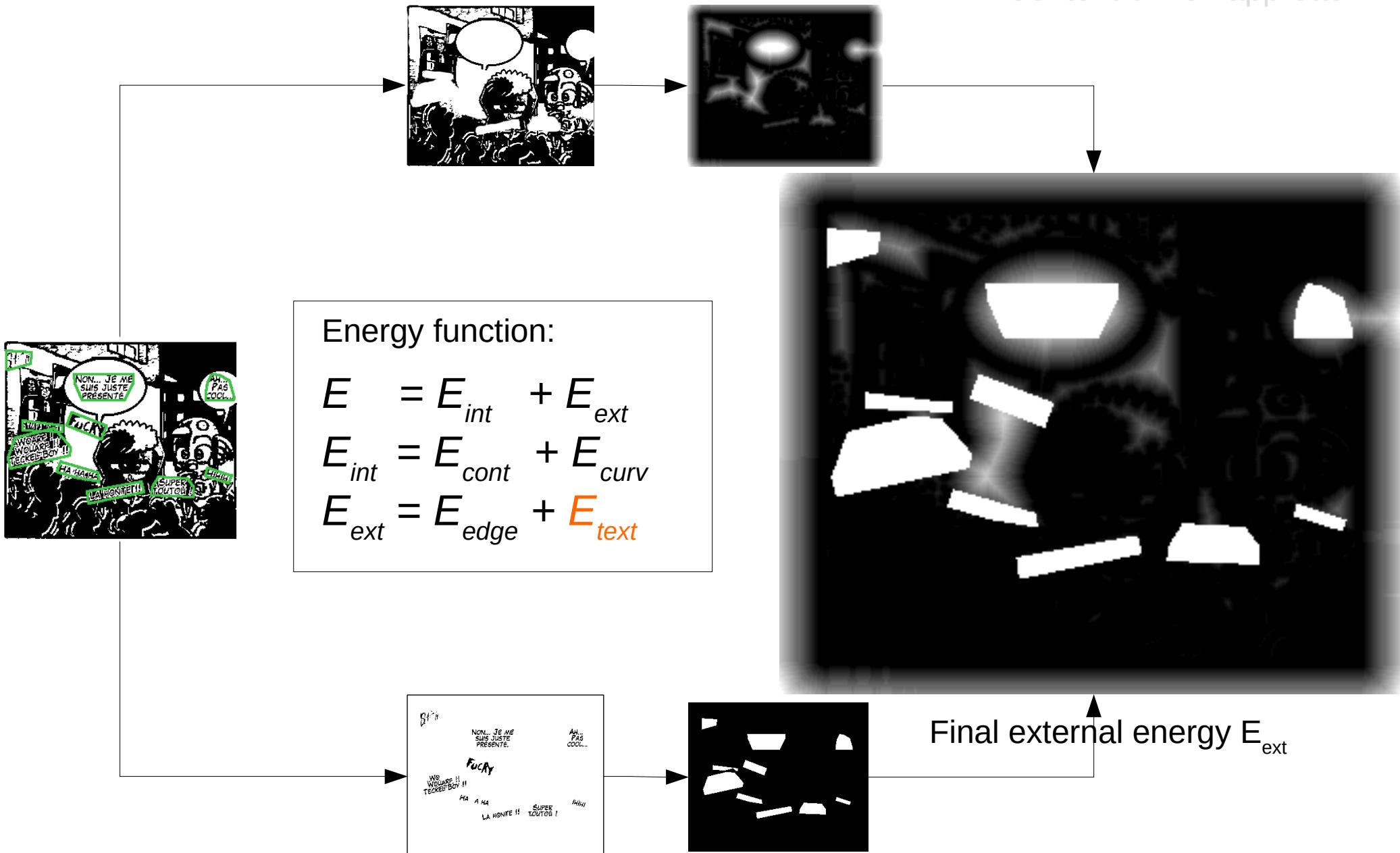
Original image and text locations



Expected result

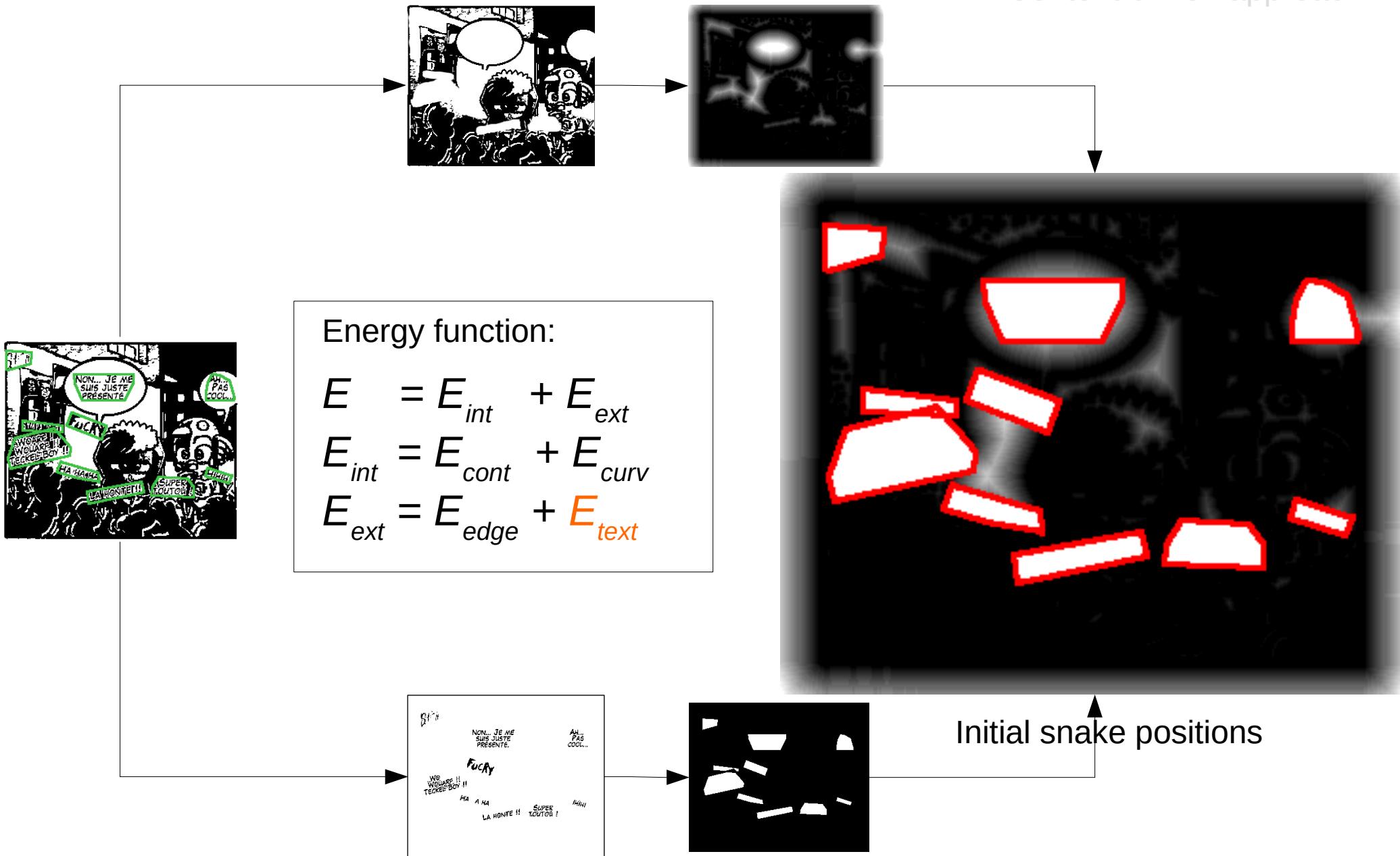
# Balloon extraction: implicit

Contributions  
Content-driven approach



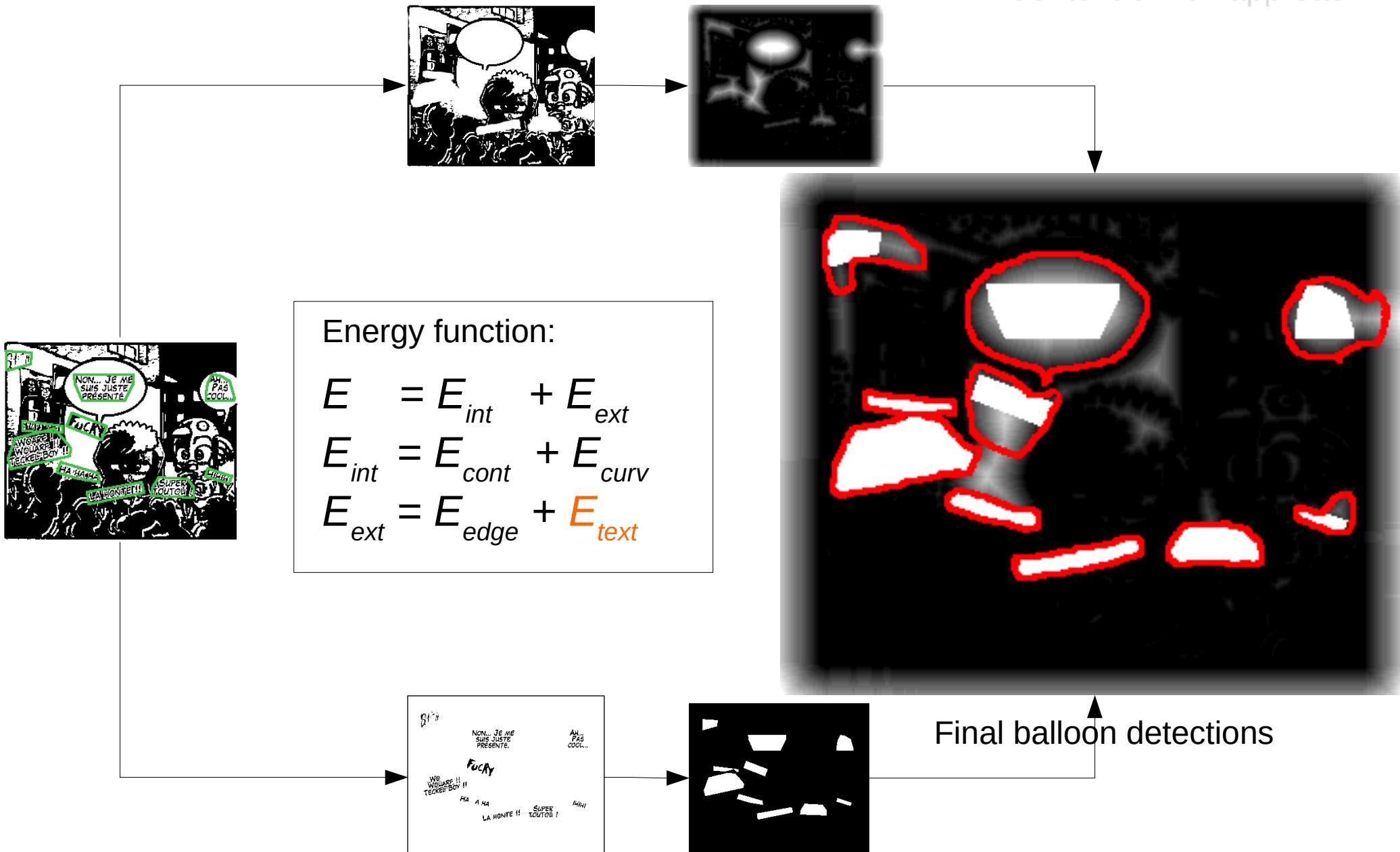
# Balloon extraction: implicit

Contributions  
Content-driven approach



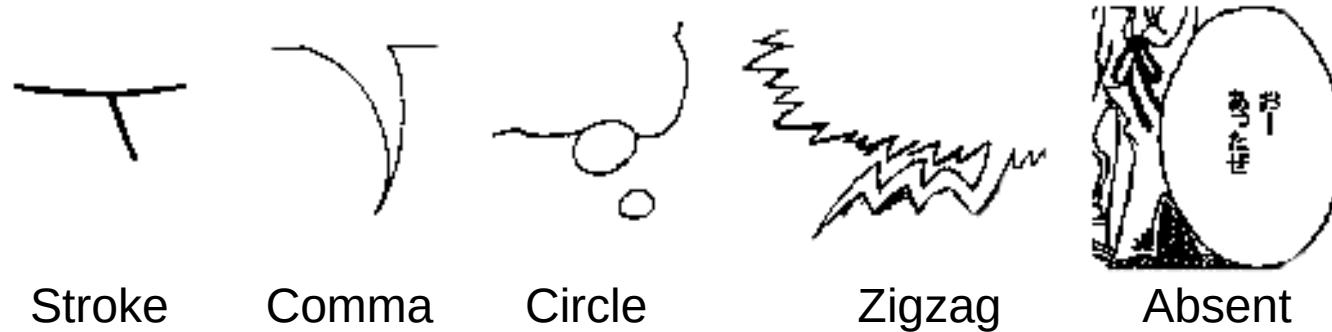
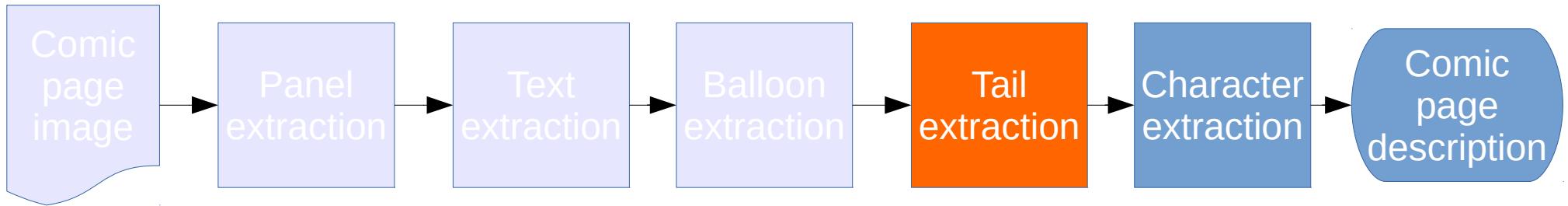
# Balloon extraction: implicit

Contributions  
Content-driven approach



# Tail extraction

Contributions  
Content-driven approach

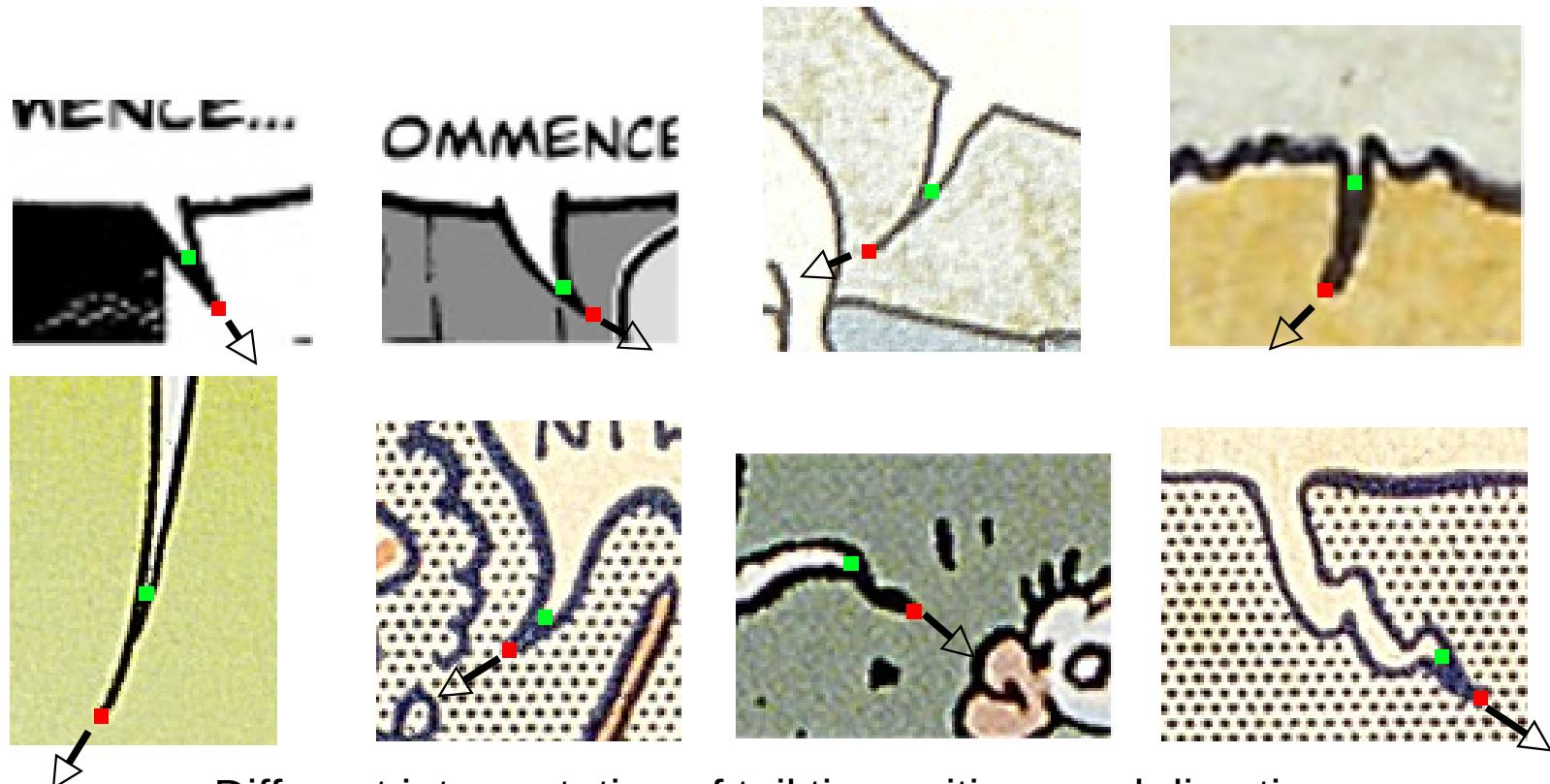


- Literature
  - First time studied in document image analysis
- Objectives
  - Detection of the tail tip position and orientation
  - Focus on comma, zigzag and absent types

# Tail extraction

Contributions  
Content-driven approach

- Tip from background
- Tip from contour
- Direction of the tail



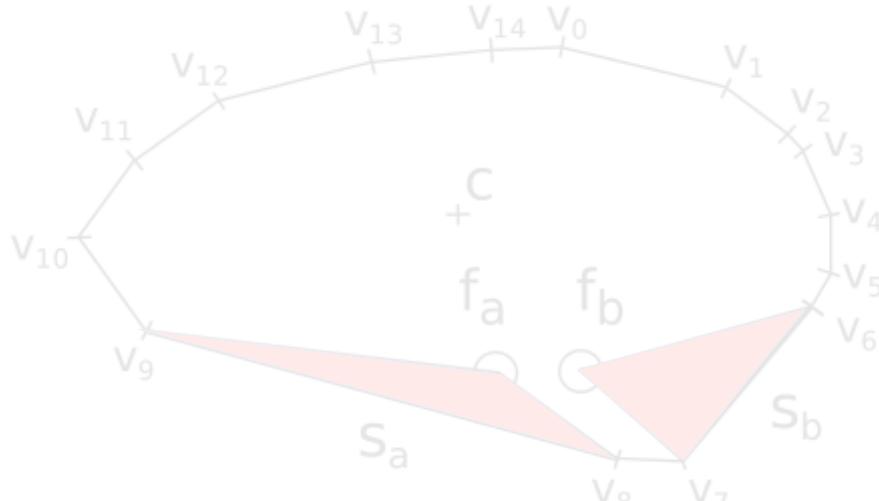
Different interpretation of tail tip positions and directions

# Tail extraction: tip position

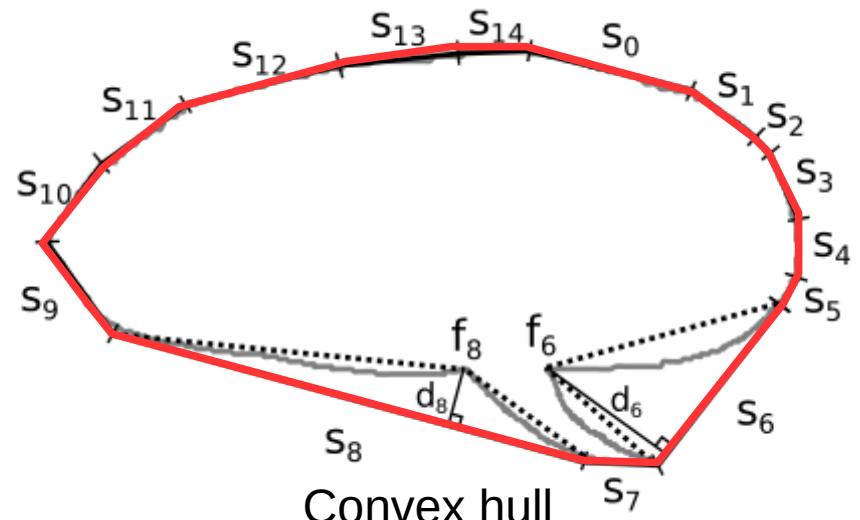
Contributions  
Content-driven approach



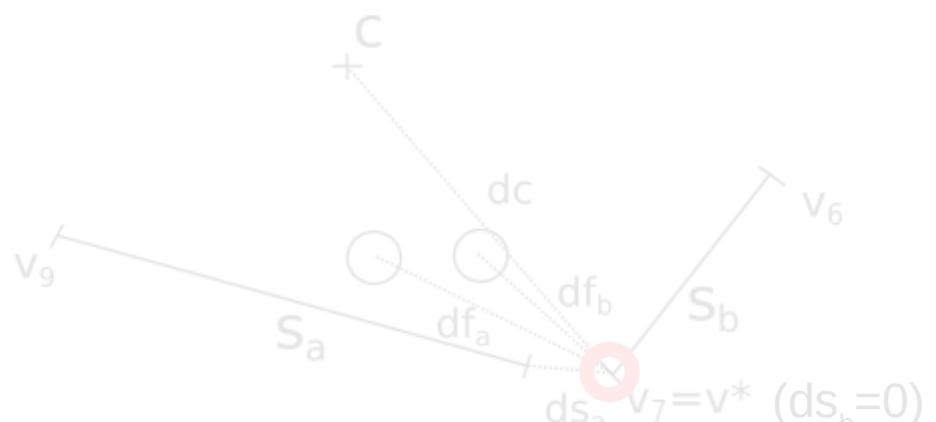
Balloon contour



Two biggest  
convexity defects



Convex hull



Tail tip position

Optimal vertex selection:

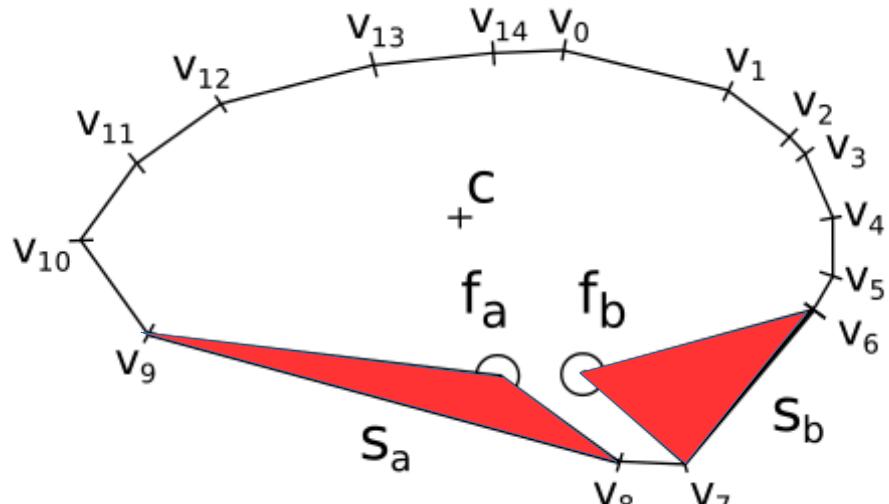
$$v^* = \operatorname{argmax}(\max(dc + df_a + df_b) + \min(ds_a + ds_b))$$

# Tail extraction: tip position

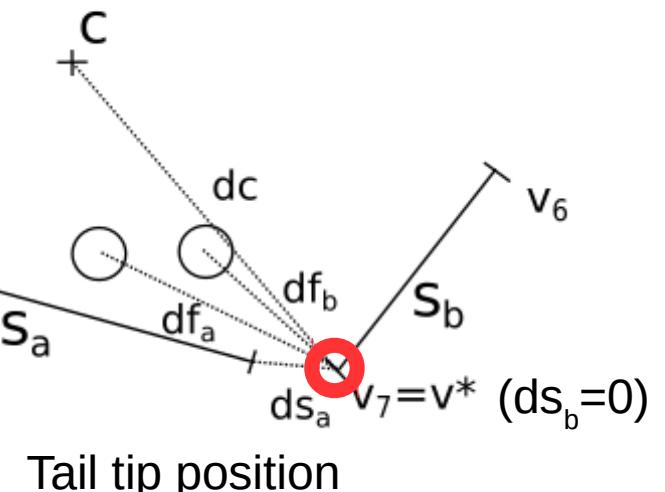
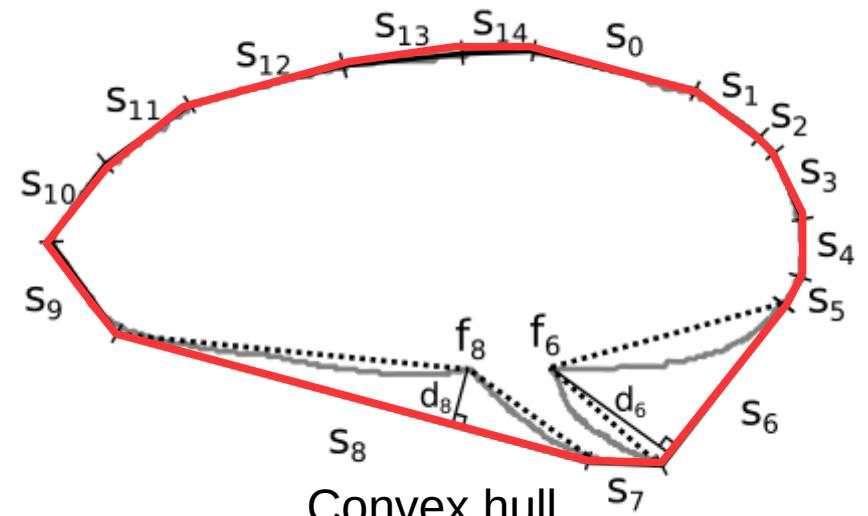
Contributions  
Content-driven approach



Balloon contour



Two biggest  
convexity defects



Optimal vertex selection:

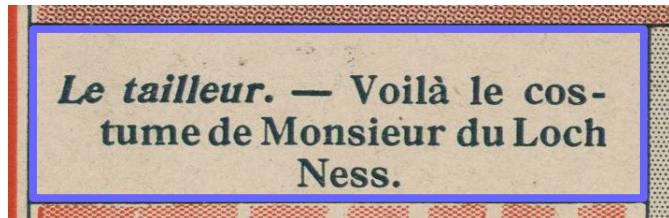
$$v^* = \operatorname{argmax}(\max(dc + df_a + df_b) + \min(ds_a + ds_b))$$

# Tail extraction: confidence value

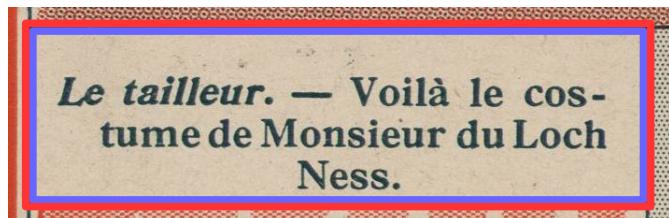
Contributions  
Content-driven approach

Balloon  
contour (blue)

Balloon 1



Convex hull  
(red)



Confidence

$$C_{tail} = \frac{(d_a + d_b)/2}{meanBalloonSize}$$

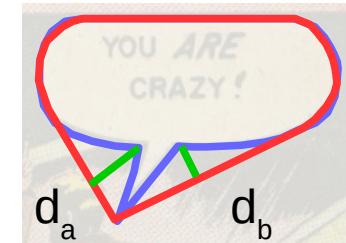
$$C_{tail} = 0.0$$

Presence of tail

NO

$$C_{tail} = 0.73$$

YES (>0)



# Tail extraction: tail direction

Contributions  
Content-driven approach

- Definition
  - Vector starting from “background” to “external edge” tail tip positions
- Approach
  - Extract **external edge**
  - Find **external edge tail tip coordinates**
  - Define the **tail direction** (N, NE, E, SE, S, SW, W, NW)



Background tail tip  
(green) and  
external edge (blue)



Closest point on  
external edge  
(red)



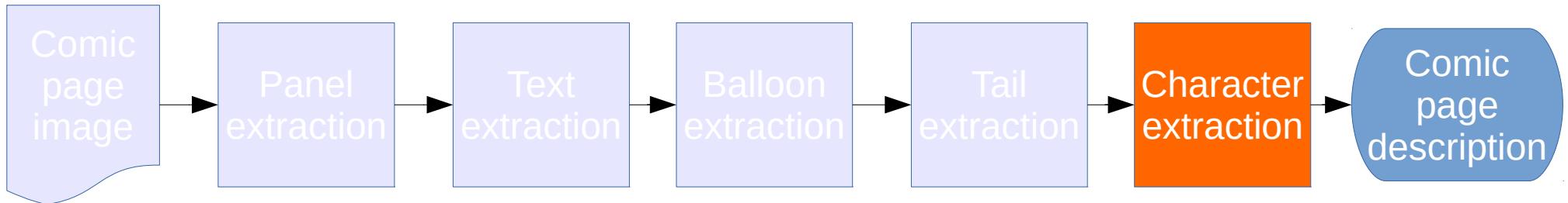
Farthest point  
from origin and tip  
(red)



Direction from tip  
to farthest point  
(white arrow)

# Comic character extraction

Contributions  
Content-driven approach

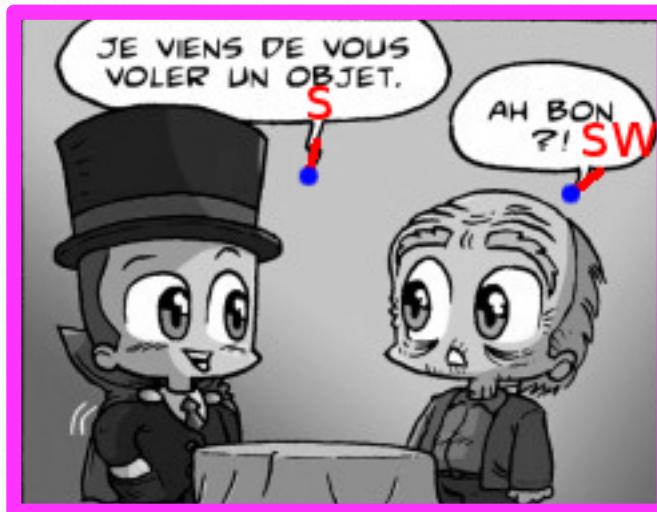


- Literature
  - Supervised approaches for manga and cartoon characters [TODO]
  - No public dataset (copyright issues)
- Challenges
  - Variety of styles of comic books
  - Intra and extra class variations of each character instance (e.g. position, scale, pose, occlusion and human-like, invented)
- Objective
  - Unsupervised and generic approach for all styles of comic books

# Comic character extraction

Contributions  
Content-driven approach

Panels + Tails = ?



# Comic character extraction

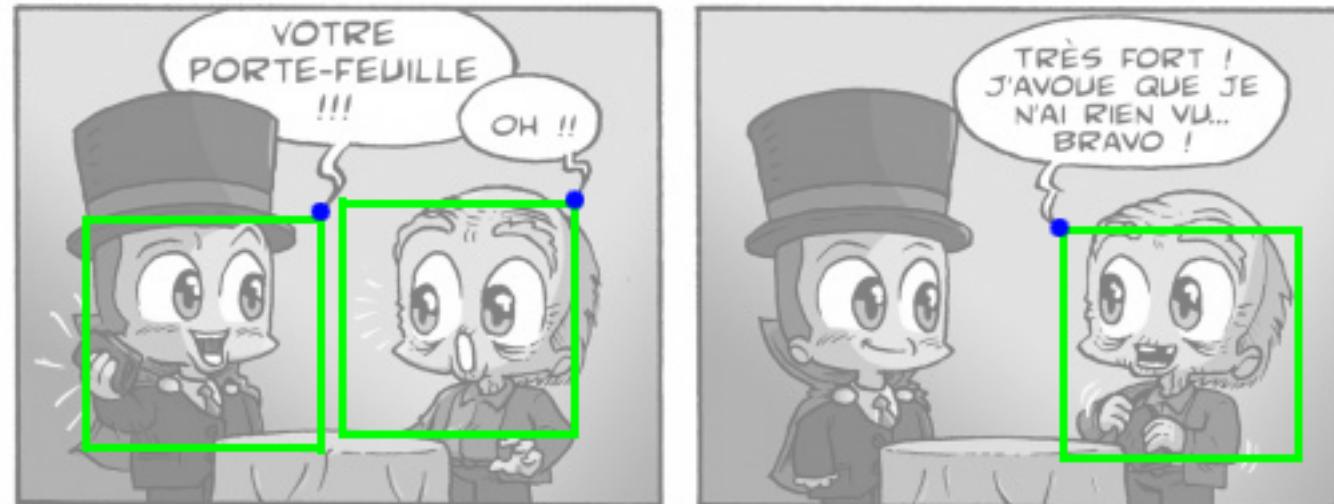
Contributions  
Content-driven approach

Panels + Tails = Comic character ROIs

Large ROI



Small ROI



- Introduction
- Content-driven approach
- Knowledge-driven approach
  - Introduction
  - Knowledge models
  - Processing sequence
  - Conclusion



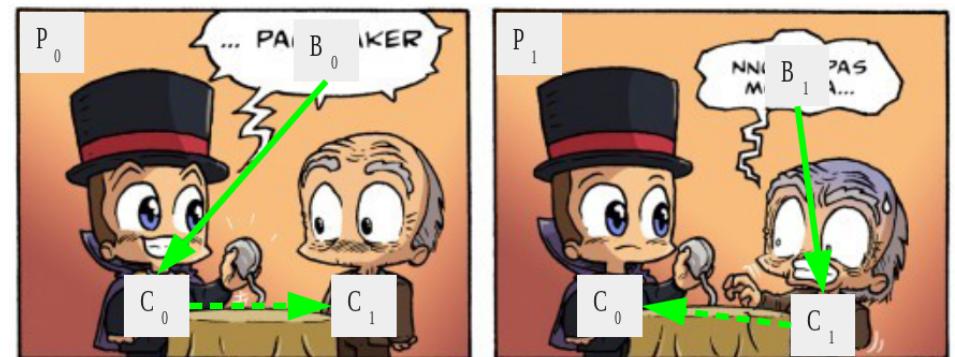
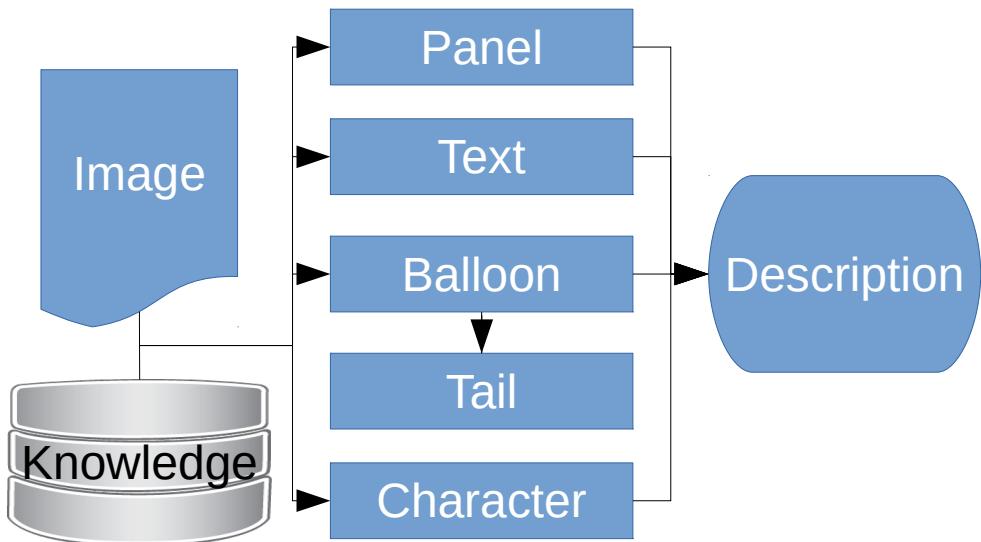
Colouring. Image credits: Le cycle des bulles, Christophe Rigaud, 2012

# Introduction

# Contributions

Knowledge-driven approach

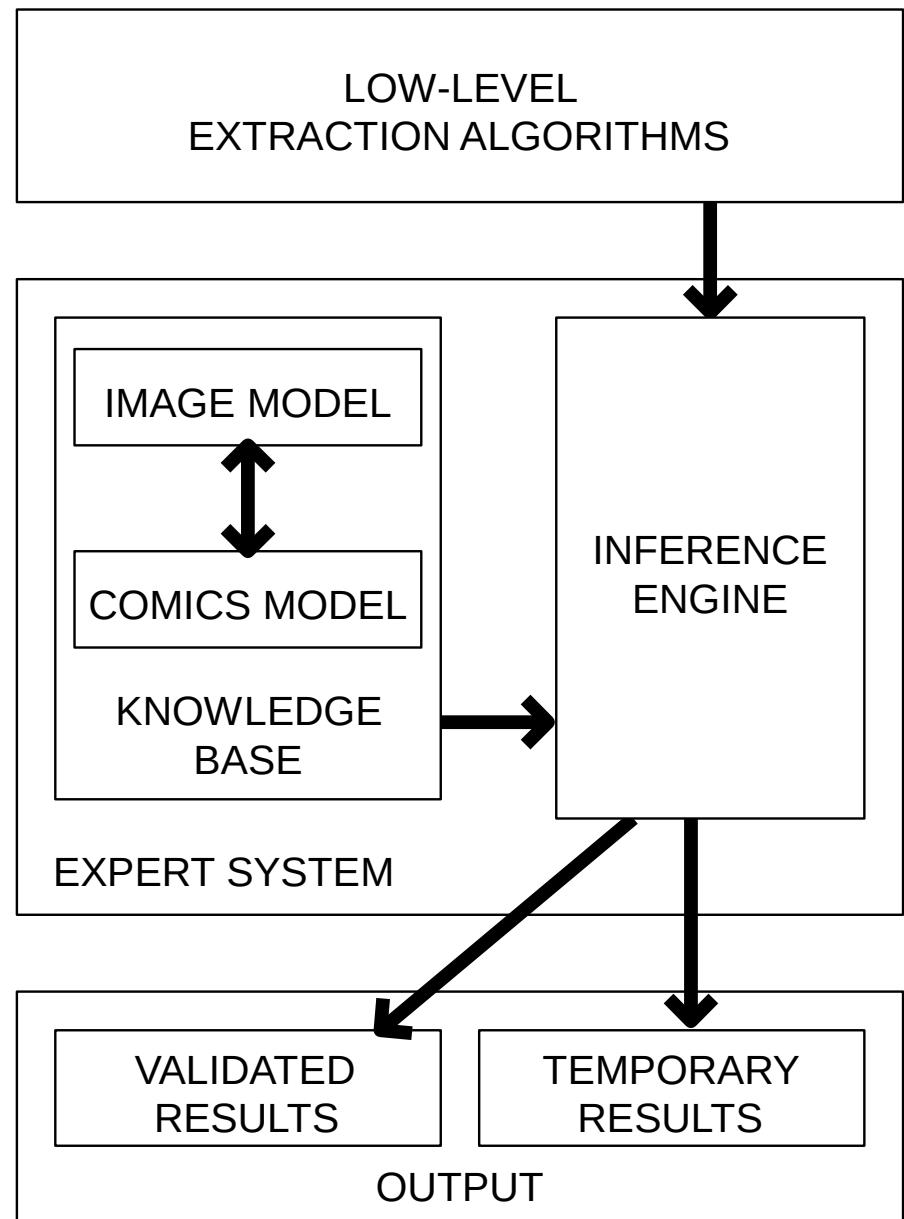
- Objective
  - High level image description for **comics understanding** (retrieve semantic information)
  - **Independent element extraction** (prevent error propagation)
  - **Collaboration** with Clément Guérin (Ph.D student from the same project)
- Process flow



Example of situation understanding

# Knowledge models

- Image domain model
  - Comics image analysis
- Comics domain model
  - Validations
    - A panel **P** is related to one page
    - A balloon **B** is related to one panel and may have a tail **Q**
    - A character **C** is related to one panel
    - A text line **T** is related to one balloon
  - Inferences
    - **B + Q + T => speech balloon SB**
    - **SB + T => speech text ST**
    - **SB + C => speaking character SC**



# Processing sequence

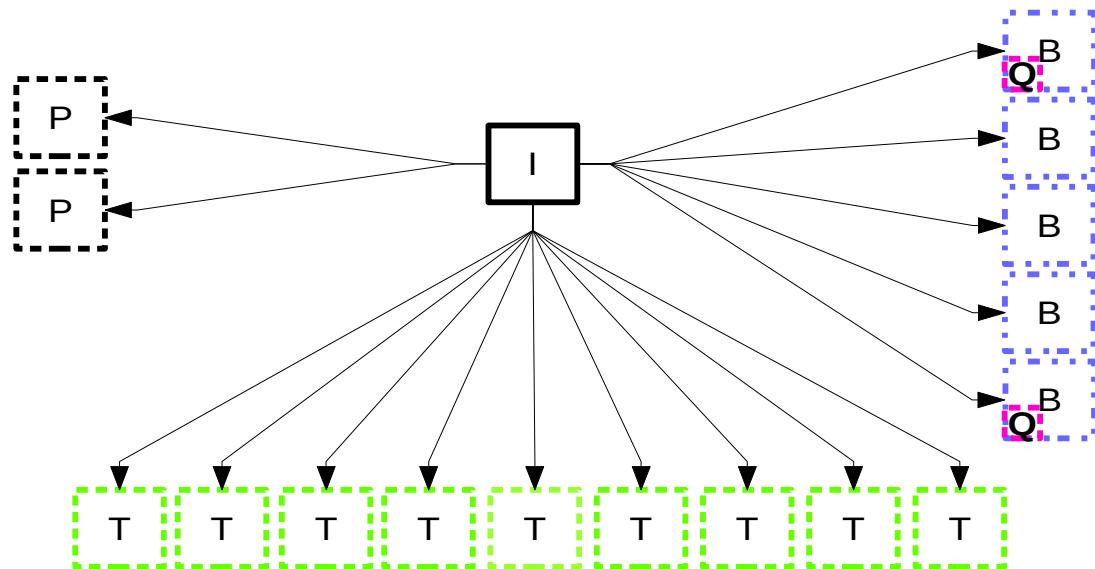
Contributions  
Knowledge-driven approach

- Process loop
  - Step 1: **formulate** hypothesis
  - Step 2: **validate** hypothesis
  - Step 3: **infer** new information
- Study case
  - Iteration 1
    - Step 1: hypotheses of **simple element** positions
    - Step 2: validation of the positions
    - Step 3: inference a new information
  - Iteration 2
    - Step 1: hypotheses of **more complex** elements
    - Step 2: validation of the positions
    - Step 3: inference a new information
  - ...

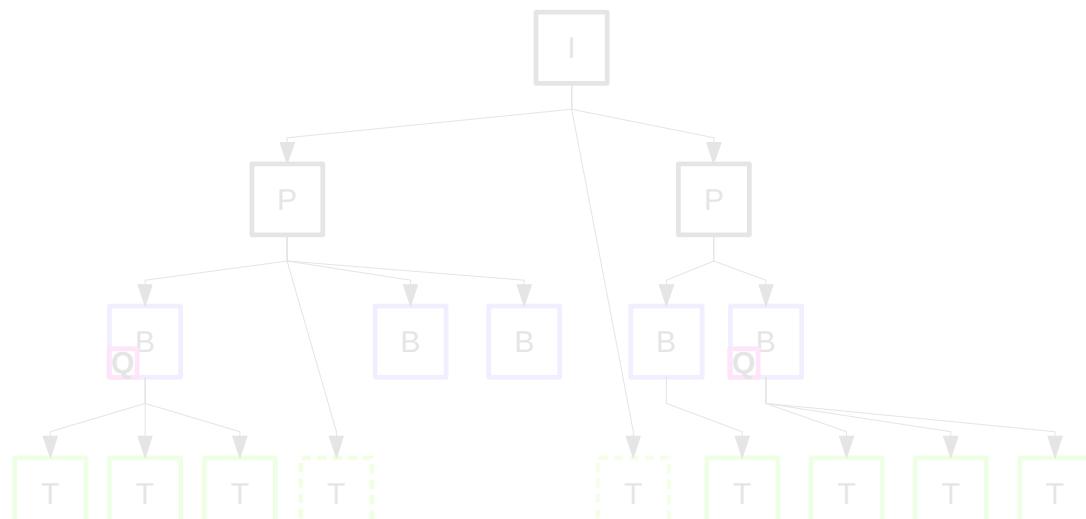


# Processing sequence 1/2

## Step 1: formulation of hypotheses

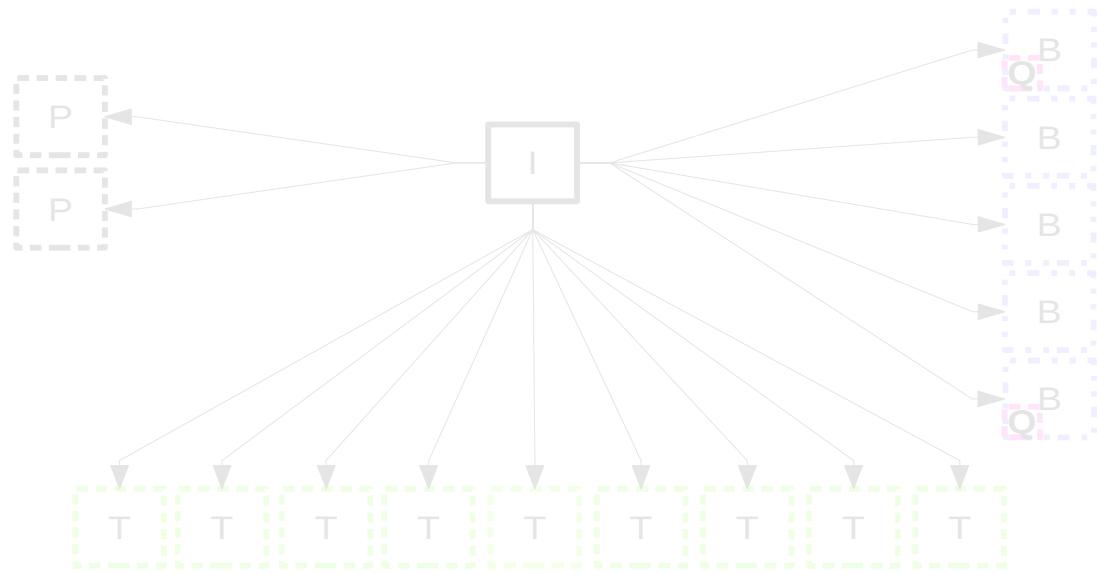


## Step 2: validation of the hypotheses

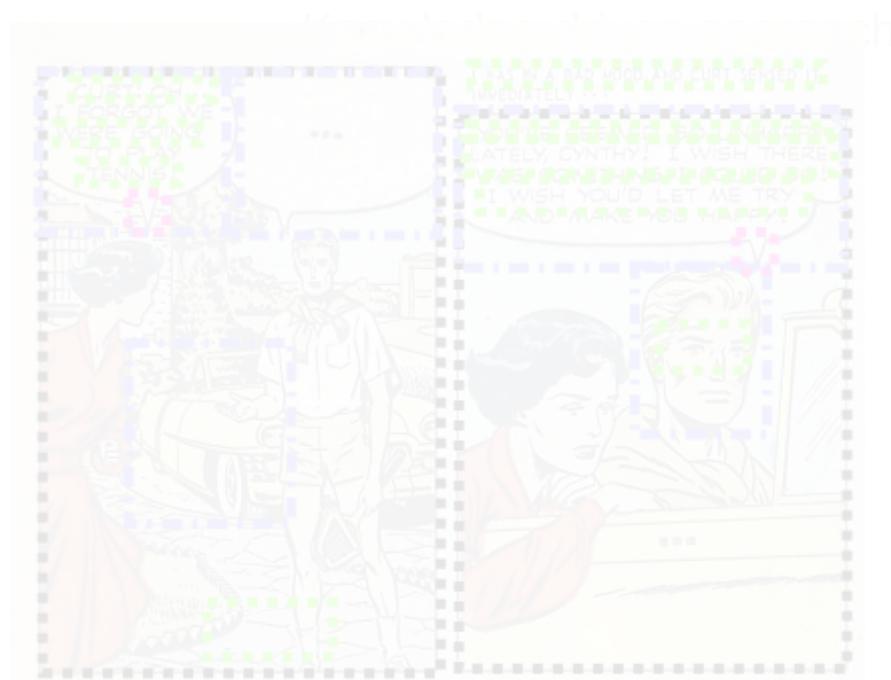


# Processing sequence 1/2

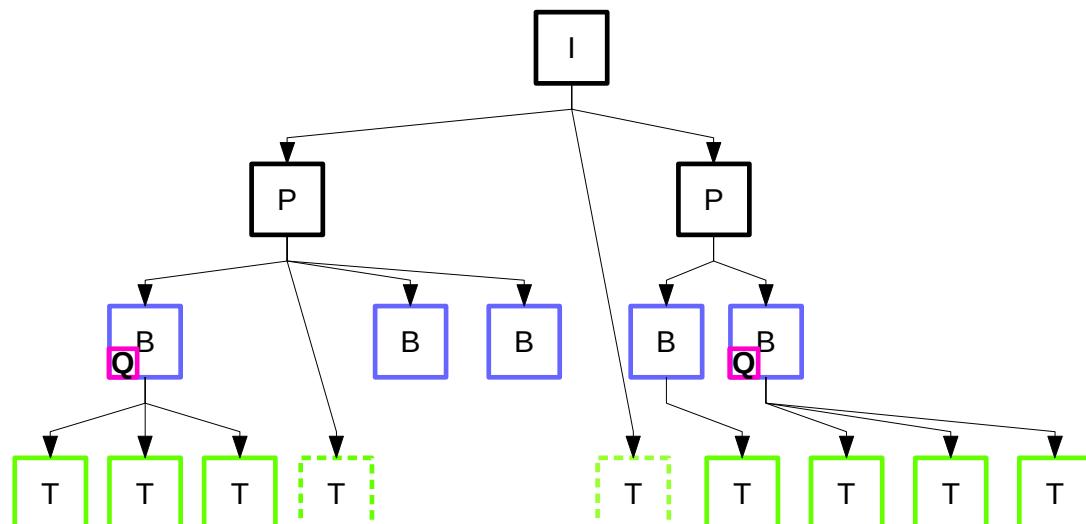
Step 1: formulation of hypotheses



# Contributions



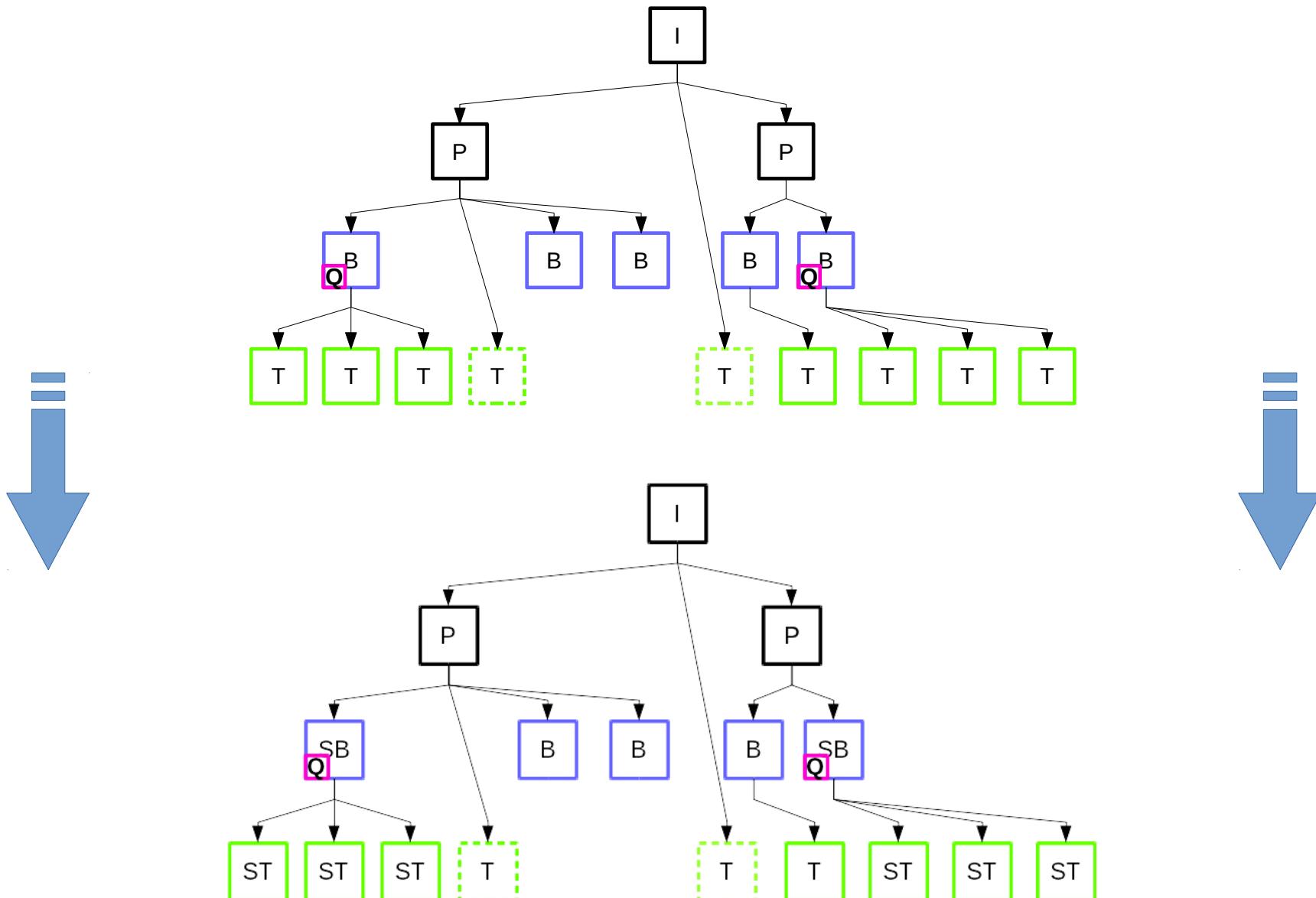
Step 2: validation of the hypotheses



# Processing sequence 1/2

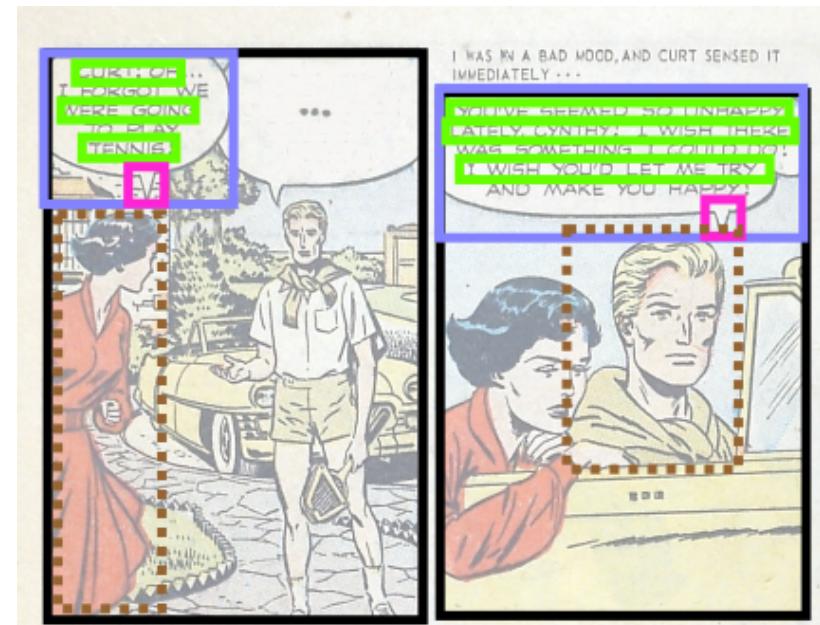
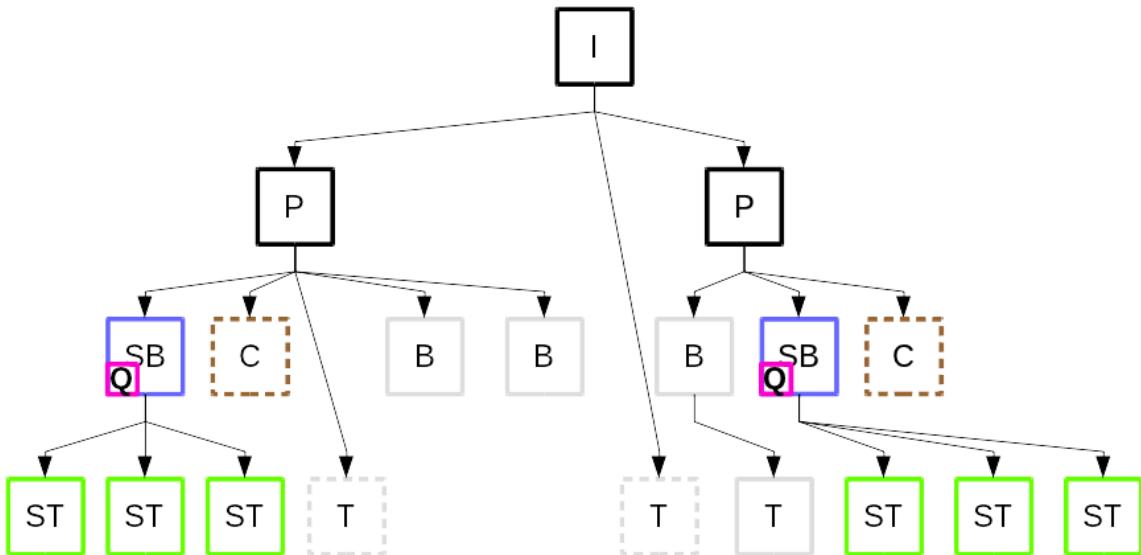
Contributions  
Knowledge-driven approach

Step 3: inference of new information

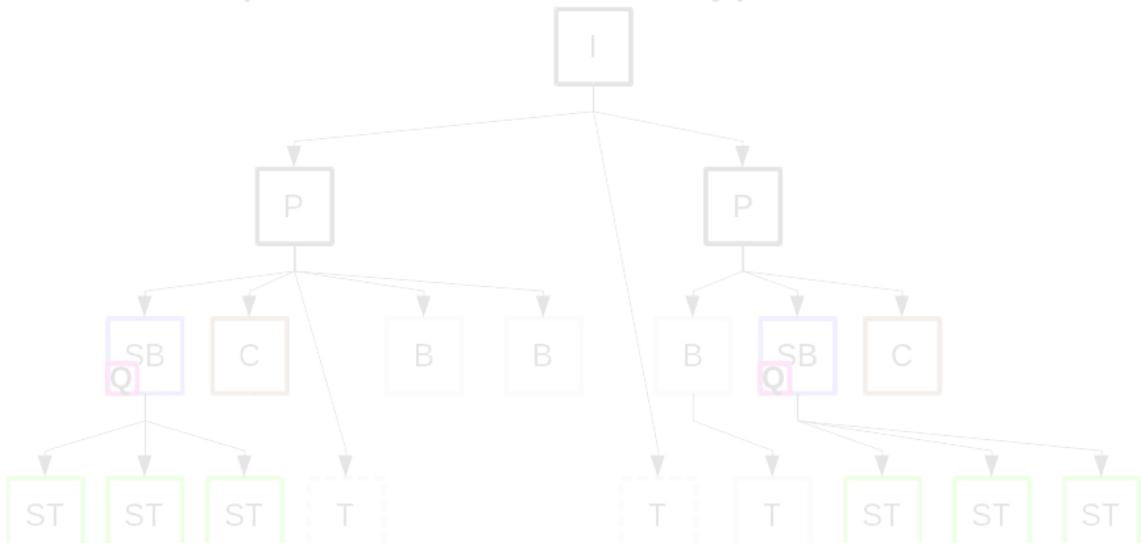


# Processing sequence 2/2

## Step 1: formulation of hypotheses

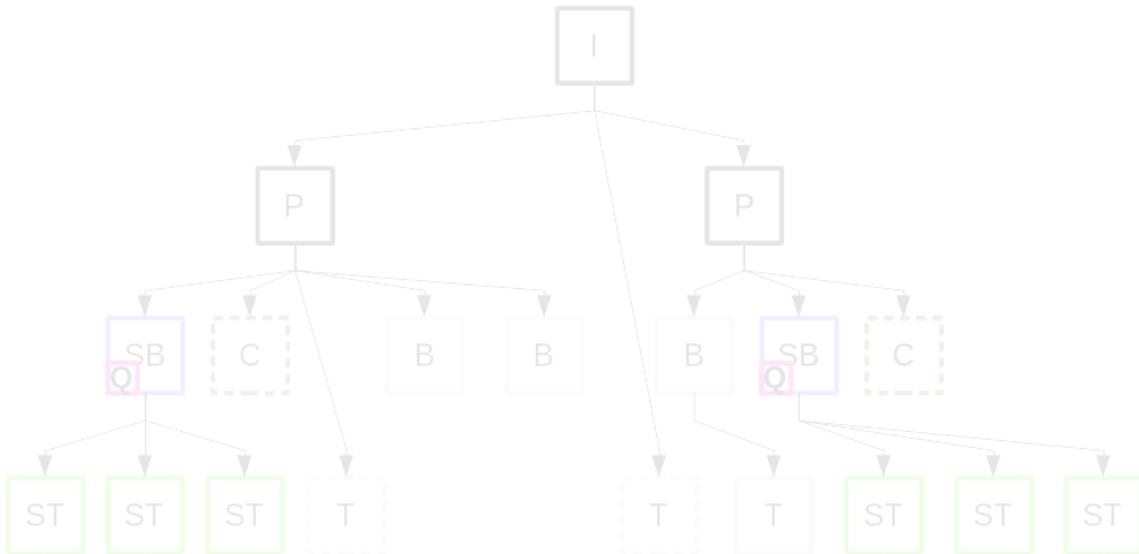


## Step 2: validation of the hypotheses

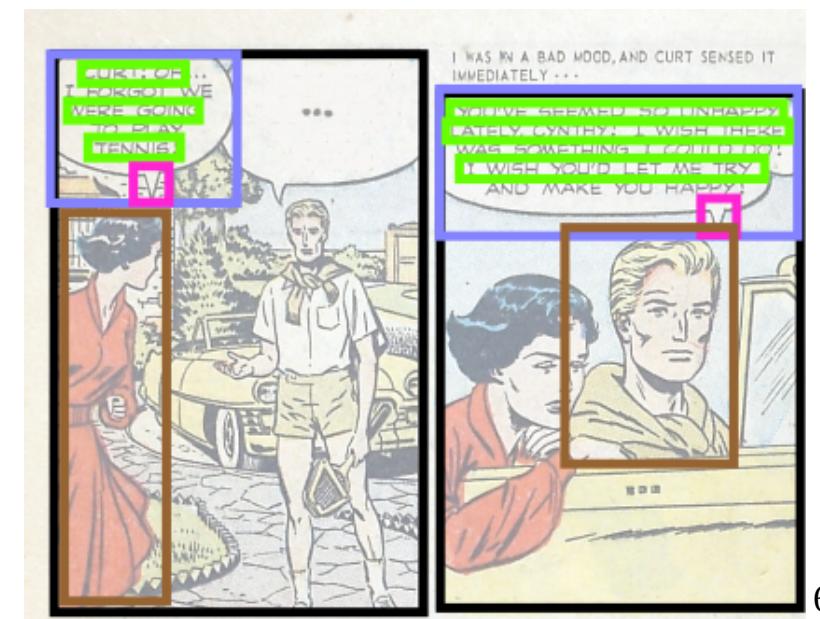
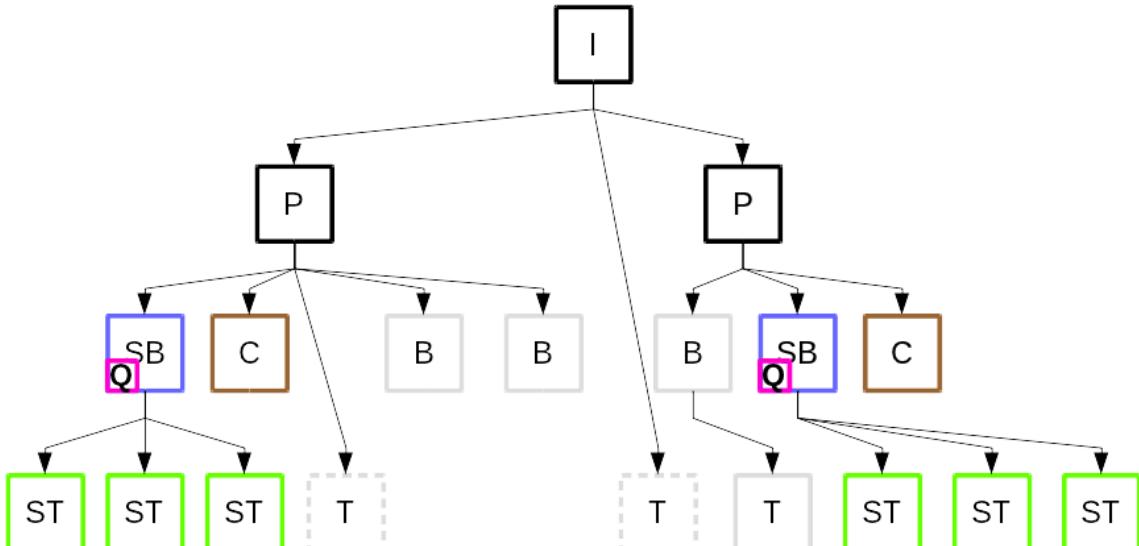


# Processing sequence 2/2

Step 1: formulation of hypotheses



Step 2: validation of the hypotheses

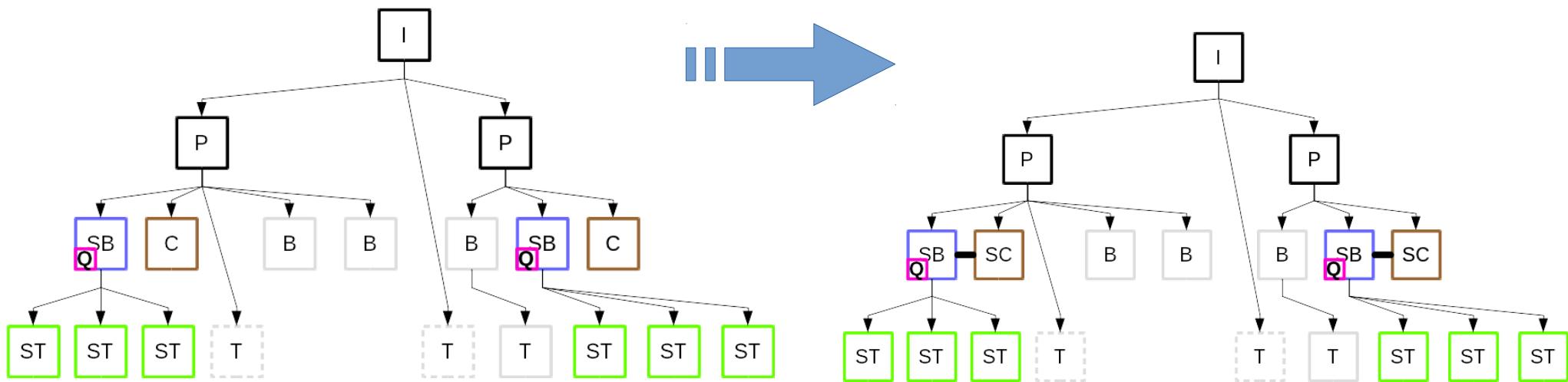


Contributions  
Knowledge-driven approach

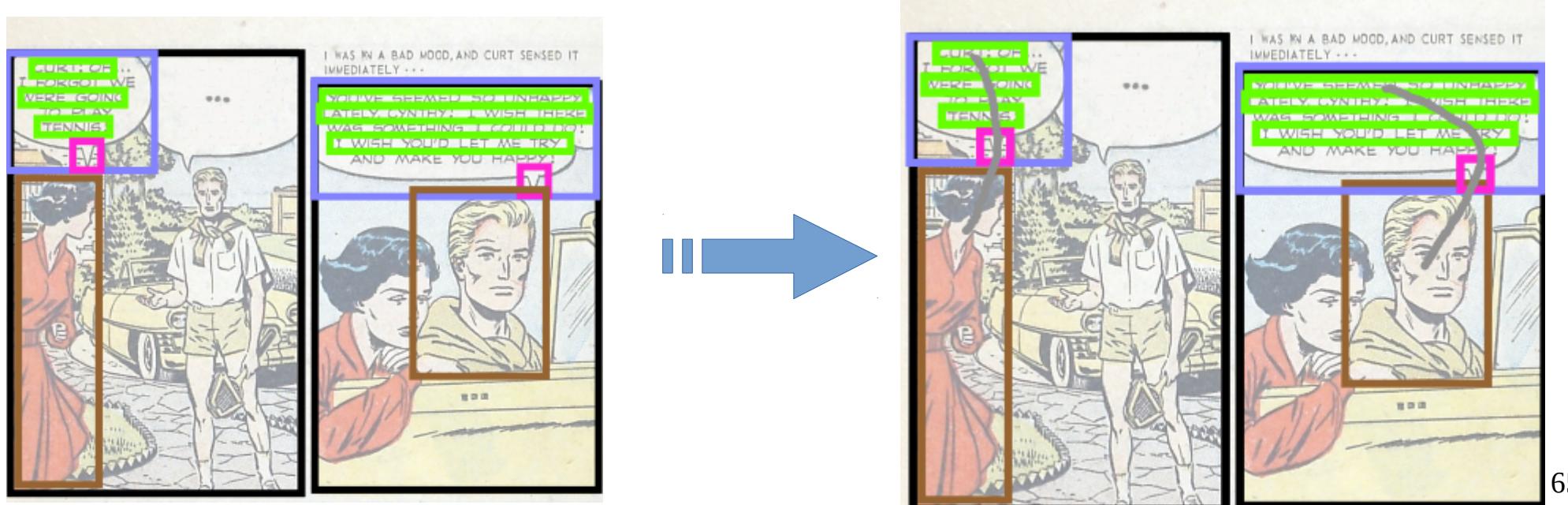
# Processing sequence 2/2

Contributions  
Knowledge-driven approach

Step 3: inference of new information



Final information about the image



- Dataset and ground truth
- Evaluations
- Conclusions



Lettering. Image credits: Le cycle des bulles,  
Christophe Rigaud, 2012

# Dataset and ground truth

# Experiments

- Absence of public dataset
- Creation of heterogeneous dataset
  - 100 mixed pages from 20 albums
  - Franco-Belgium “bandes dessinées”, American comics and Japanese manga
  - From 1905 to 2012, paper and webcomics
  - Rights holder permissions agreement
- Online: <http://ebdtheque.univ-lr.fr>

## Bibliographic annotations



**PAGE** (100)  
**Collection:** Chilling Tales  
**Album:** 17 Geo  
**Editor:** Youthful Magazines  
**Drawer:** Matt Fox  
**Writer:** Matt Fox  
**Language:** English  
**Page number:** 16  
**Release date:** 1953

## Visual and semantic annotations



**PANEL** (850)  
**Rank:** 1  
**BALLOON** (1092)  
**Rank:** 2  
**Shape:** Oval  
**Tail direction:** South-West  
**TEXT LINE** (4691)  
**Text:** « STARK RAVING »  
**CHARACTER** (1550)  
**LinkedToBalloon:** 2

# Evaluations

# Experiments

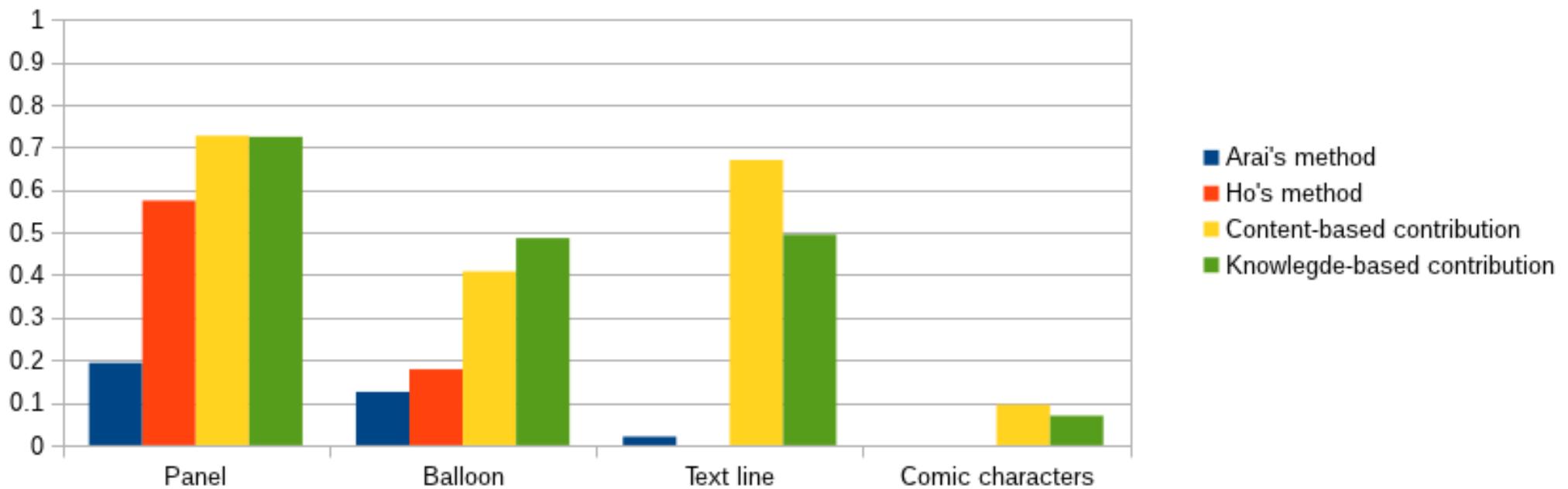
$$a_0 = \frac{\text{area}(B_p \cup B_{gt})}{\text{area}(B_p \cap B_{gt})}$$

$B_p$  = predicted region

$B_{gt}$  = ground truth region

$B_p$  valid if  $a_0 > 0.5$

Element localisation results (F-score)



- Global conclusions
- Global perspectives
- Publications



Lettering. Image credits: Le cycle des bulles,  
Christophe Rigaud, 2012

# Global conclusions

# Conclusion

- Reached objectives
  - Comics **image segmentation** and understanding
  - 3 years
- Contributions of the thesis
  - Comic book content **extraction** methods **improvement**
  - **First approaches** for tail detection, balloon classification and speaker extraction
  - Public **dataset** and ground truth
- Research impacts
  - **L3i** is now a **main actor** of comic book analysis in Europe
  - New Ph.D. **thesis** started in 2013 (Nam Le Thanh)
  - **Dataset** used by international peers ()
  - **National projects** (PIA Actialuna + LIP6, ANR 2015 EXPION)
  - **International project** on manga analysis (Campus France SAKURA)

- Retrieve implicit, overlapping and connected panels
- Deeply investigate text extraction and recognition
- Improve implicit and external border balloon extraction and evaluation
- Non-speaking comic character extraction and identification
- Increase the number of pages of the eBDtheque dataset
- Continue to enrich the ground truth (e.g. panel view angle and situation, text tone, multi-part character segmentation, character names and roles)

# Publications

# Conclusion

Thank you + github + c-r

Conclusion