European Ph.D. defense

Segmentation and indexation of complex objects in comic book images

Christophe Rigaud
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Co-supervised by:

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Dimosthenis Karatzas[2]
Jean-Marc Ogier[1]

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Comic books

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Wikipédia, 2014

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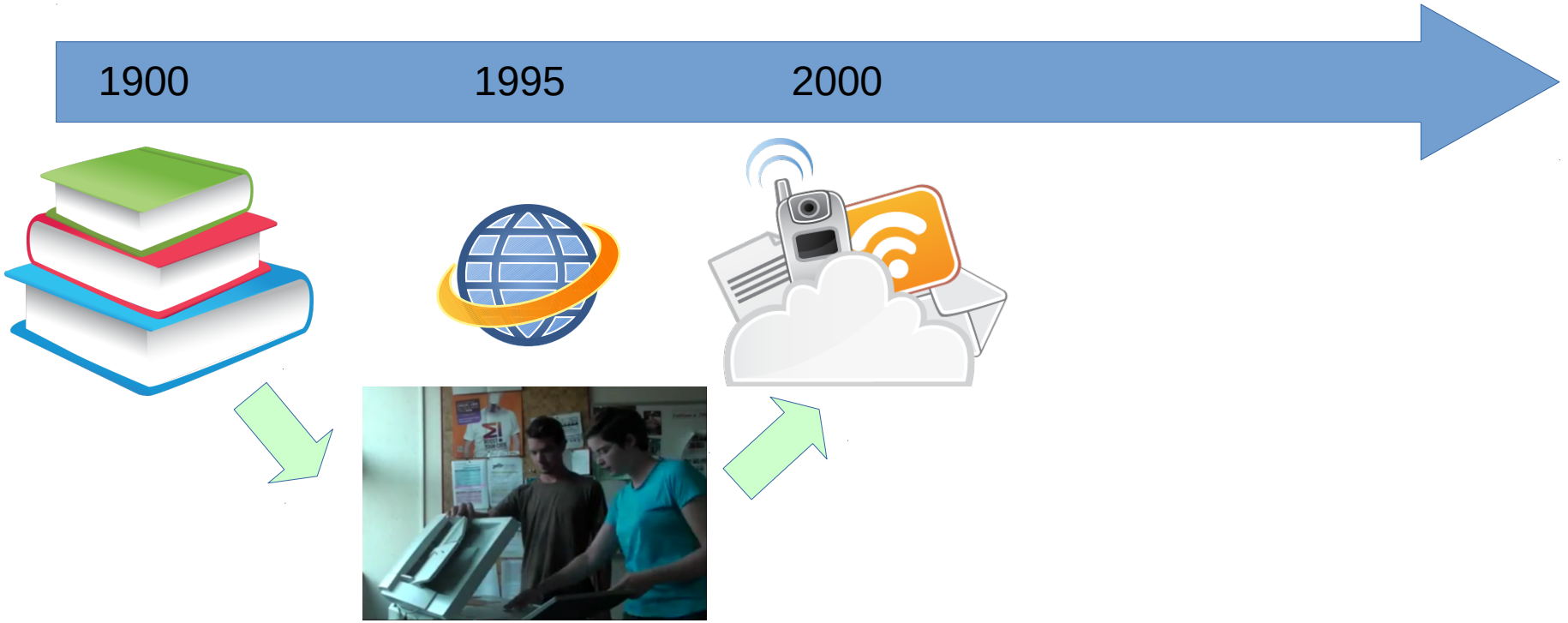

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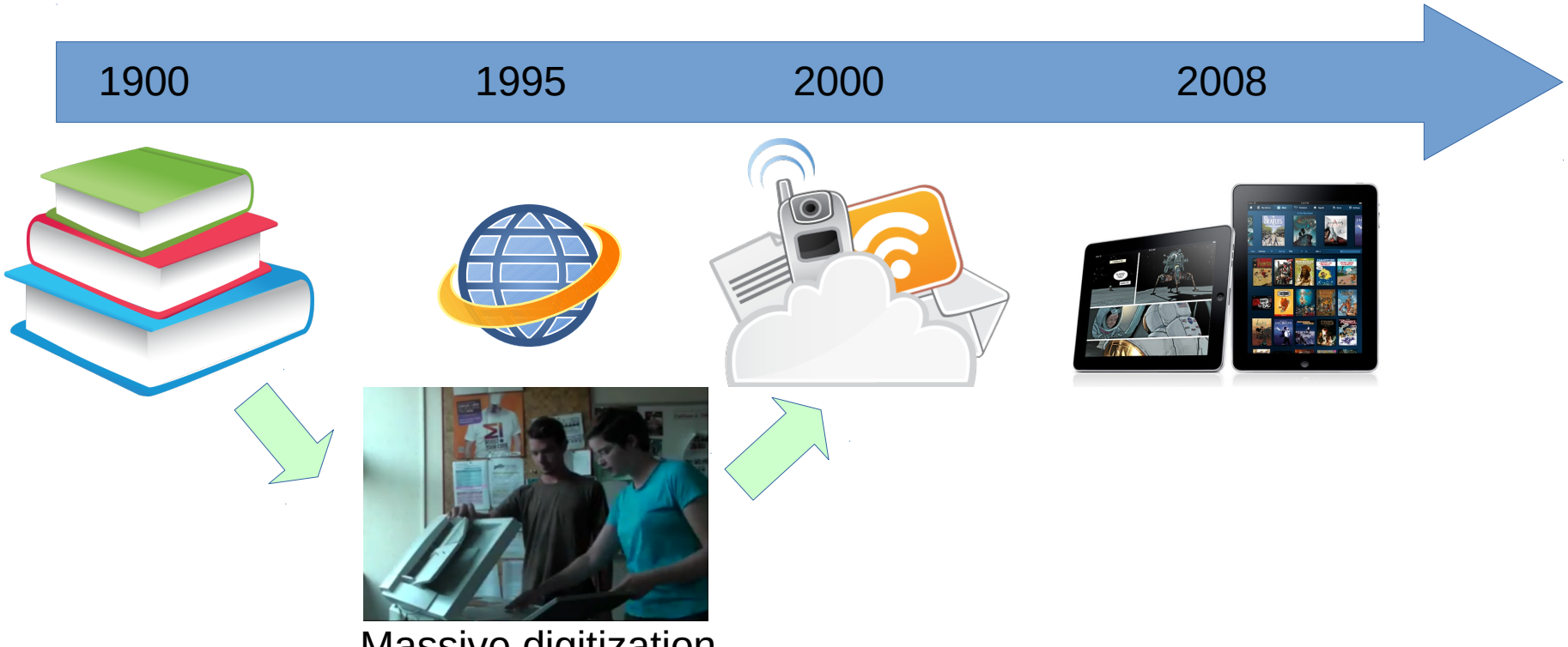
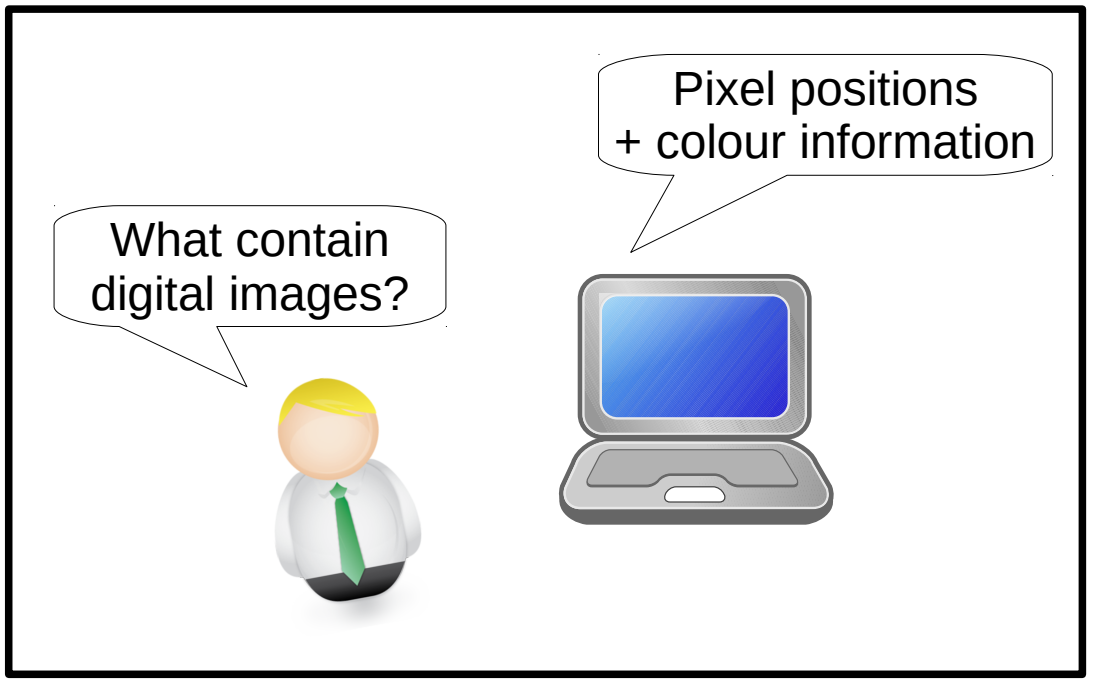
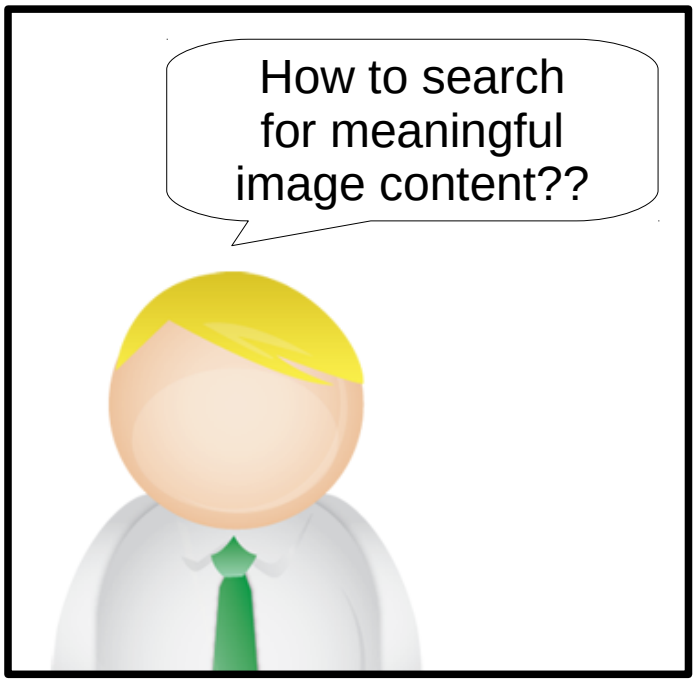


Problematic





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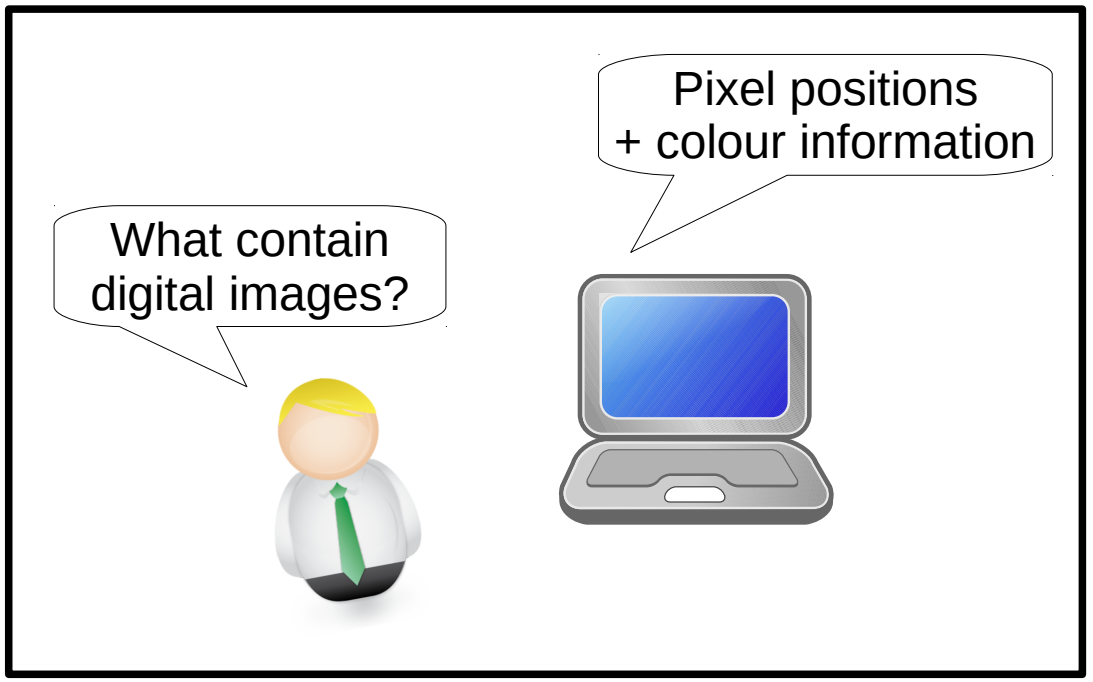

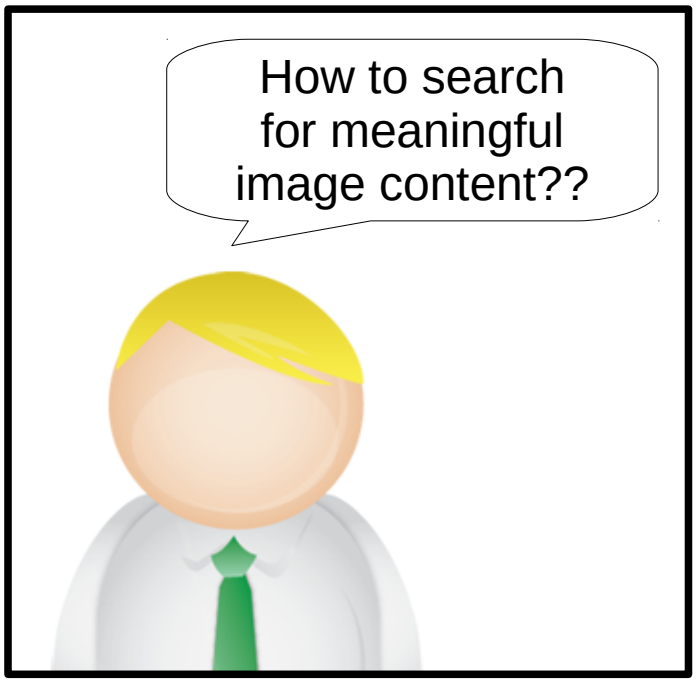

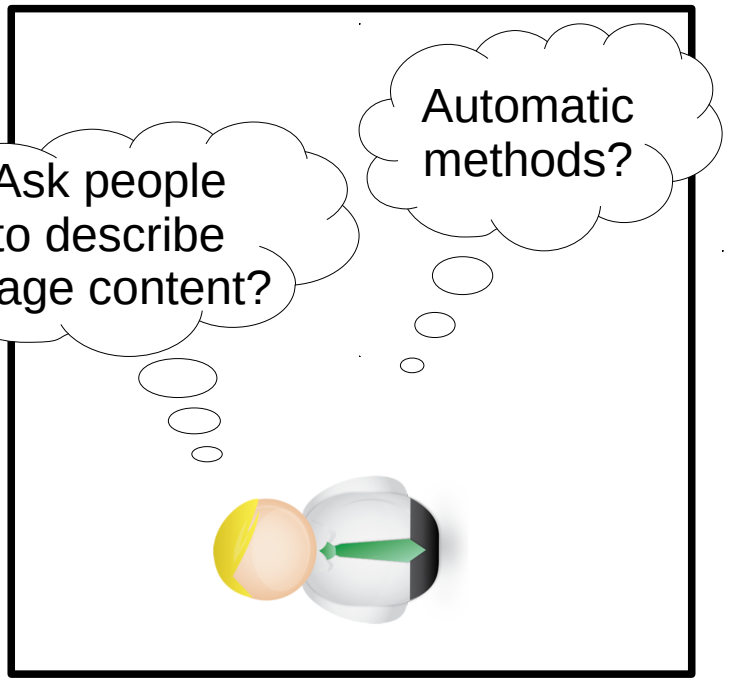

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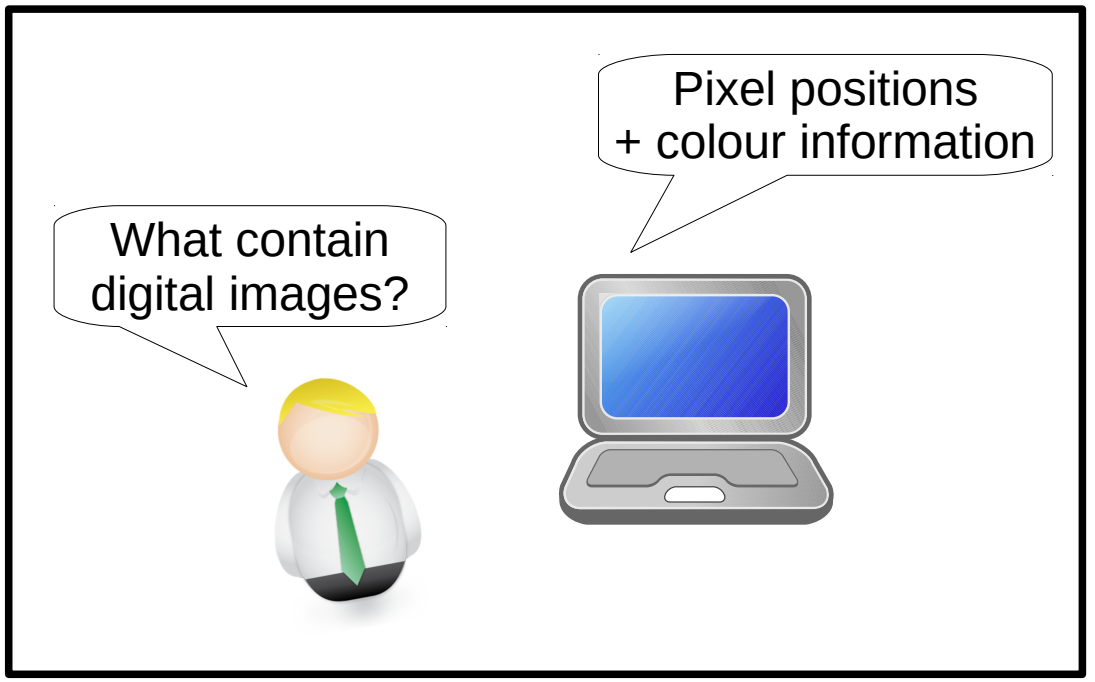

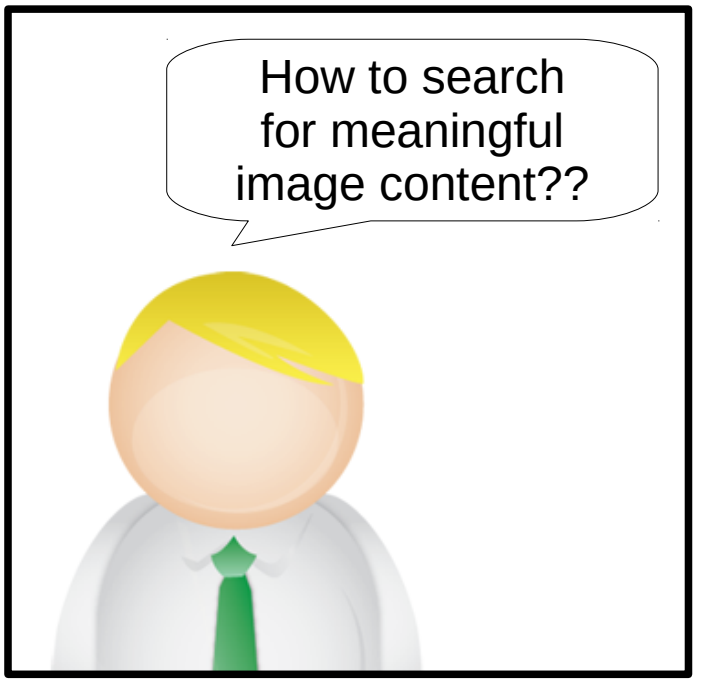

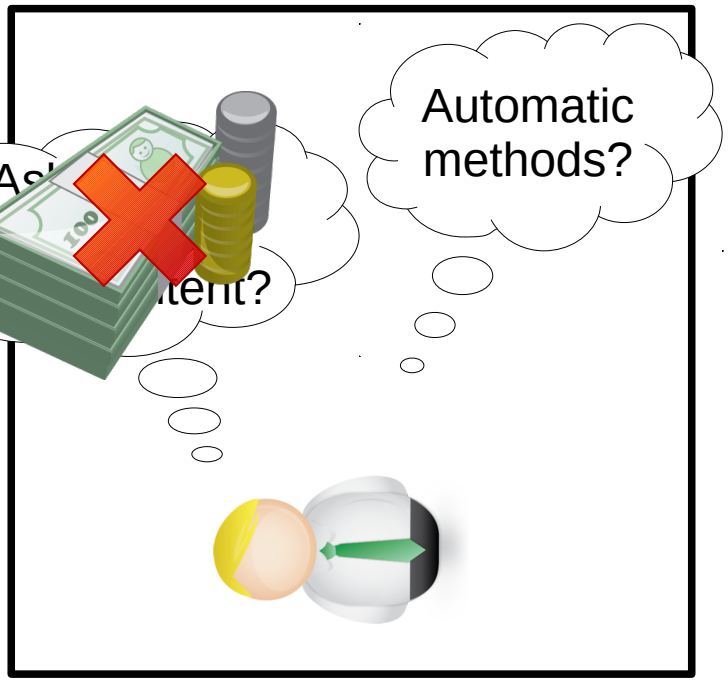

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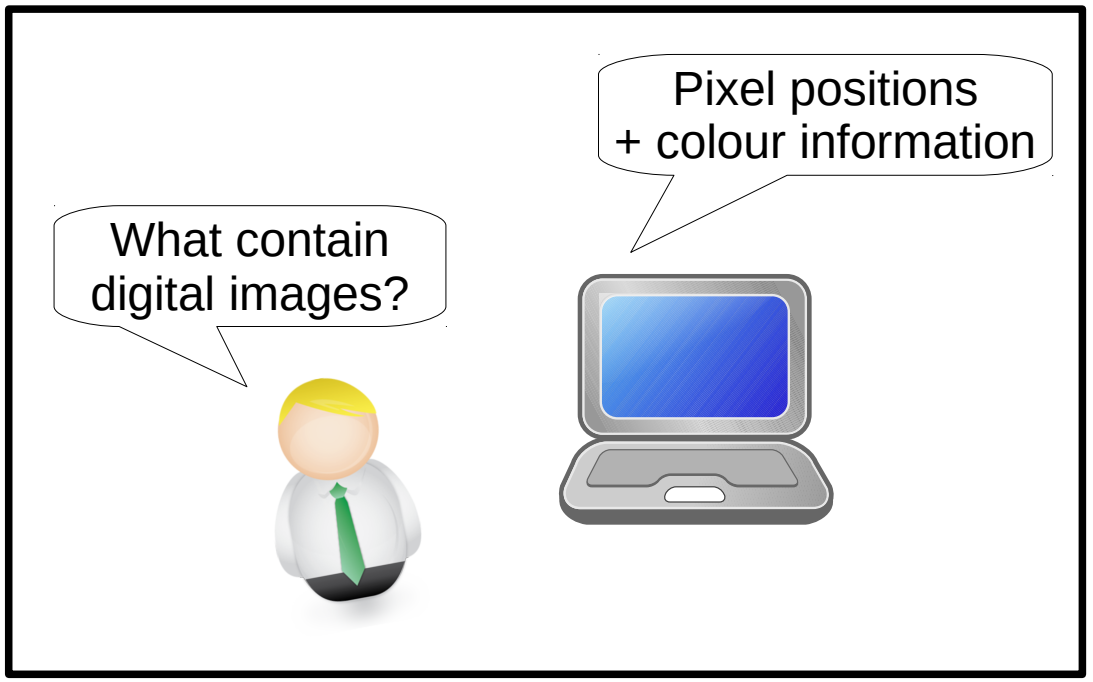

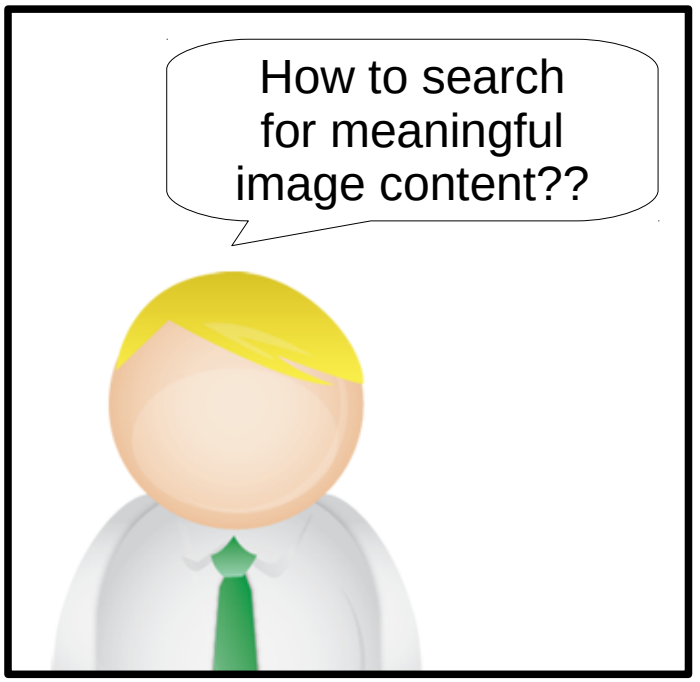

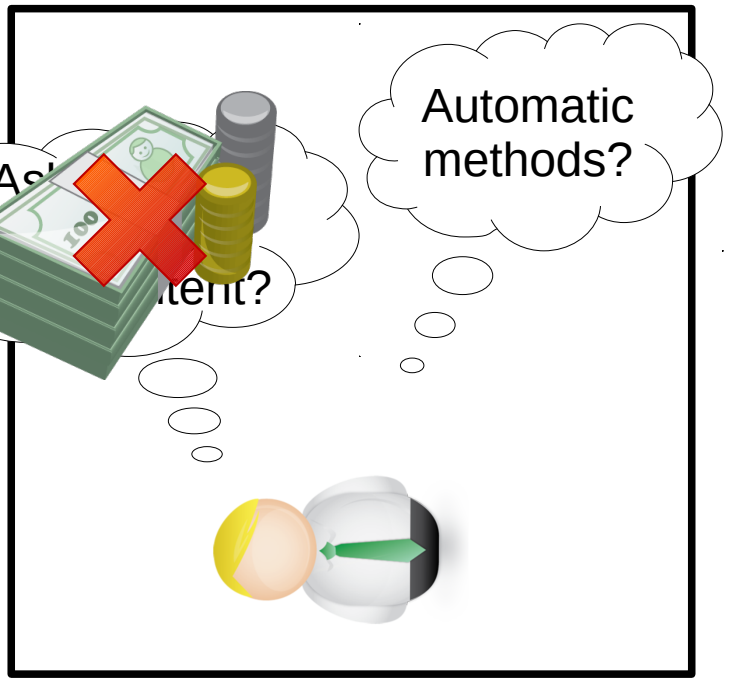

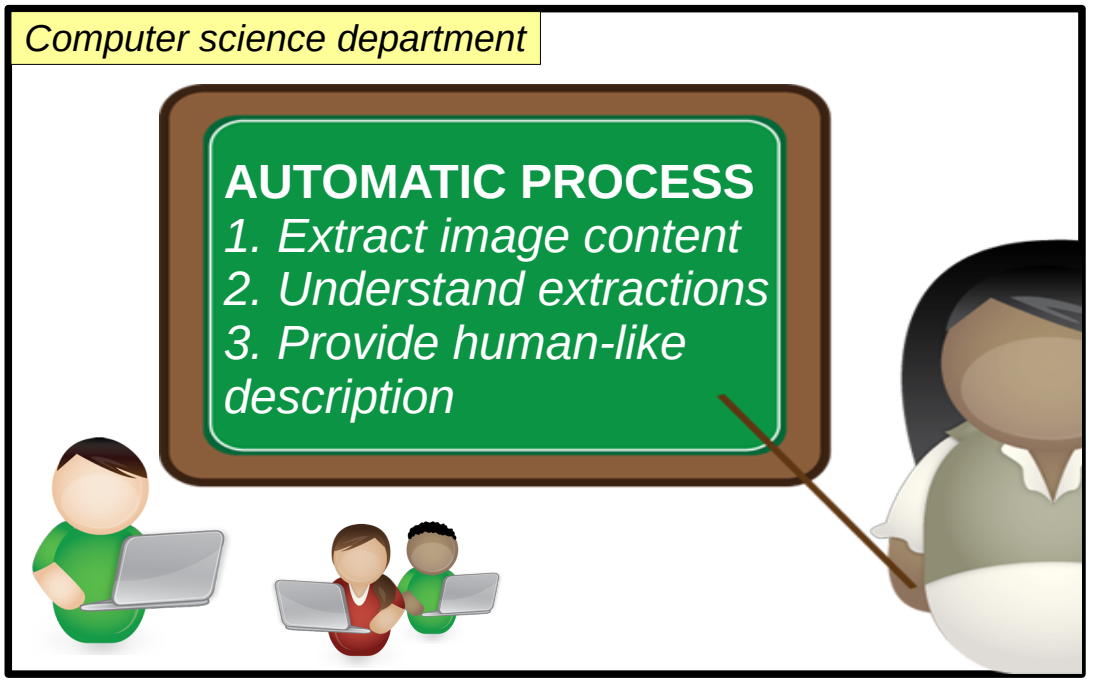

Solution from L3i lab

- eBDthèque project (since 2011)
  - Add value to paper-based comics using the new technologies
  - Public founding CPER 2007-2013
  - 2 Ph.D. students, 1 engineer, 1 post doc
  - 6 professors

- Research axes
  - Extracting content of digitized comic books
  - Understanding the semantic of the content

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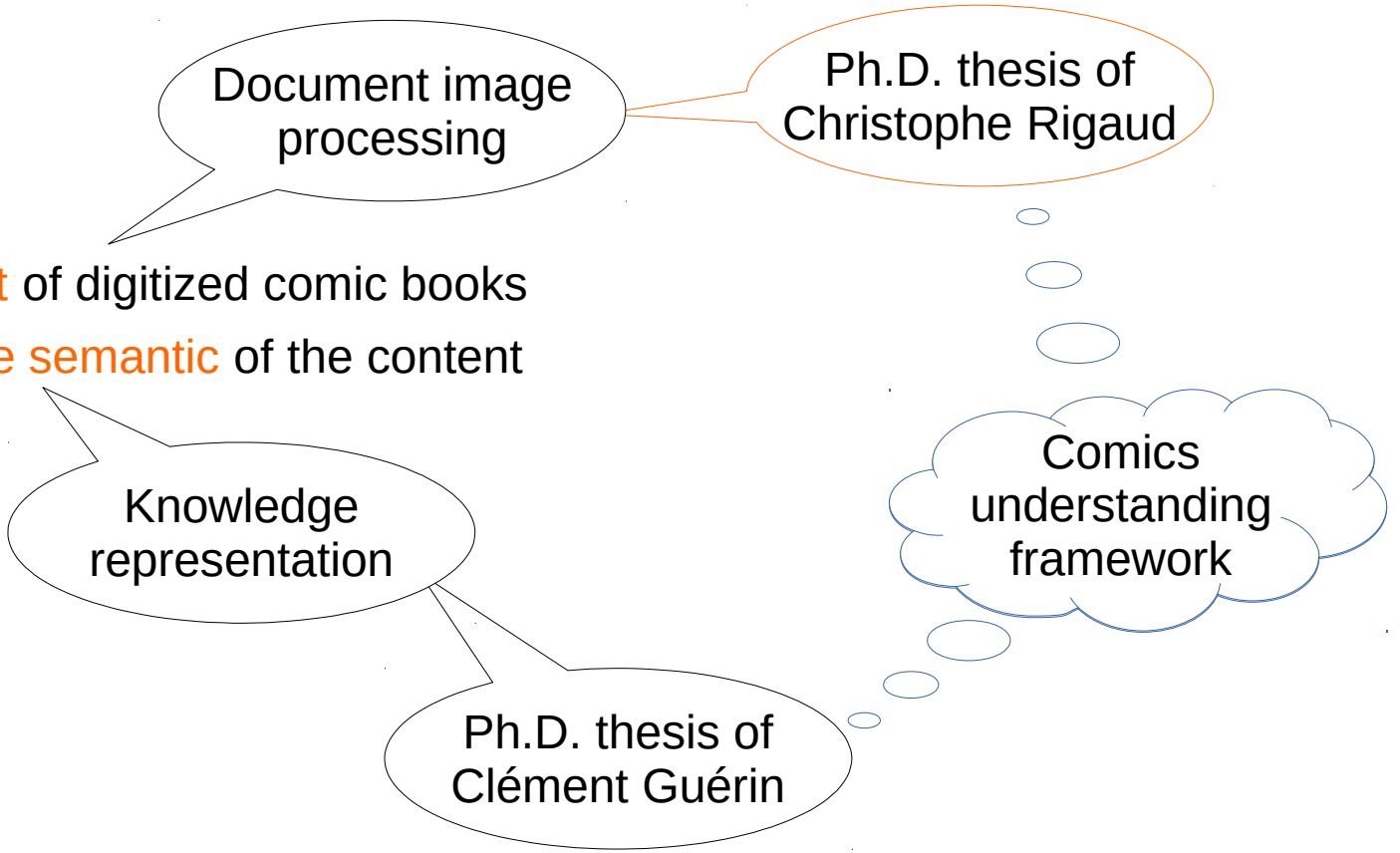

- Comic book images
- Content extraction
  - Panels
  - Balloons
  - Text
  - Comic characters

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

Comic book images

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

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

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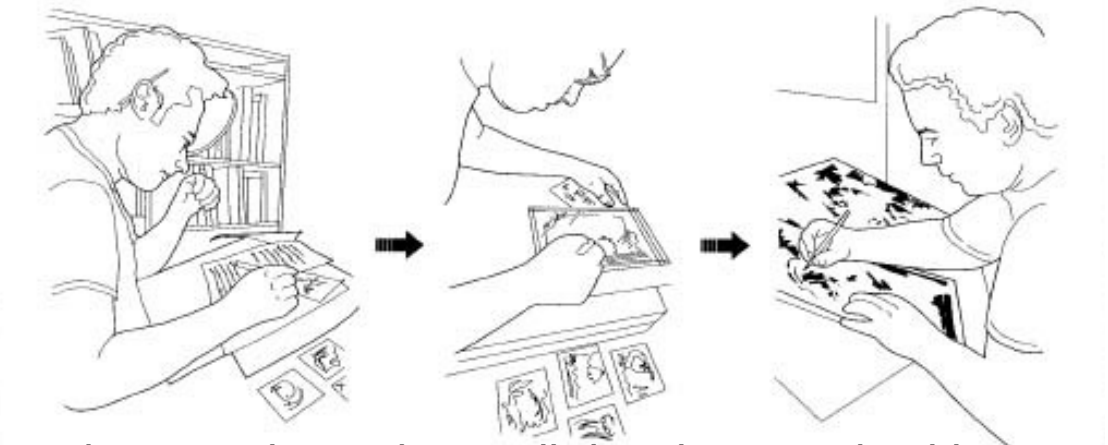


1) Scenario 2) Pencil drawing 3) Inking

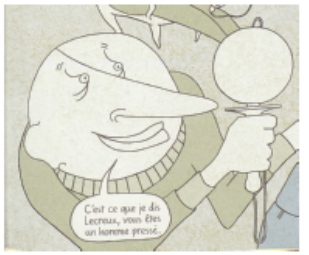
4) Flatting/colouring 5) Lettering

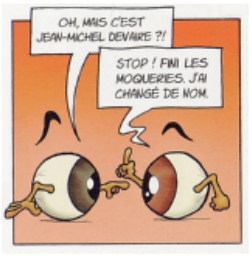
Image source: http://www.madehow.com/Volume-6/Comic-Book.html

Panel extraction

- Challenges
  - Diversity of styles
  - Semi-structured layout

- Panel extraction
  - White line cut
  - Recursive X-Y cut algorithm
  - Gradient
  - Connected-components
  - Polygon detection
  - Corners and line segments





- Conclusions
  - Problem solved for common manga and European comics if treated separately
  - Remaining difficulties are for connected, nested and implicit panels
  - No approach tested over all comics styles, no dataset, no reproductive results

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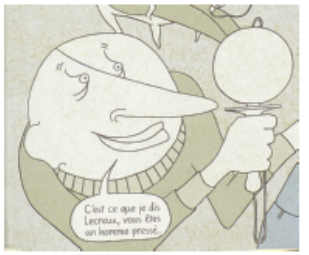

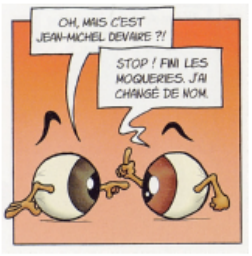

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  - No public dataset, no reproductive results

Balloon extraction

State of the art

- Challenges
  - Diversity of balloons intra/inter comics
  - Implicit balloons
  - (Interface between text and graphics)
- Extraction
  - Shape vs contour
  - Blob detection [Arai 2011, Ho 2012]
- Classification
  - Speech tone information (contour)
- Tail detection
  - Indicate the position of the emitter
- Conclusions
  - Closed balloon solved (sequential)
  - Implicit, classification and tail were not explored

Image	Shape	Contour
	Oval	Smooth
	Rectangle	Smooth
	Oval	Wavy
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	Oval / implicit	Smooth / Implicit

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Text extraction and recognition

State of the art

- Challenges
  - Non-standard fonts
  - Multi-script/orientation/scale
  - Complex background (sound effects)
  - Short length, hyphenation
  - Voluntary spelling mistakes
- Extraction
  - Scene text localization
  - Connected-components approach
  - SVM and Bayesian classifier
  - Sound effects have not been investigated yet
  - TOADD: http://dl.acm.org/citation.cfm?id=2549547
- Recognition
  - At is early stage
  - OCR trained for a specific comics font

- Conclusions
  - Speech text studied but not solved
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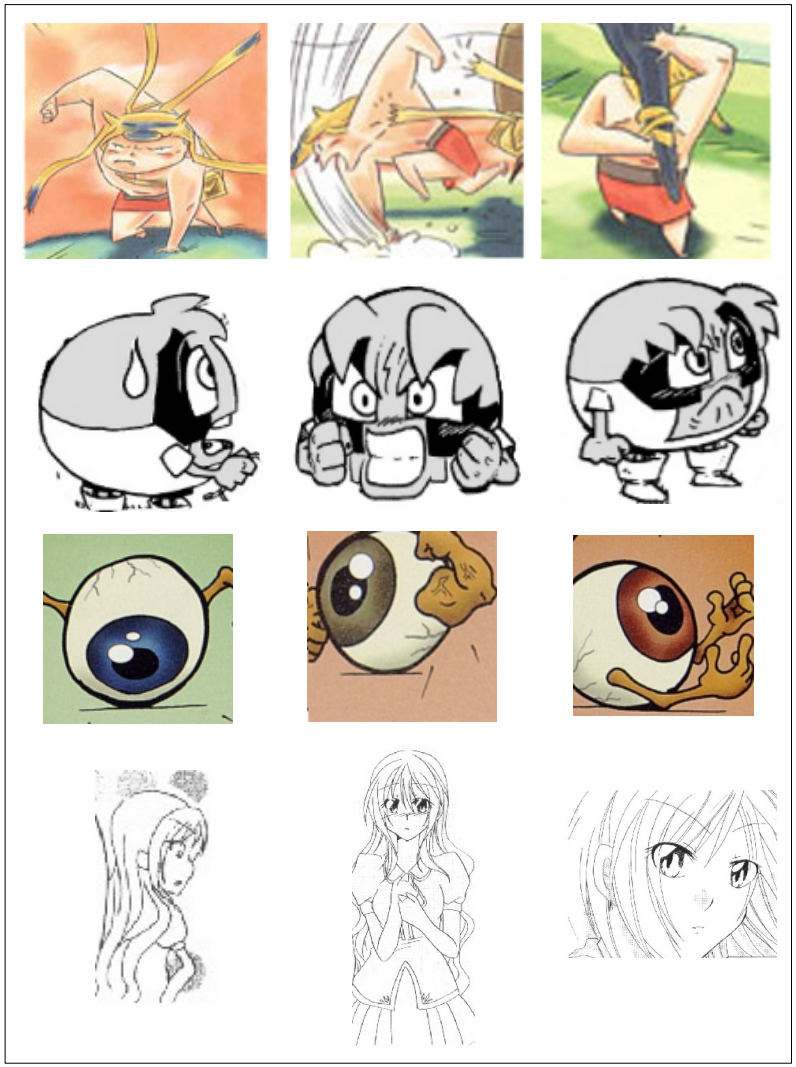
Comic character extraction

- Challenges
  - Hand-drawn, stroke-based
  - Intra/inter class variability
  - Scale, deformation, posture, occlusion
- Extraction & recognition
  - Manga faces [Cheung2008, Sun2010, Kohei2012]
  - Cartoons [Khan2012]
- Conclusions
  - Preliminary results
  - Complex and versatile structure
  - Contains most of the interesting information



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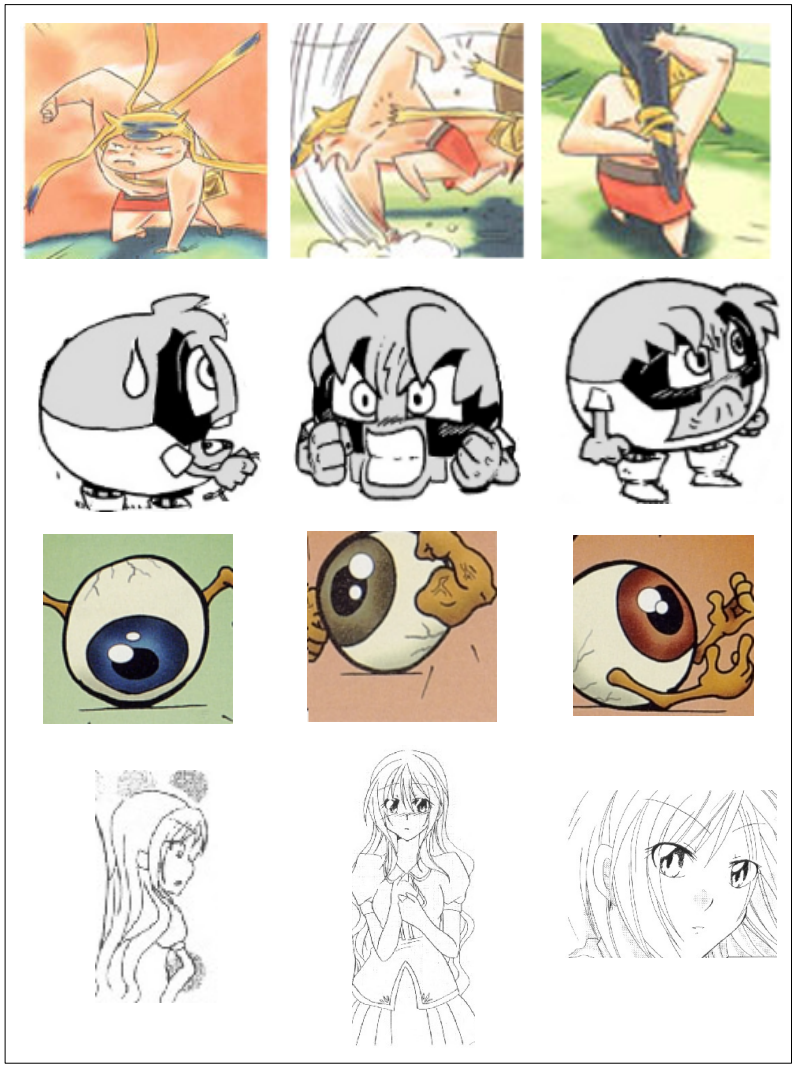
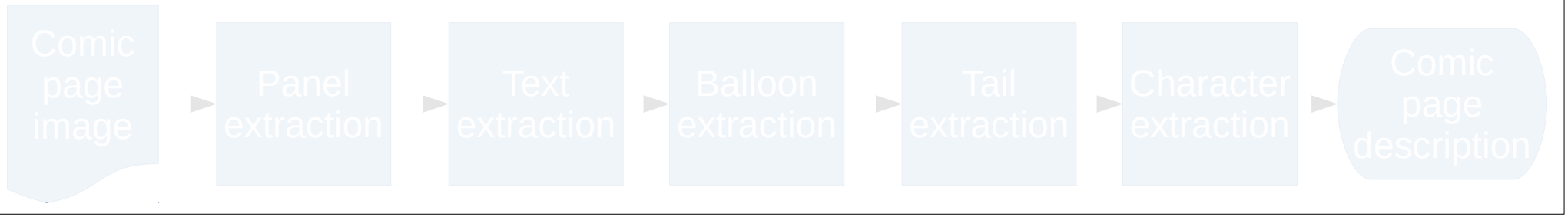


Content-driven (sequential)



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Knowledge-driven (independent)

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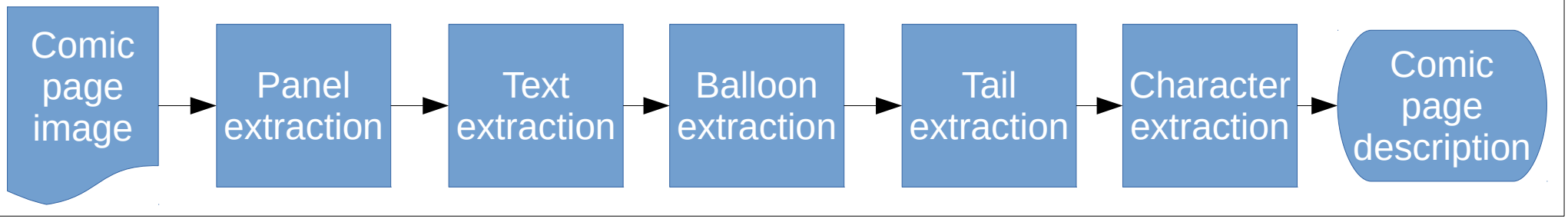

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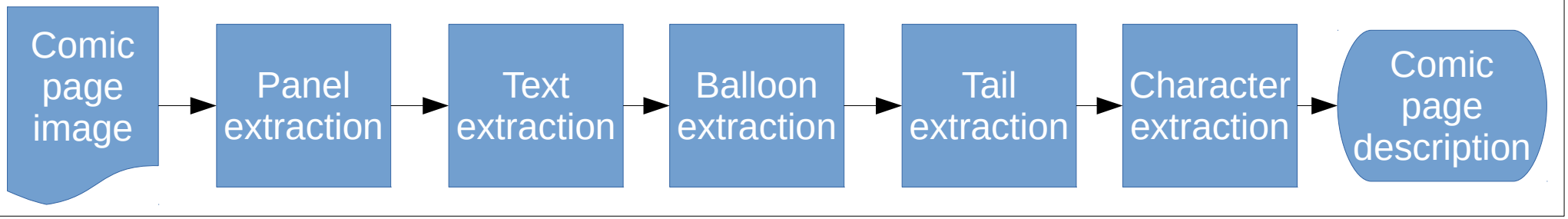

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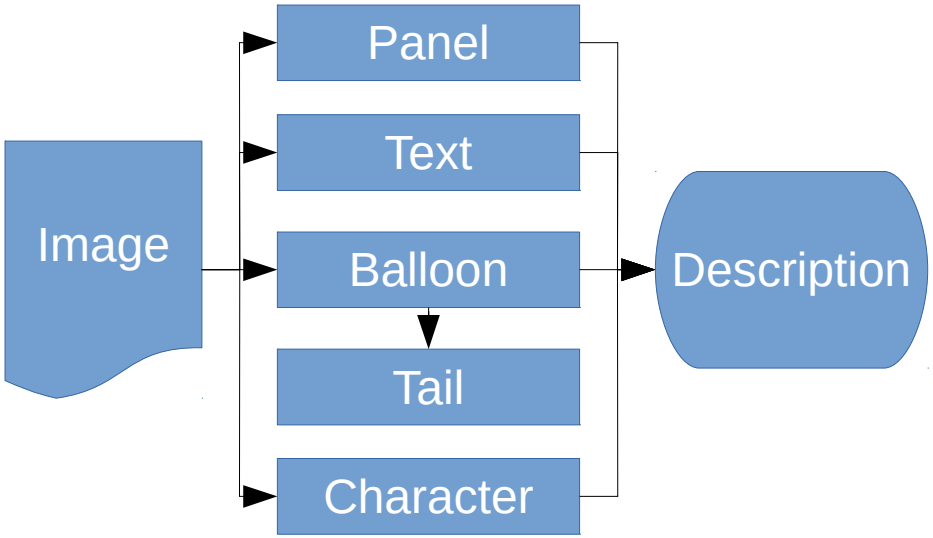

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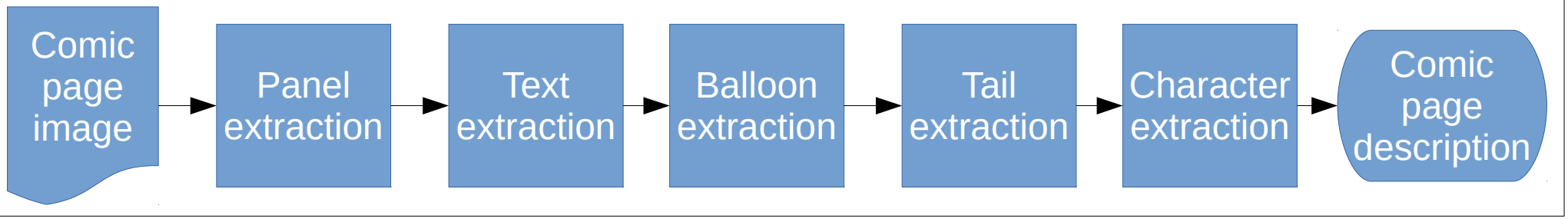

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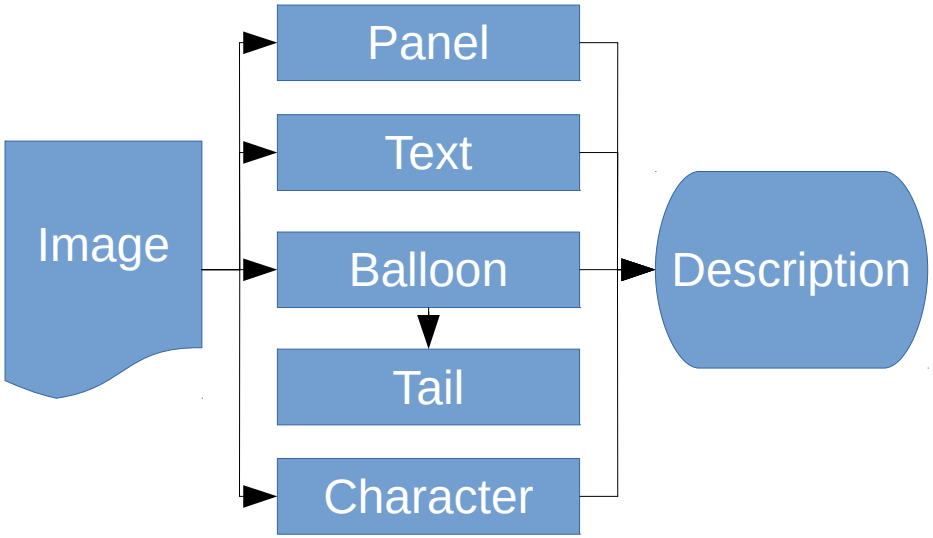

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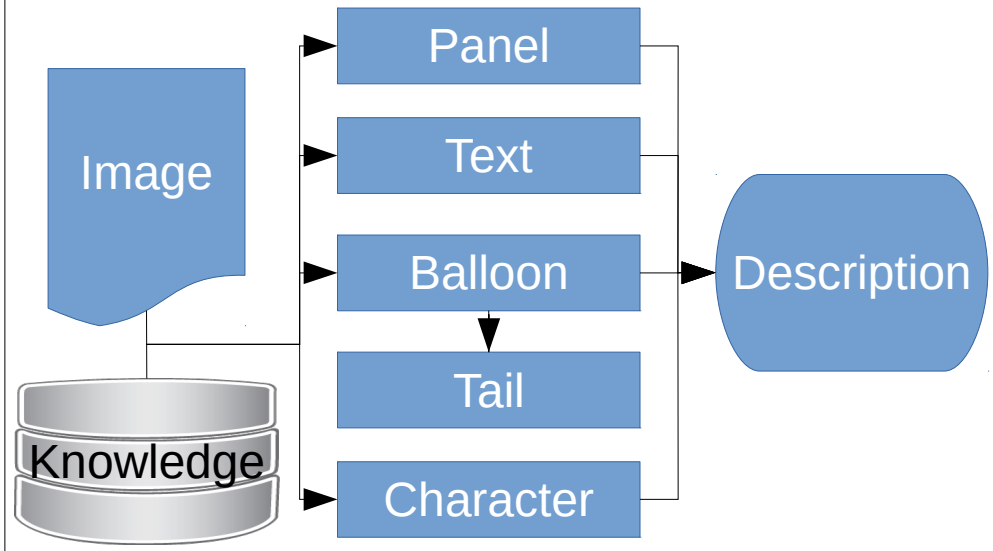
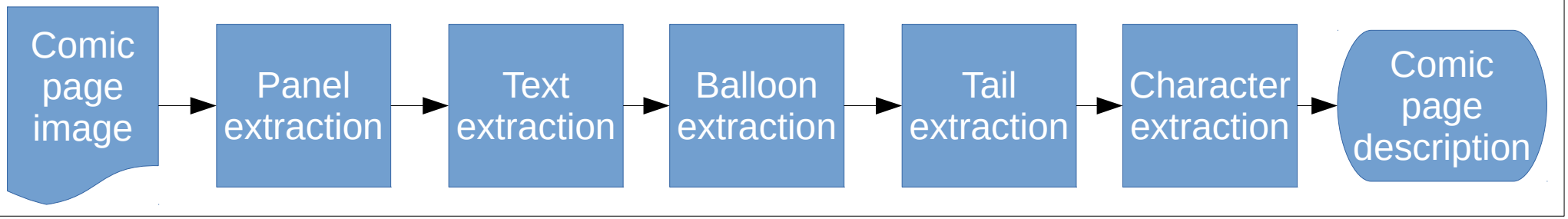


Content-driven (sequential)



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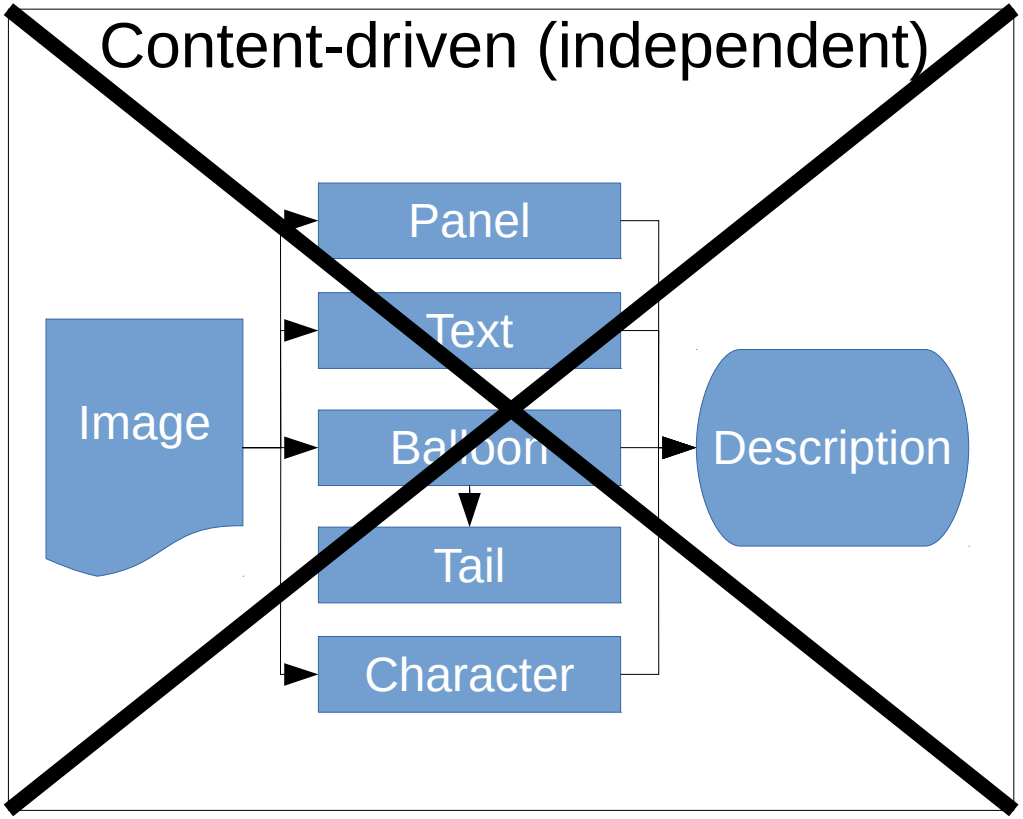

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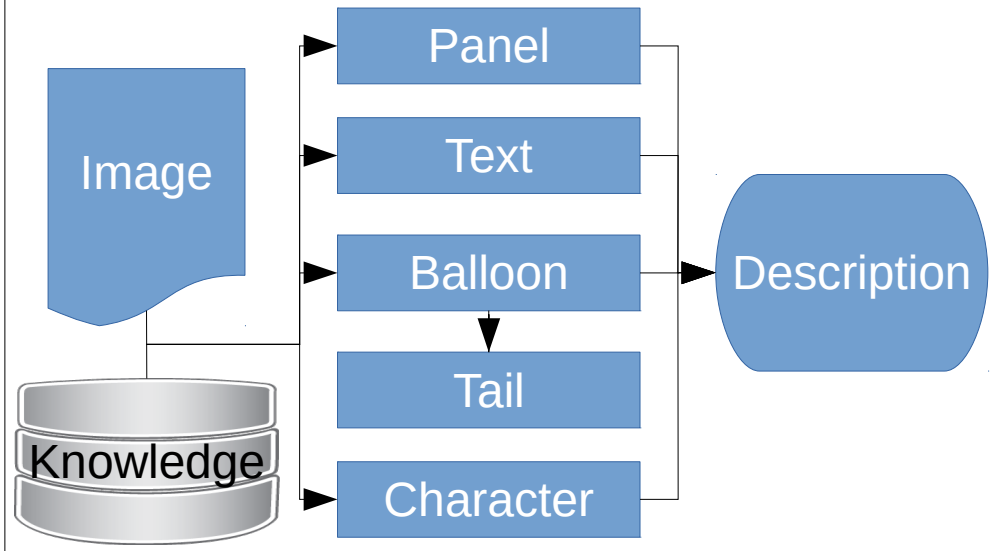

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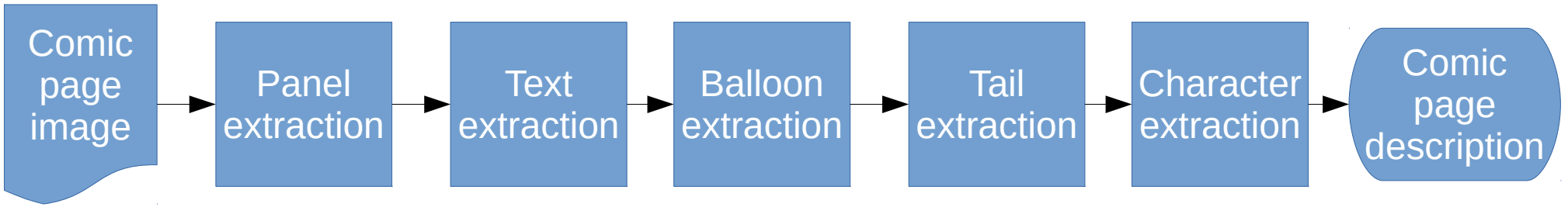

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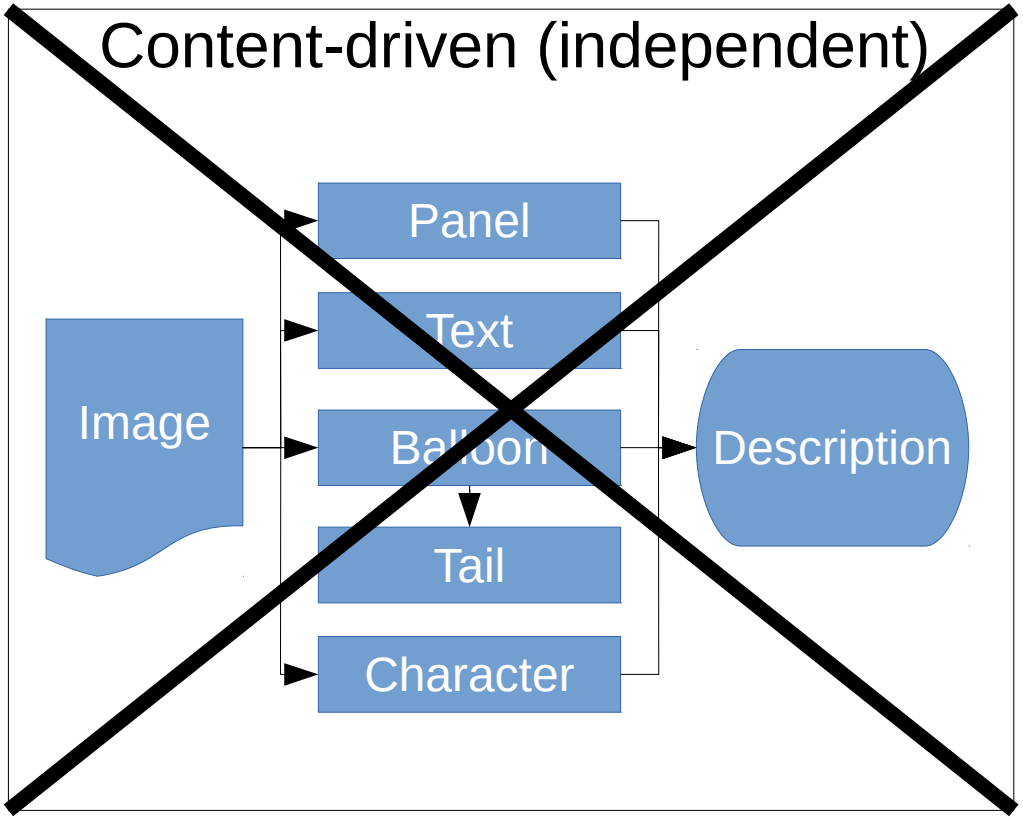

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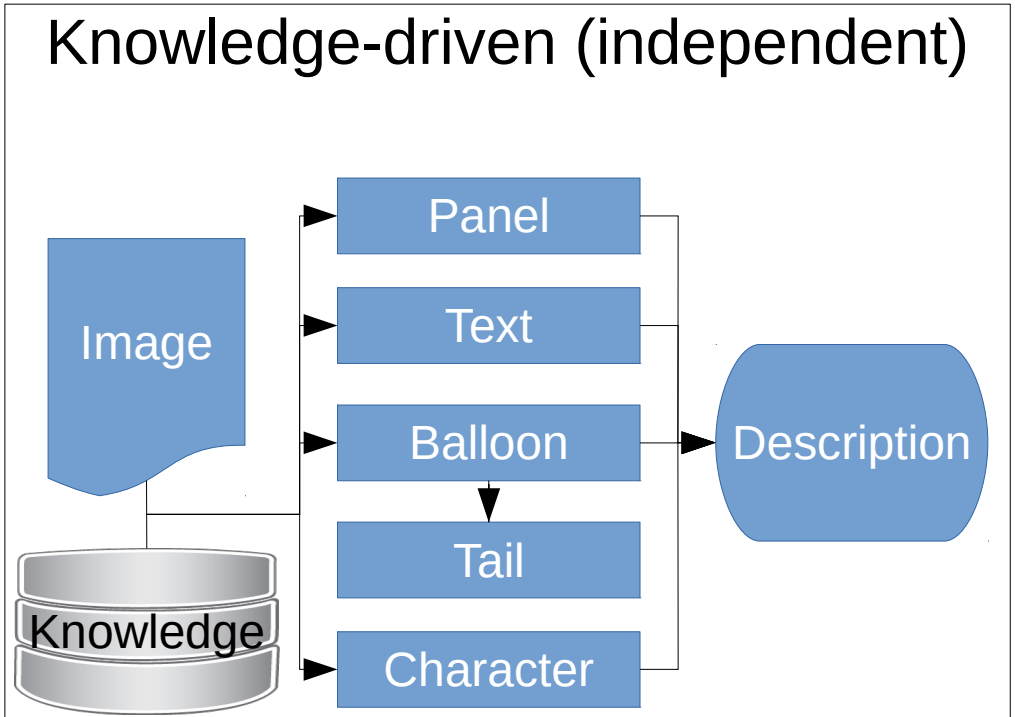
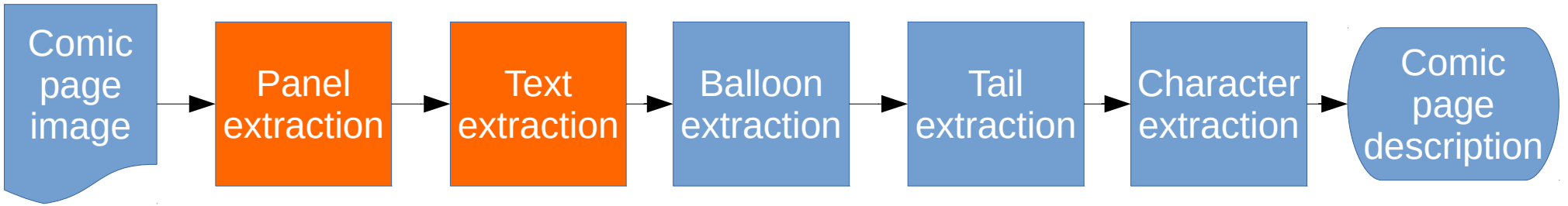


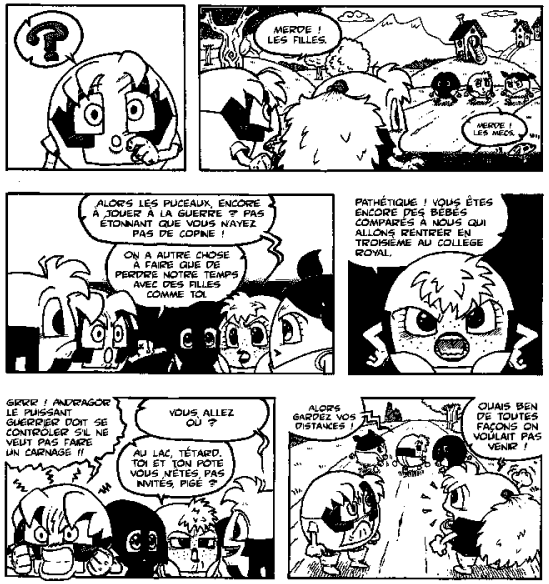
Panel and text extraction

- Processing sequence

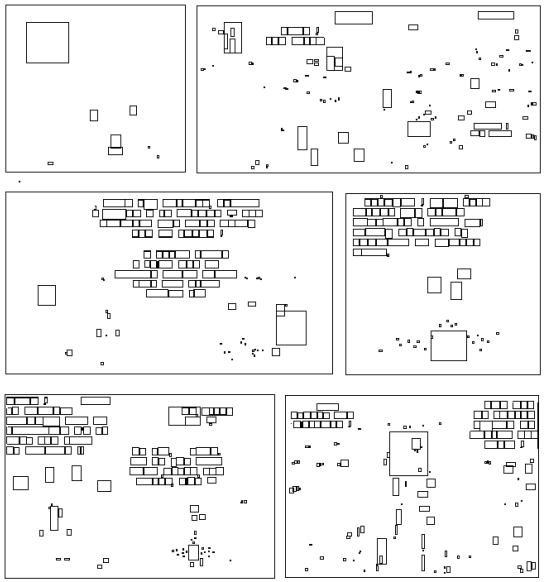


- Literature
  - Panel, balloon, text extraction [Ho2012, Arai2010]
  - TODO M. Stommel, L. Merhej, and M. M¨lle Segmentation-free detection of comic panels. In LNCS 2012.
  -
  - Text only extraction [Li2013]
- Contribution
  - Simultaneous panel and text extraction

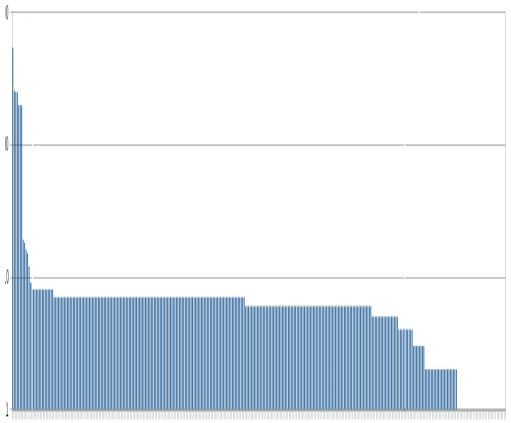
Panel and text extraction



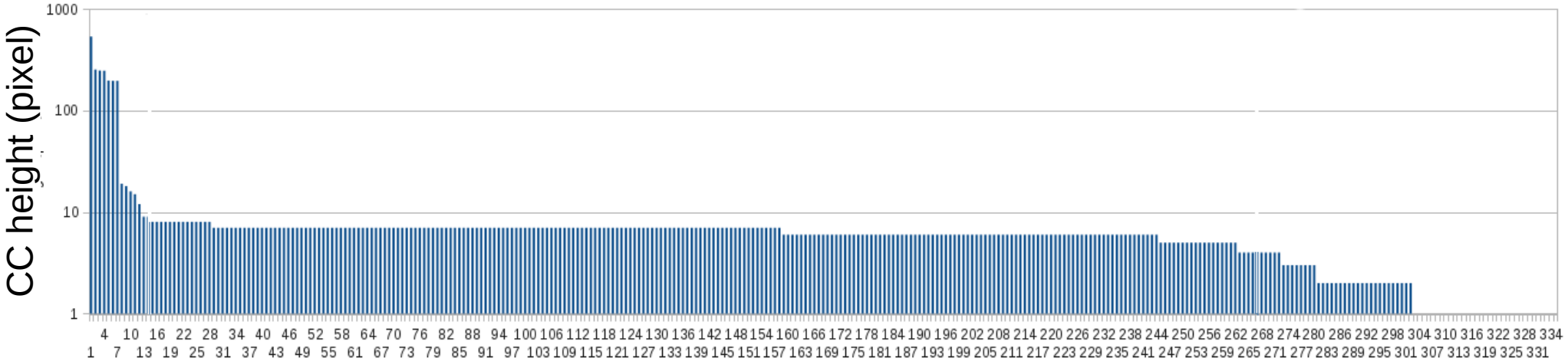
Binary image



Connected-component (CC) bounding boxes



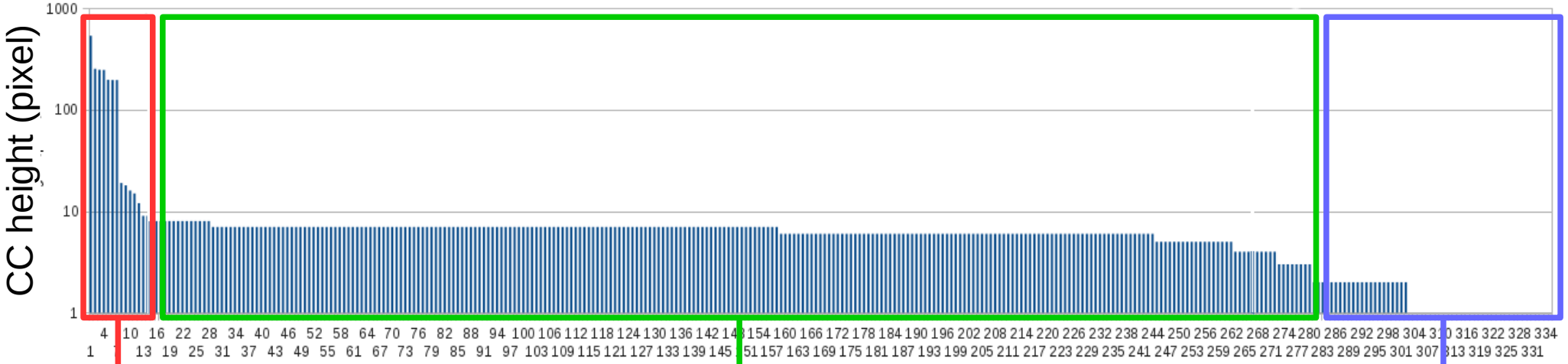
Histogram of heights of CC



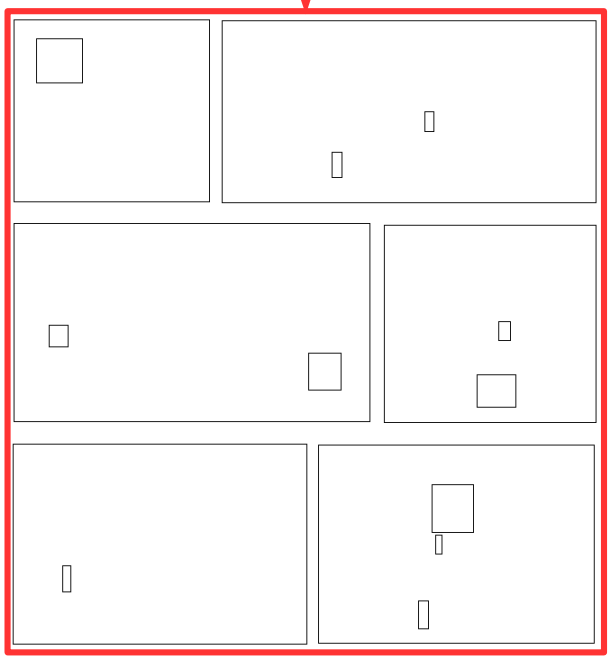
Histogram of heights (descendent order)

Panel and text extraction

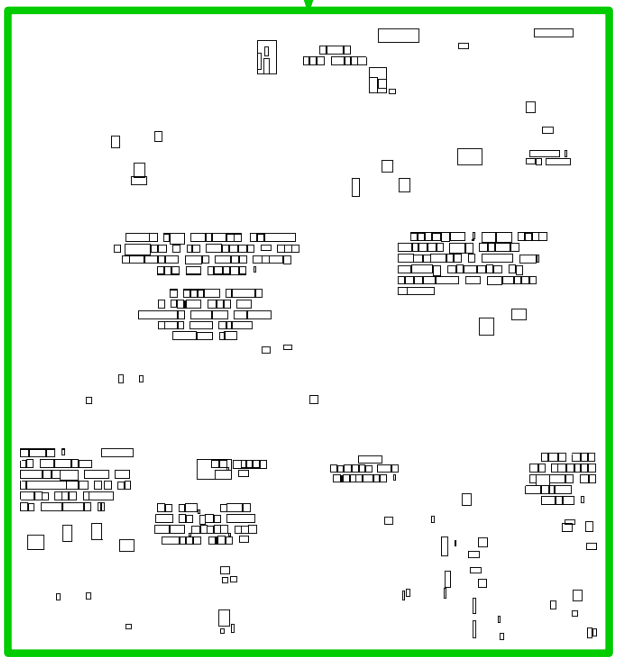
K-means clustering (k=3)



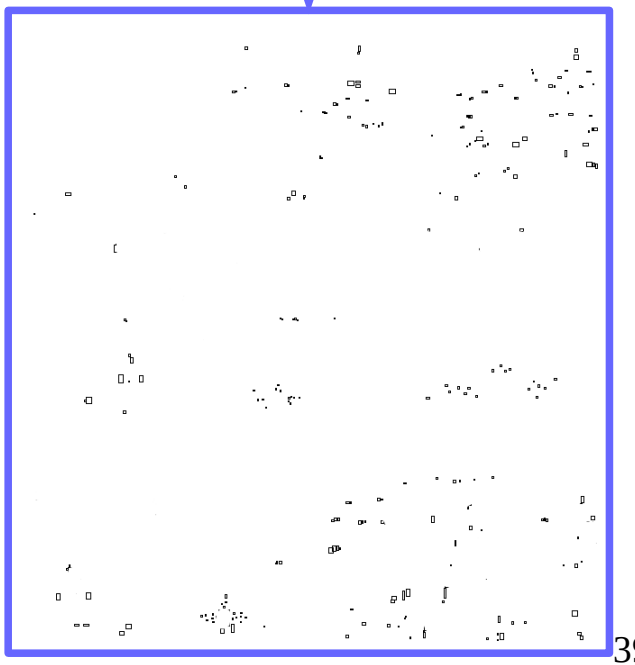
Panels



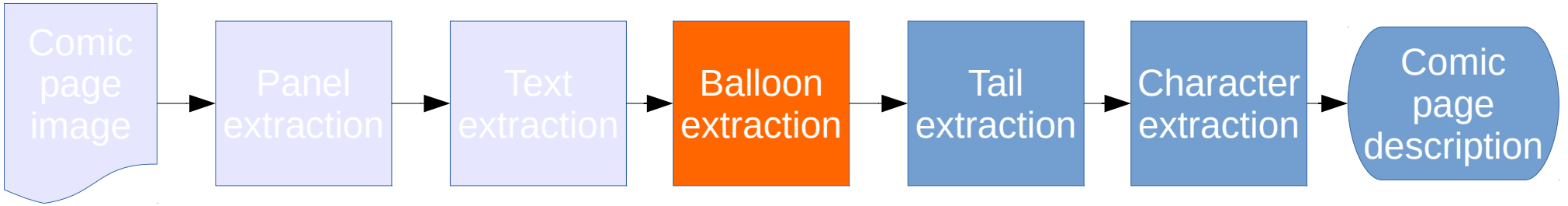
Text

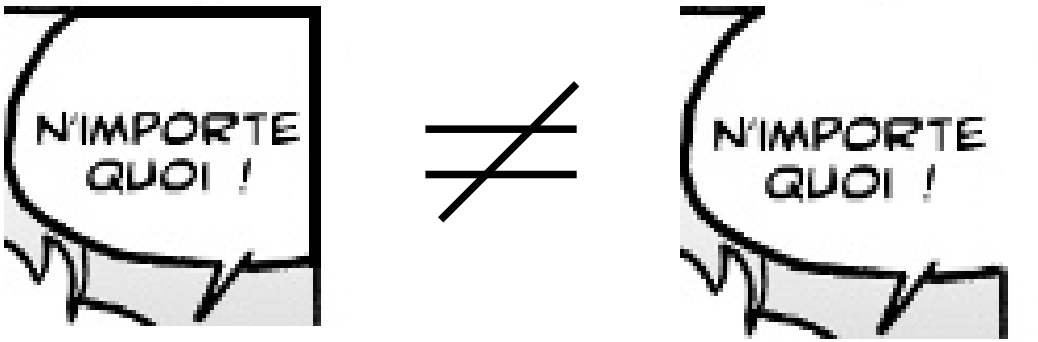


Noise



Balloon extraction

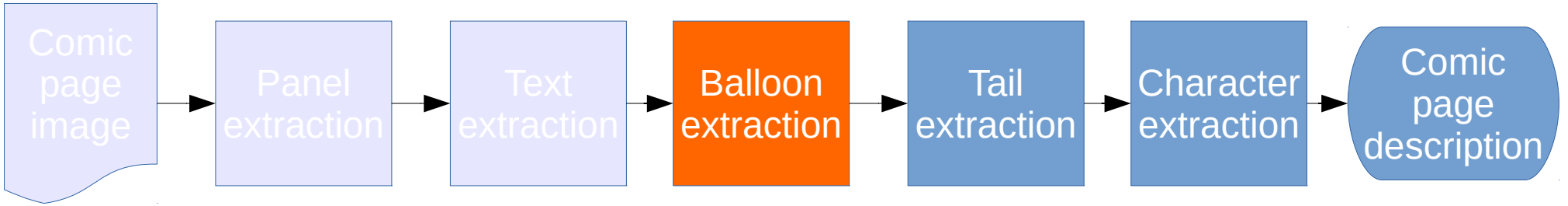


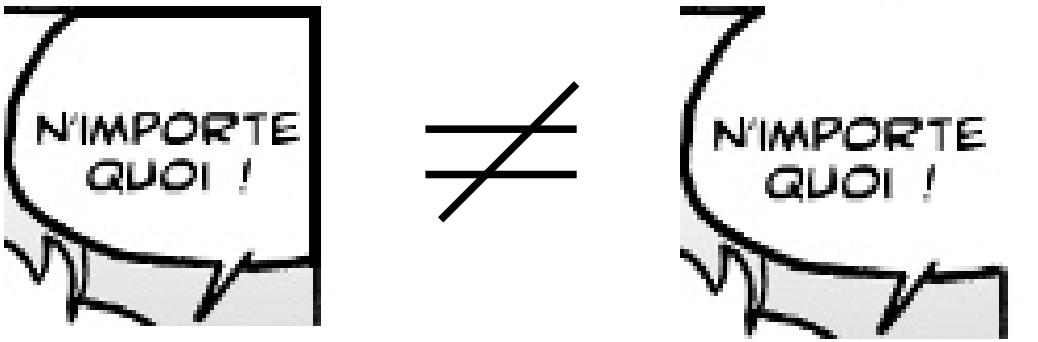


Regular balloon ≠ Implicit balloon

- 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





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

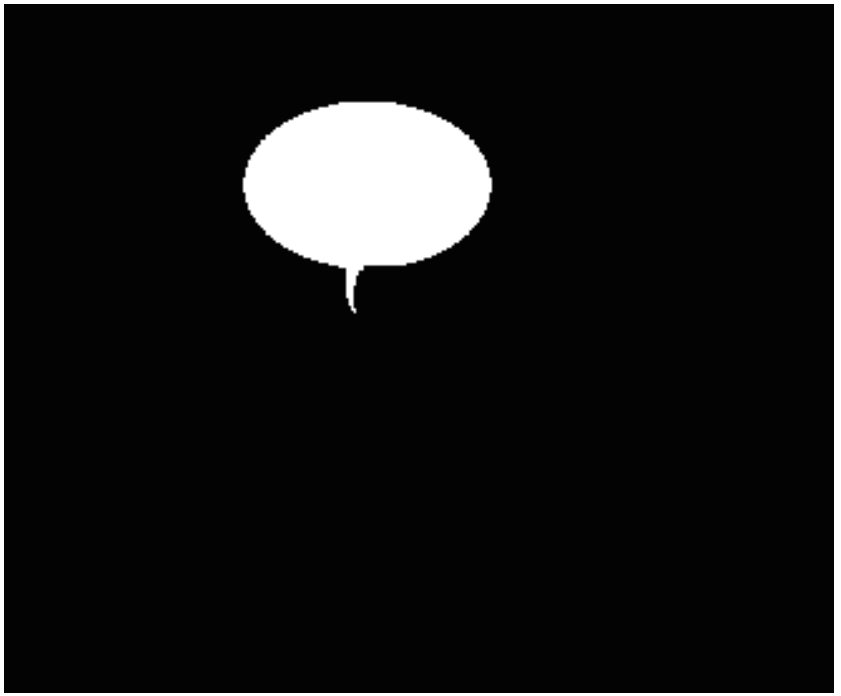
Balloon extraction: regular

- 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

- 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

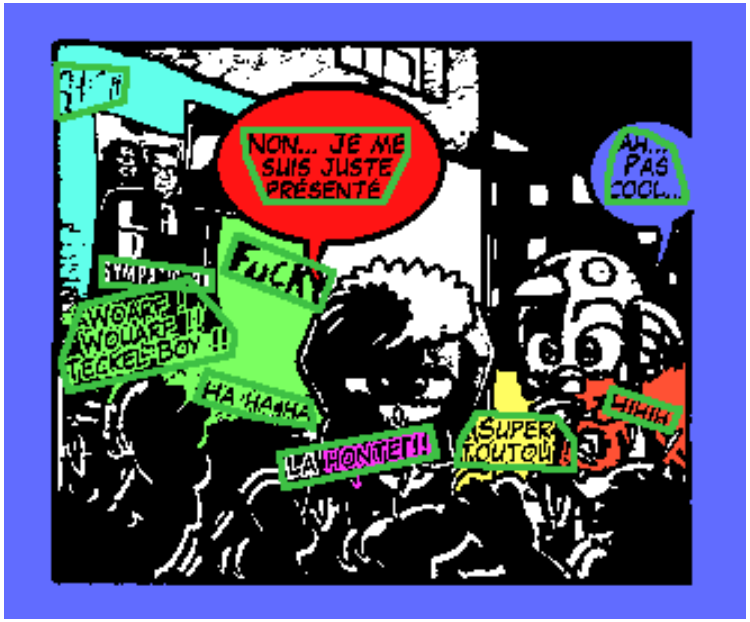


Expected result

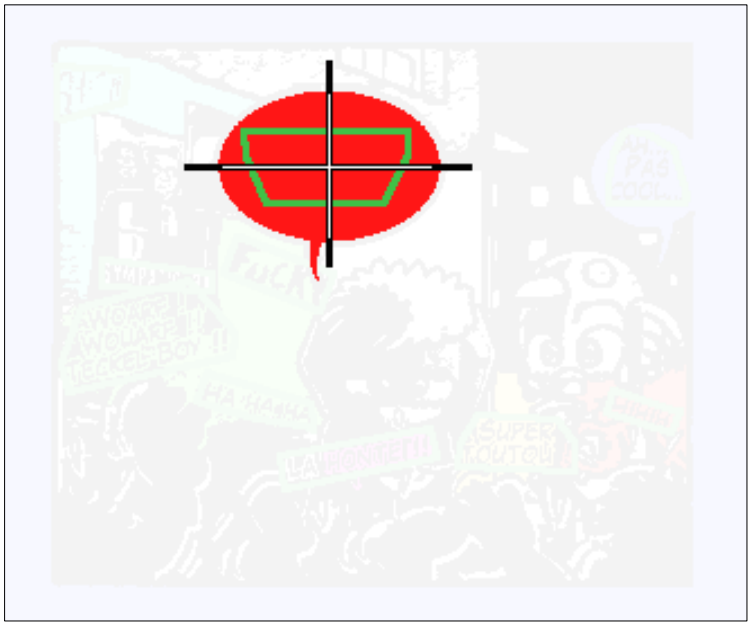
Balloon extraction: regular

Original image

Text block positions (green)



Regions including text blocks (coloured)

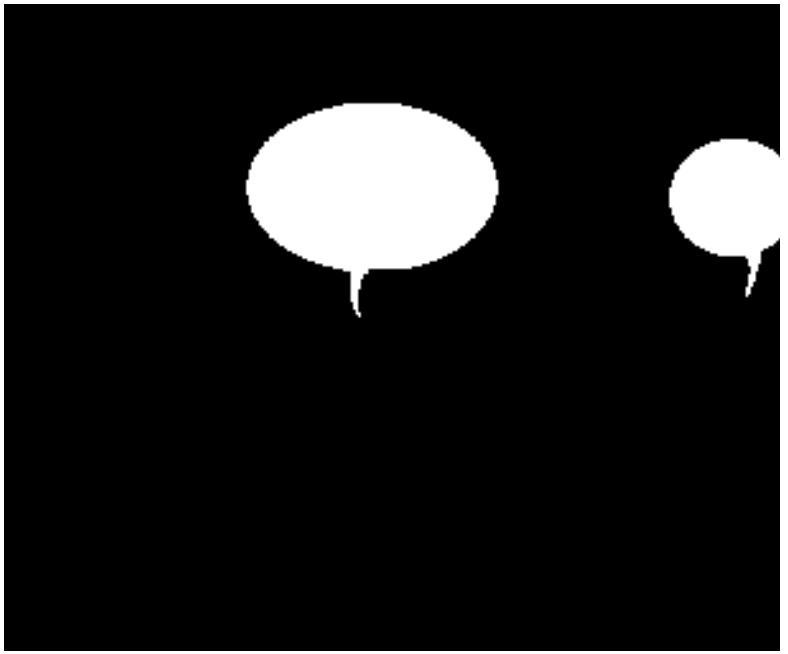


Regions including aligned text blocks

Balloon extraction: implicit

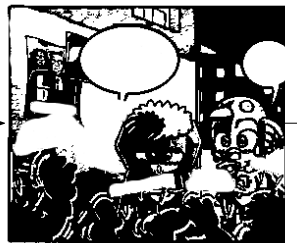
- Prerequisites
  - Text block positions are known
  - Implicit balloons contain text
- Observation
  - Text is fully included and centred in balloons
- Proposition
  - Extract implicit balloons from text regions by inflating a deformable contour
  - Adaptation of active contour model (snake)

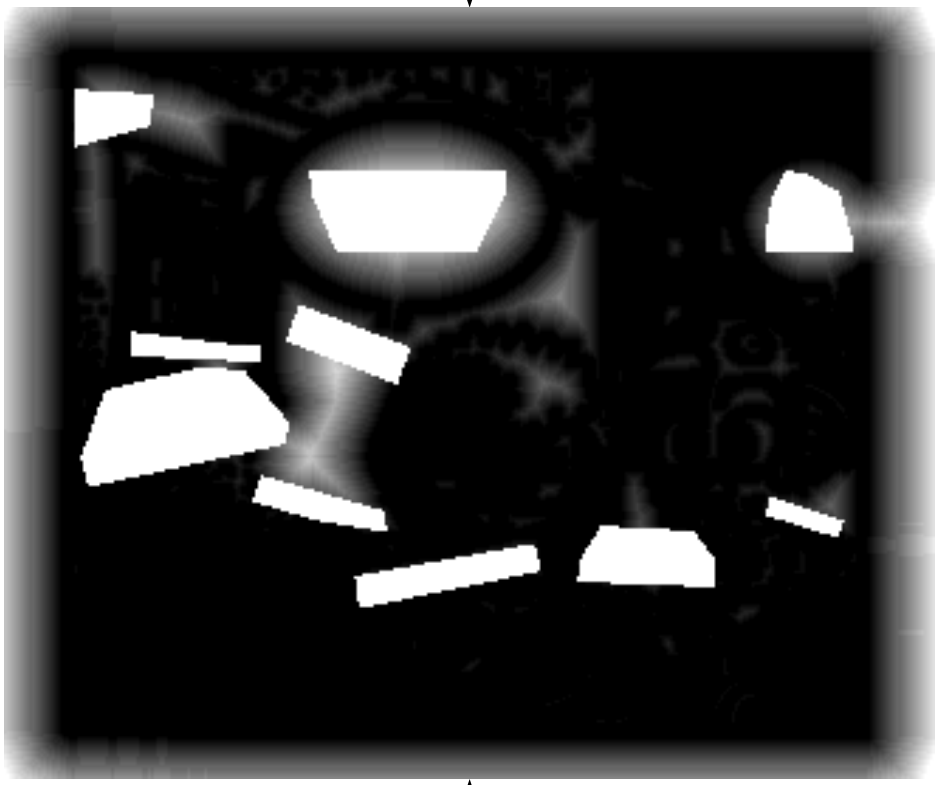
Original image and text locations



Expected result

Balloon extraction: implicit



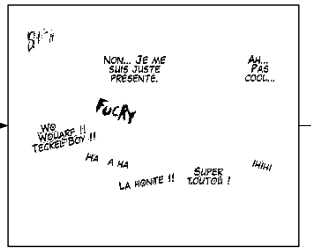


Energy function:

$$E = E_{int} + E_{ext}$$

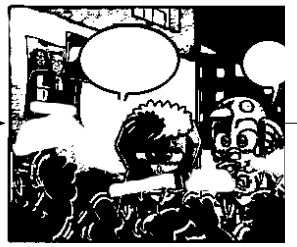
$$E_{int} = E_{cont} + E_{curv}$$

$$E_{ext} = E_{edge} + E_{text}$$



Final external energy E_{ext}

Balloon extraction: implicit

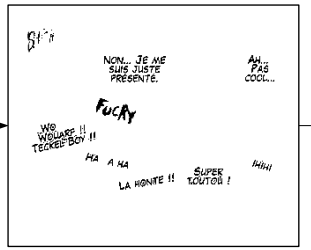


Energy function:

$$E = E_{int} + E_{ext}$$

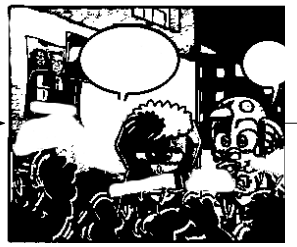
$$E_{int} = E_{cont} + E_{curv}$$

$$E_{ext} = E_{edge} + E_{text}$$



Initial snake positions

Balloon extraction: implicit

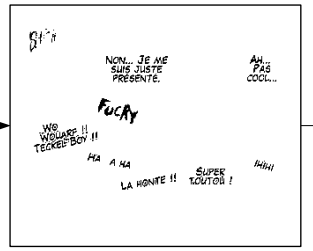


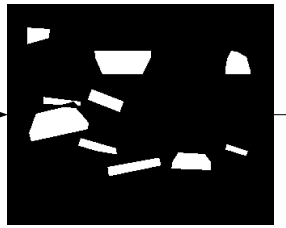
Energy function:

$$E = E_{int} + E_{ext}$$

$$E_{int} = E_{cont} + E_{curv}$$

$$E_{ext} = E_{edge} + E_{text}$$

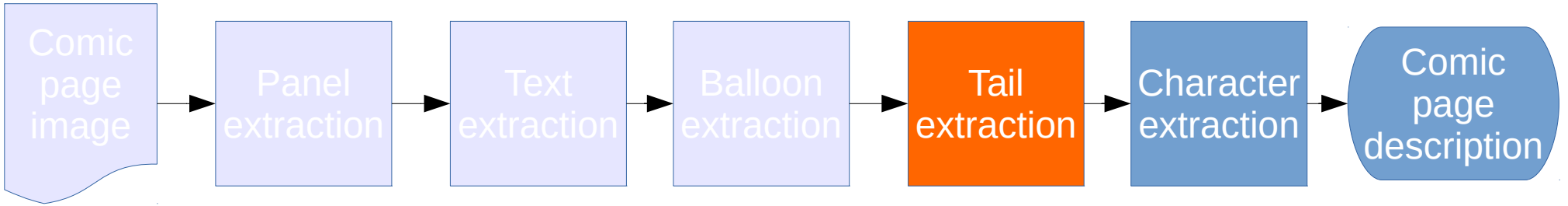


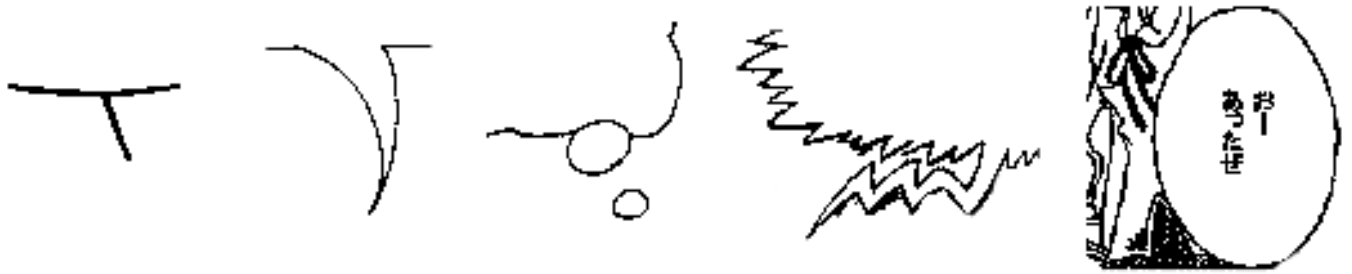


Final balloon detections

The snake is attracted to the “dark side”

Tail extraction

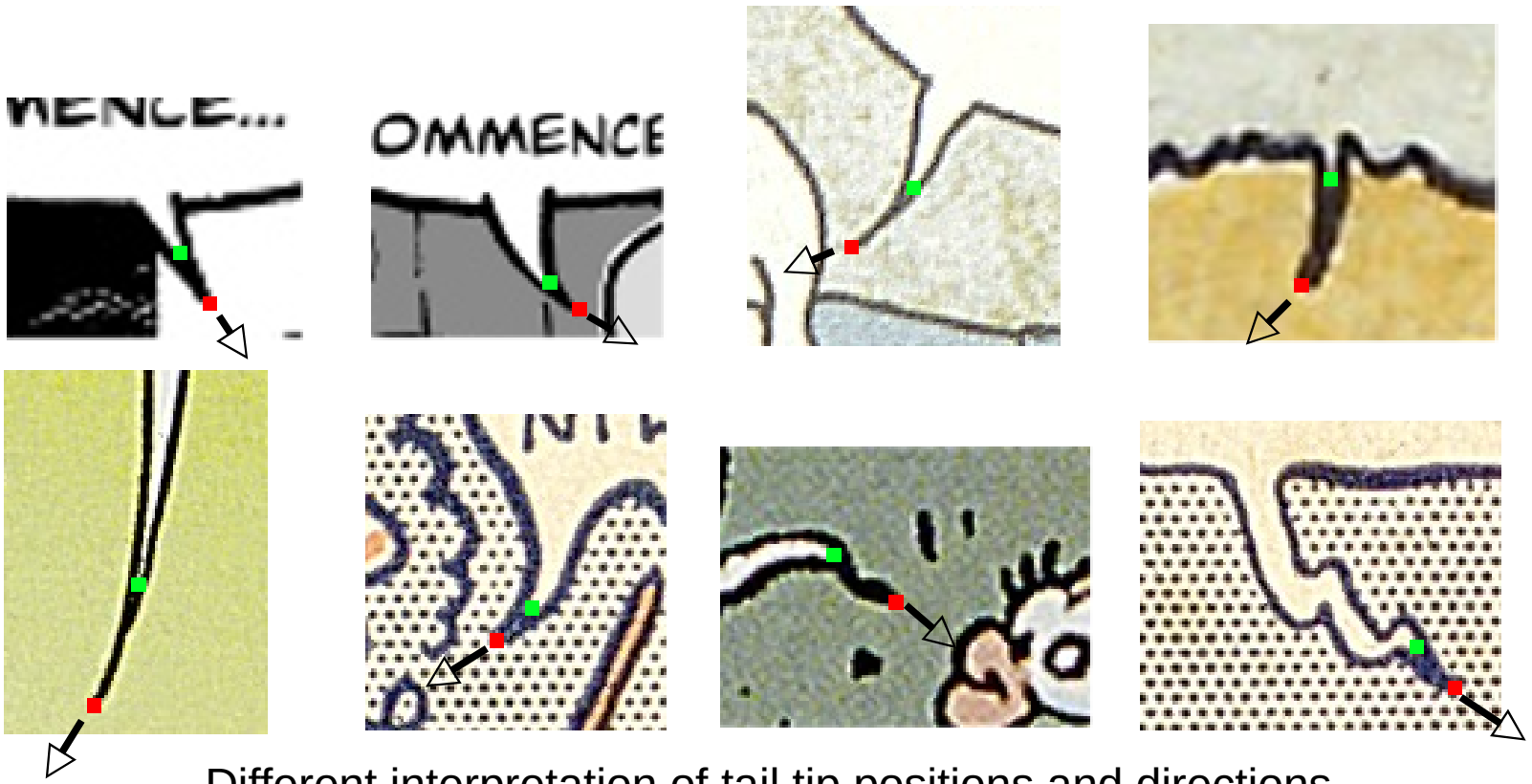




- Literature
  - First time studied in document image analysis
- Objectives
  - Detection of the tail tip position and orientation
  - Focus on comma, zigzag and absent types

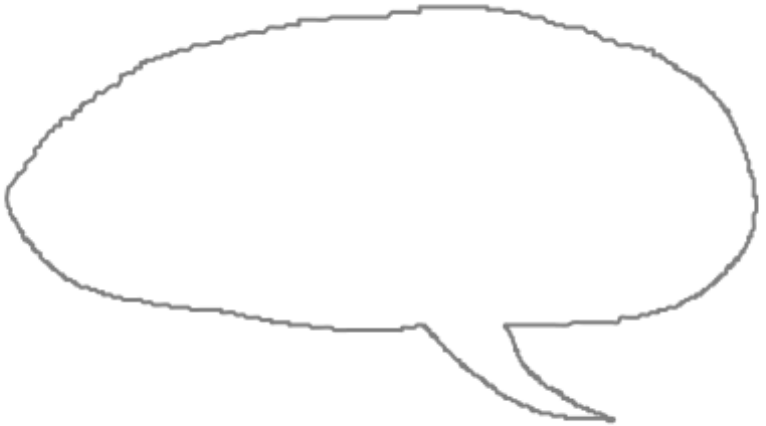
Tail extraction

Tip from background
Tip from contour
Direction of the tail

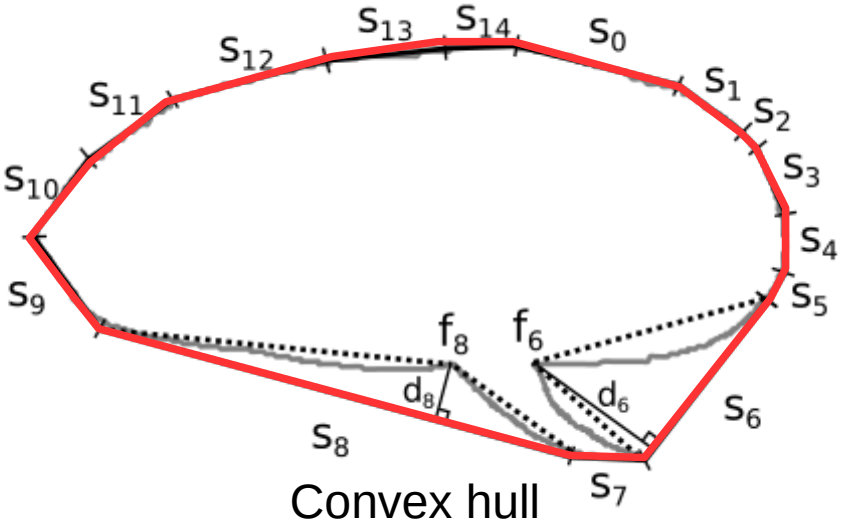


Different interpretation of tail tip positions and directions

Tail extraction: tip position



Balloon contour



Convex hull

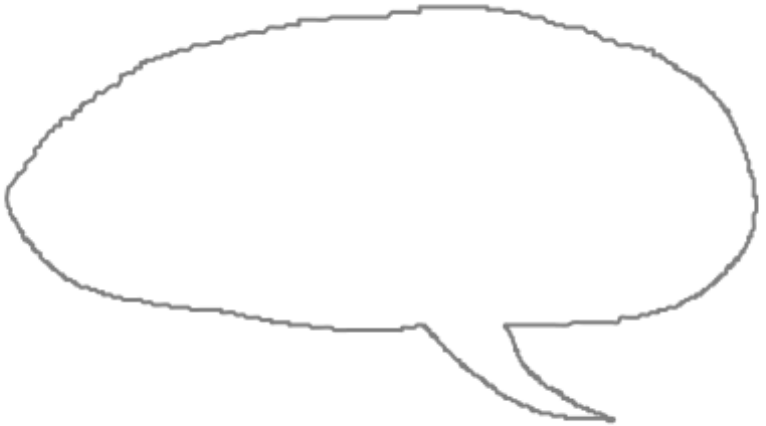
Two biggest convexity defects

Tail tip position

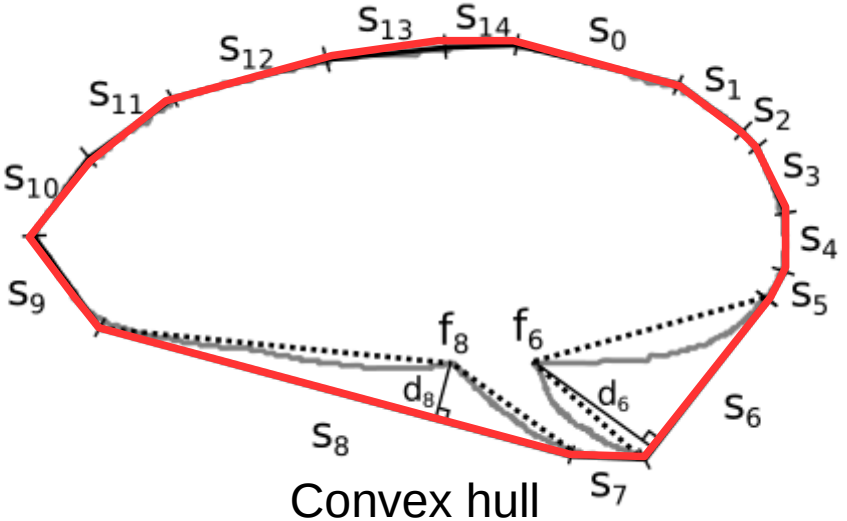
Optimal vertex selection:

$v* = argmax\left(max(dc + df_a + df_b) + min(ds_a + ds_b)\right)$

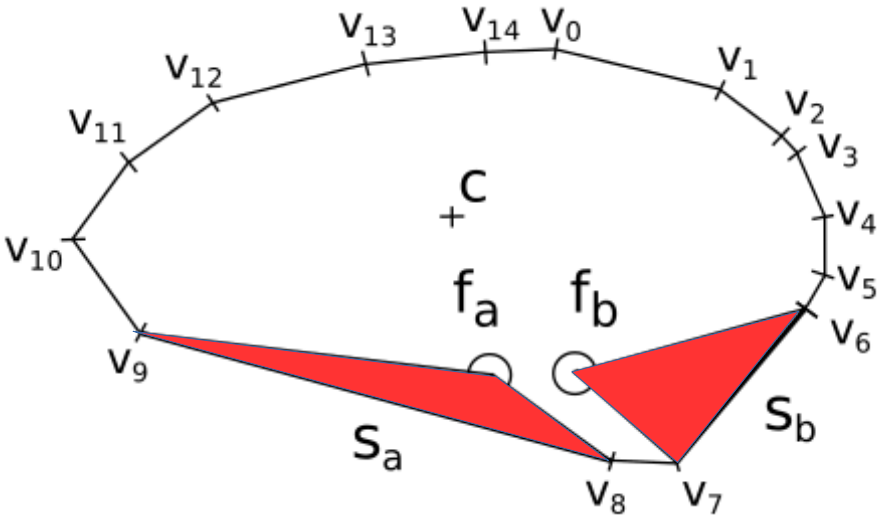
Tail extraction: tip position



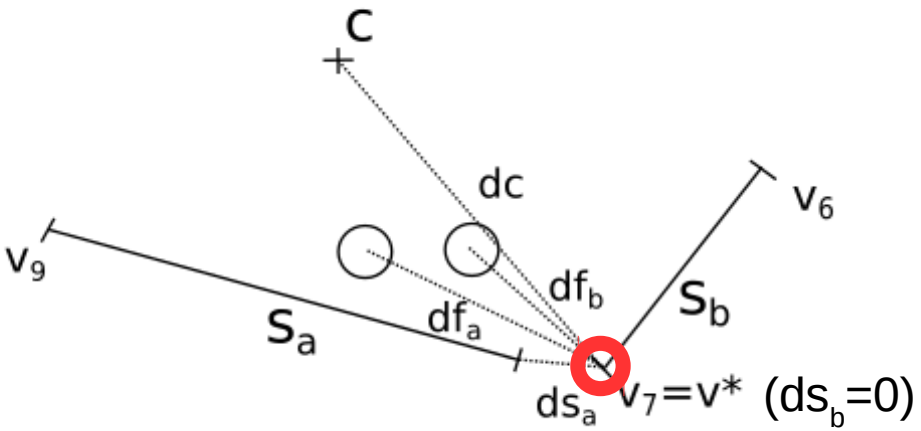
Balloon contour



Convex hull



Two biggest convexity defects

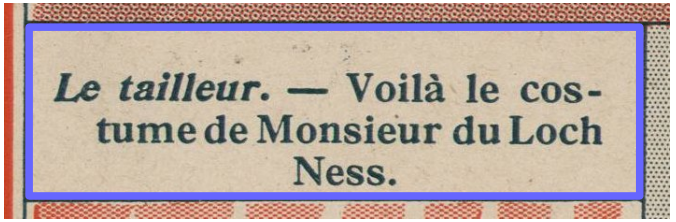
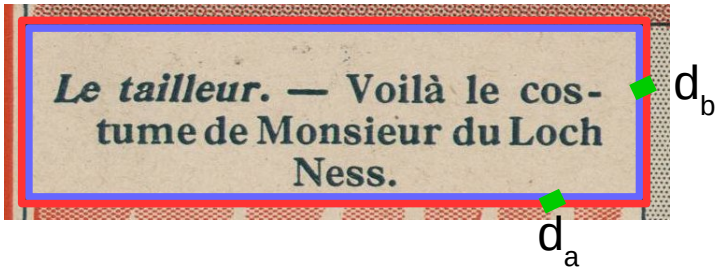
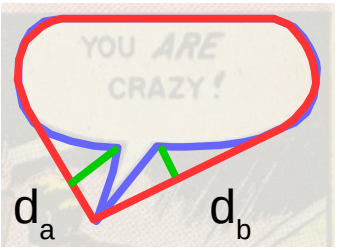


Tail tip position

Optimal vertex selection:

$v* = argmax(max(dc + df_a + df_b) + min(ds_a + ds_b))$

Tail extraction: confidence value

	Balloon 1	Balloon 2
Balloon contour (blue)		
Convex hull (red)		
Confidence	$C_{tail} = \frac{(d_a + d_b)/2}{meanBalloonSize}$	
	$C_{tail} = 0.0$	$C_{tail} = 0.73$
Presence of tail	NO	YES (>0)

Tail extraction: tail direction

- 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)

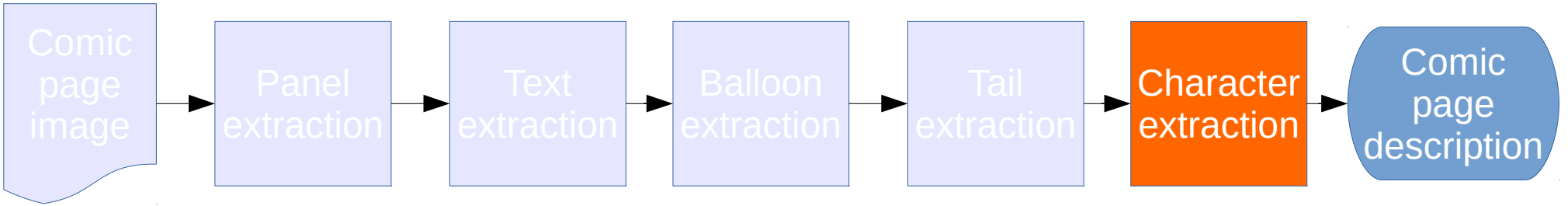
Background tail tip (green) and external edge (blue)

Closest point on external edge (red)

Farthest point from origin and tip (red)

Direction from tip to farthest point (white arrow)

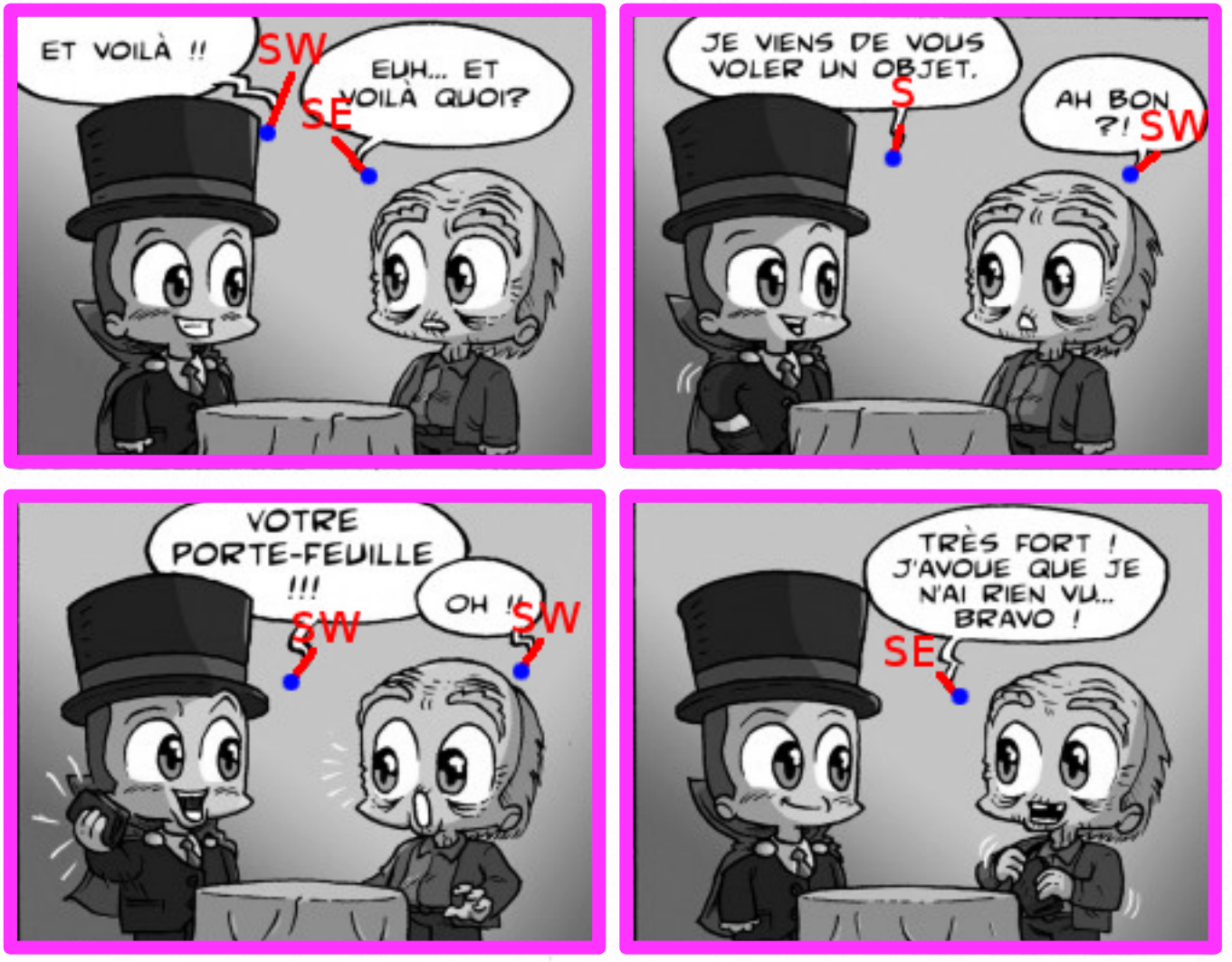
Comic character extraction



- 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

Panels + Tails = ?

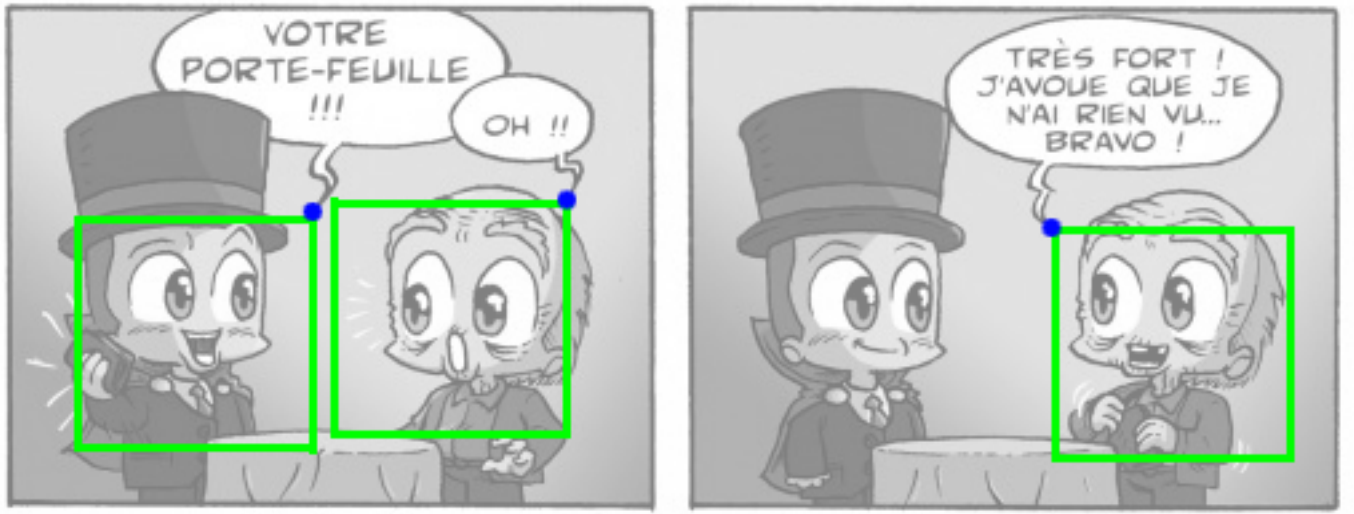


Comic character extraction

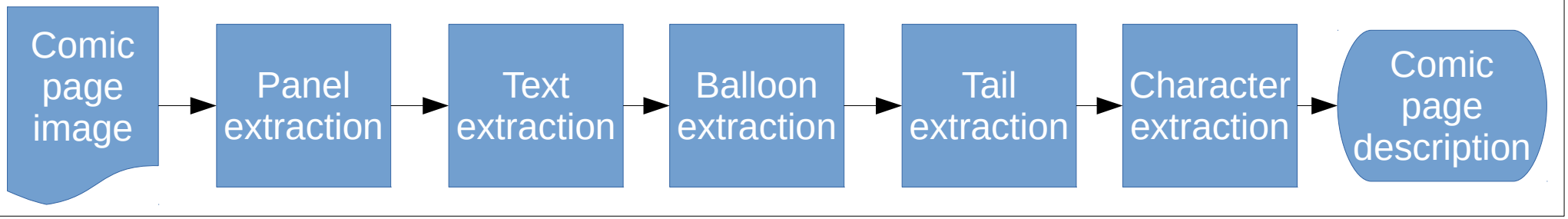
Panels + Tails = Comic character ROIs

Large ROI

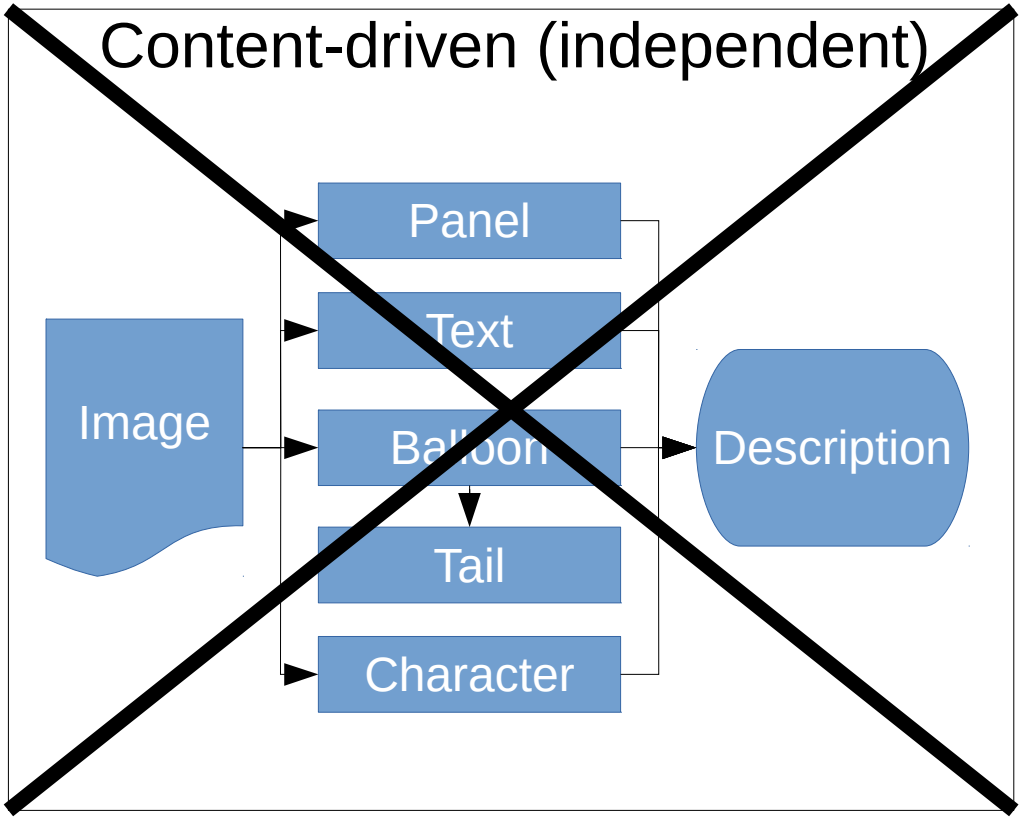
Small ROI



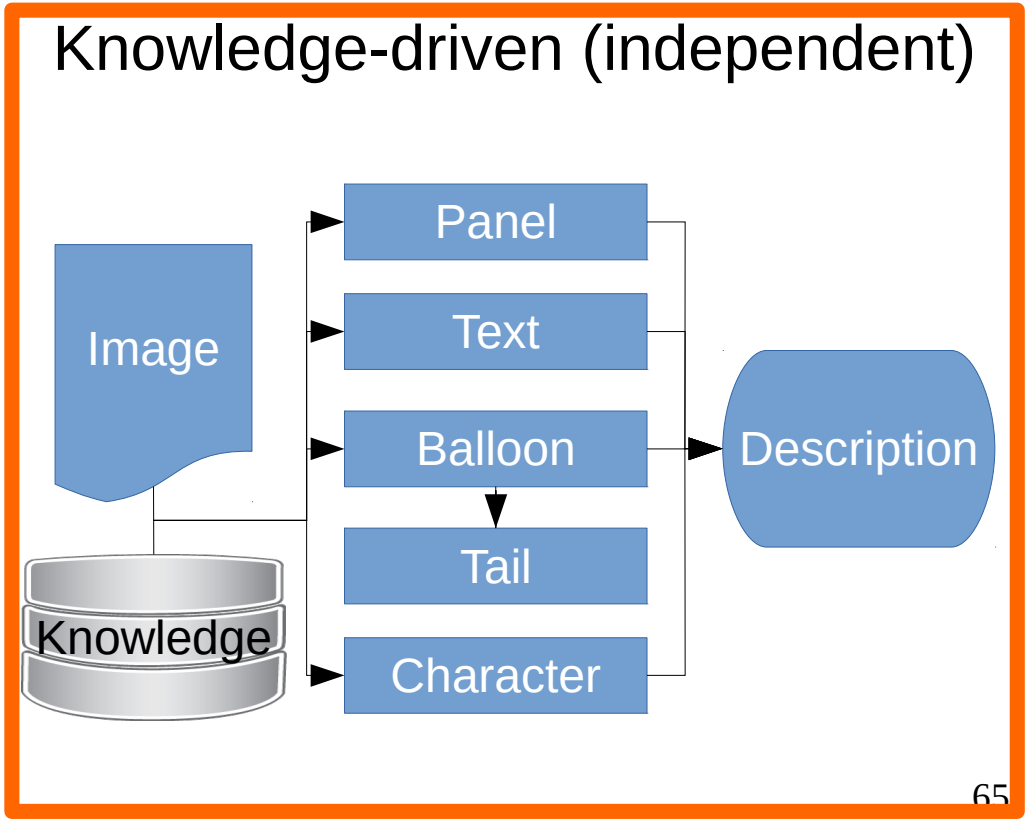
Content-driven (sequential)



Content-driven (independent)

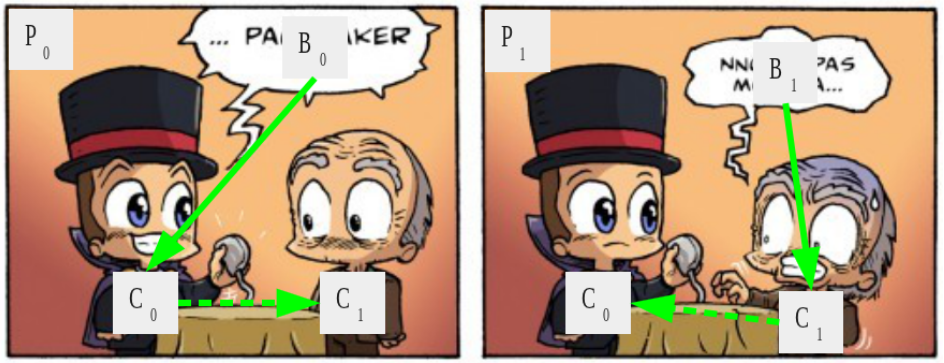


Knowledge-driven (independent)

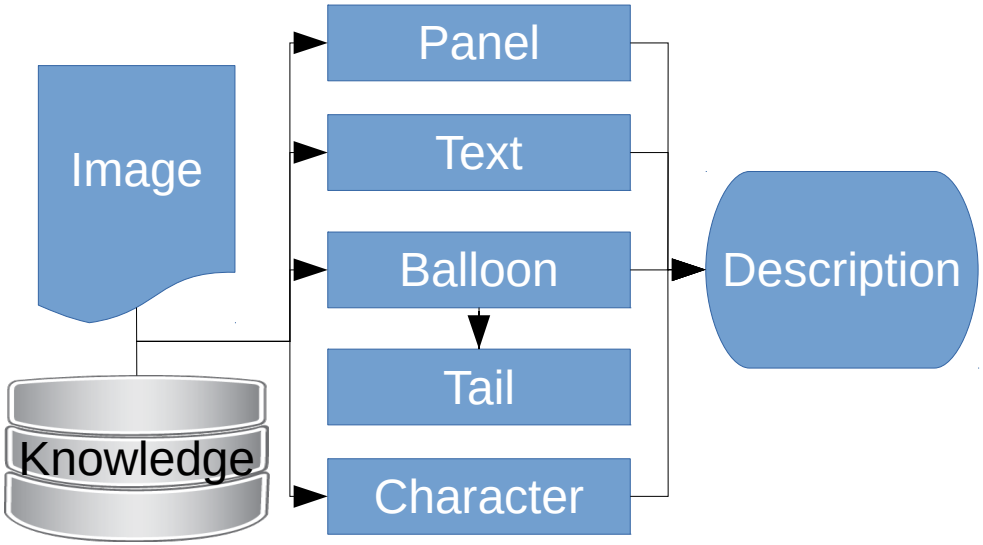


Introduction

- High level image description
- Independent element extraction
- Framework for comics understanding
- Collaboration with Clément Guérin



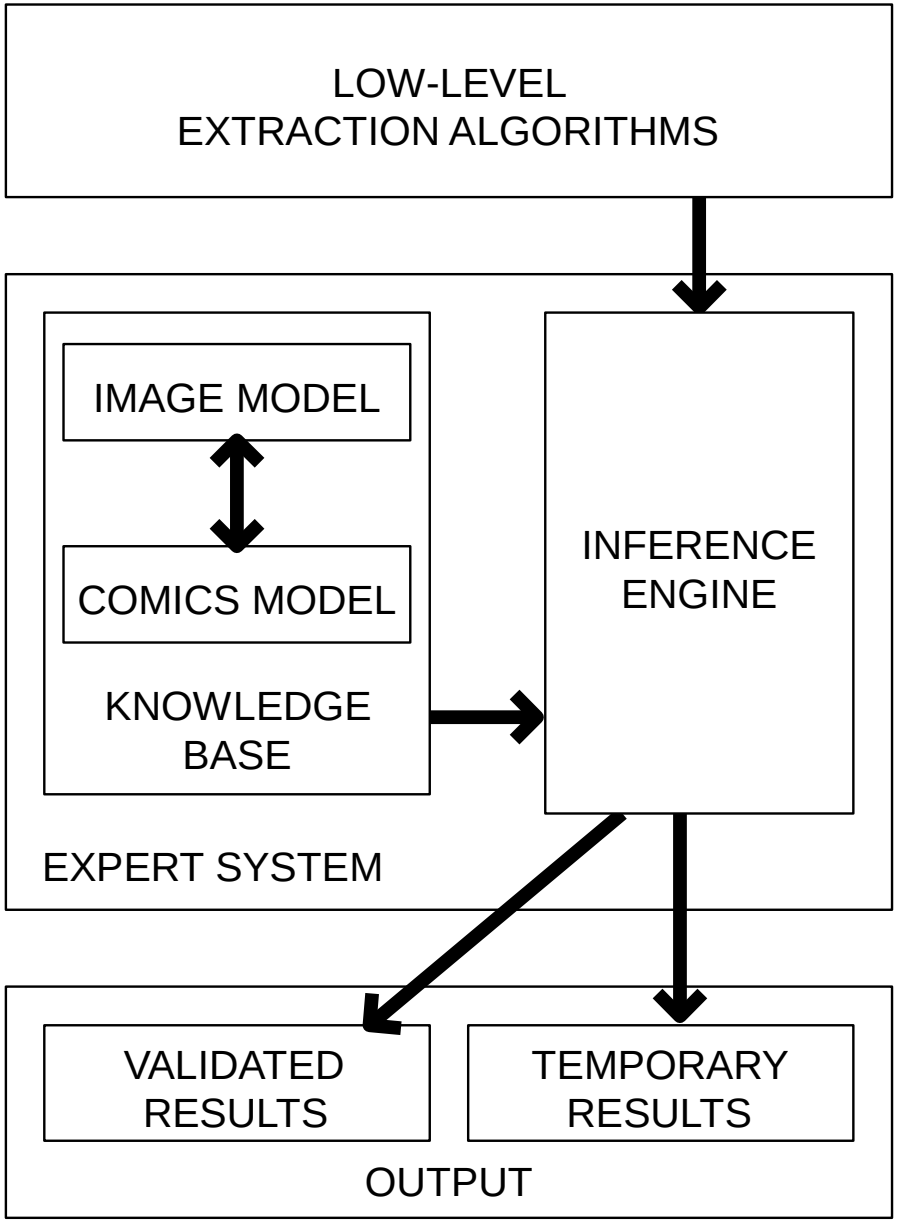
Example of situation understanding



Knowledge representation

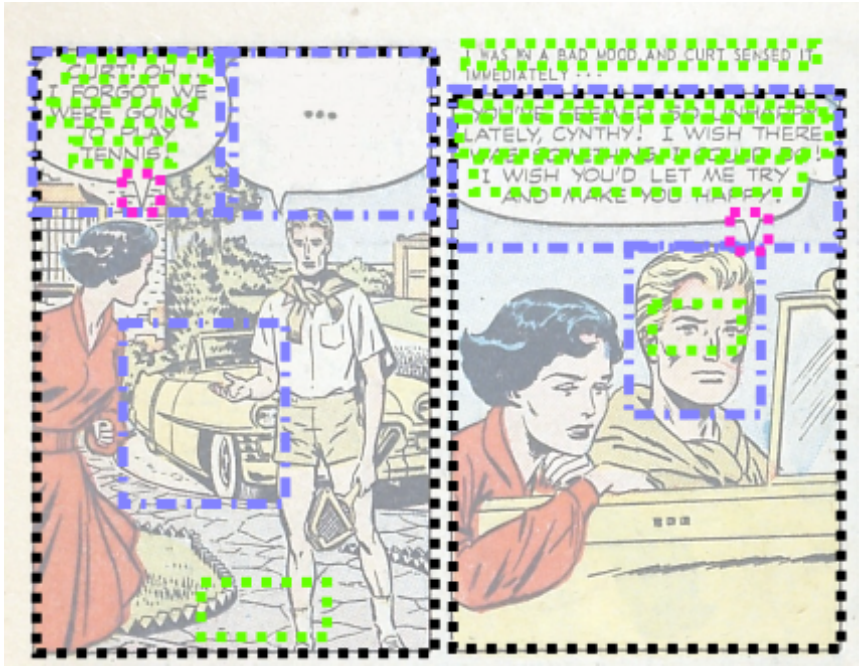
- Image model
  - Physical support
  - Region of interests

- Comics 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**

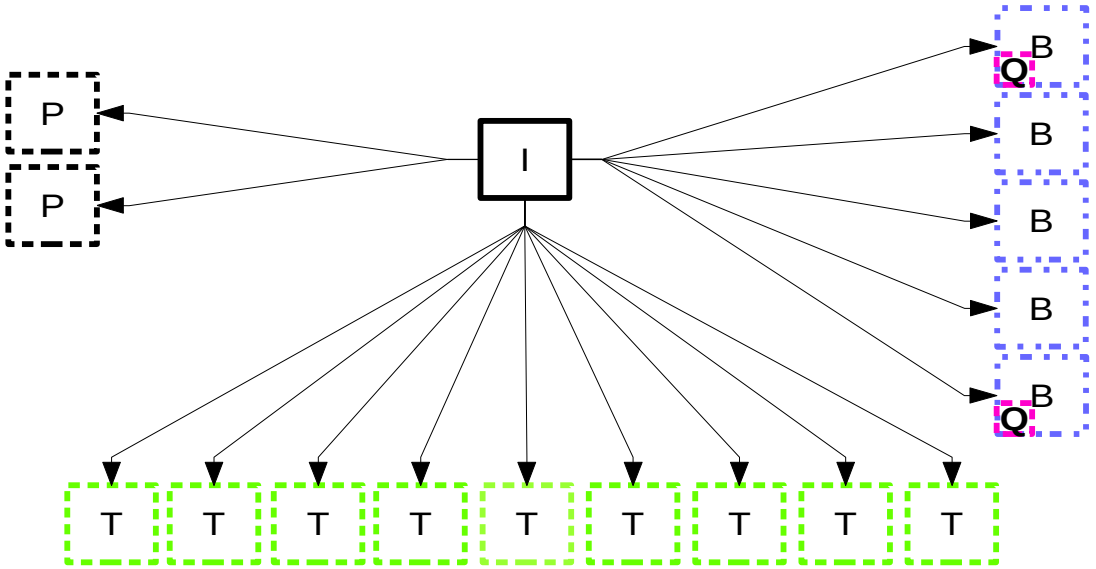


Processing sequence

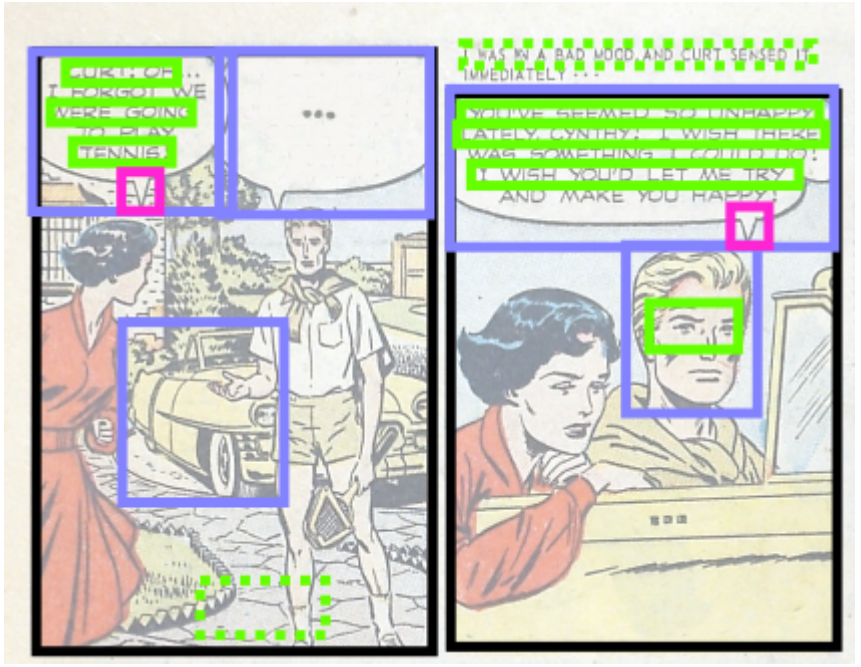
Processing sequence



Hypotheses of panels, balloons and text lines

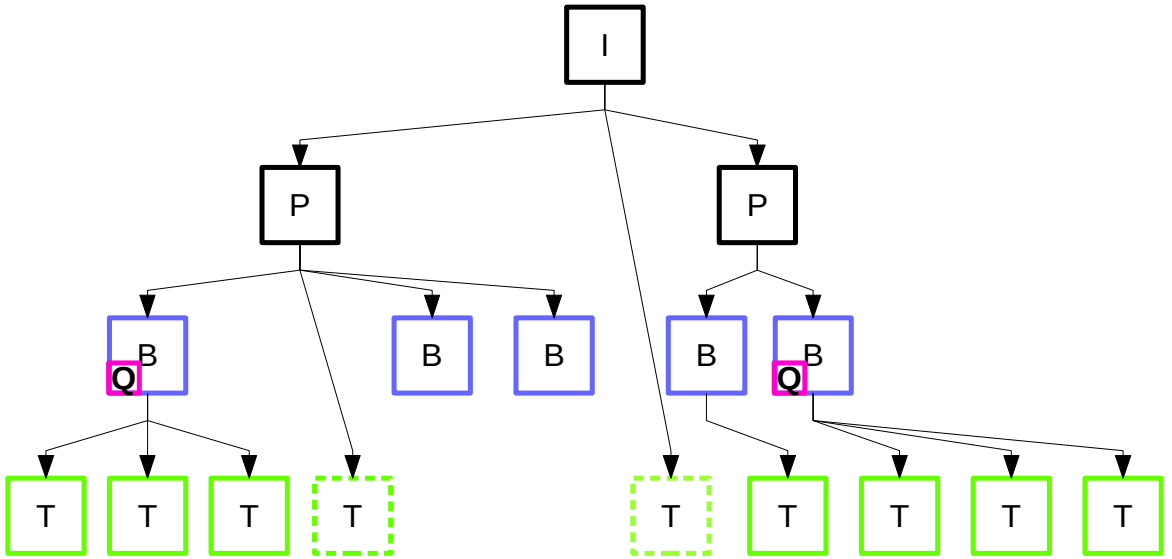


Processing sequence

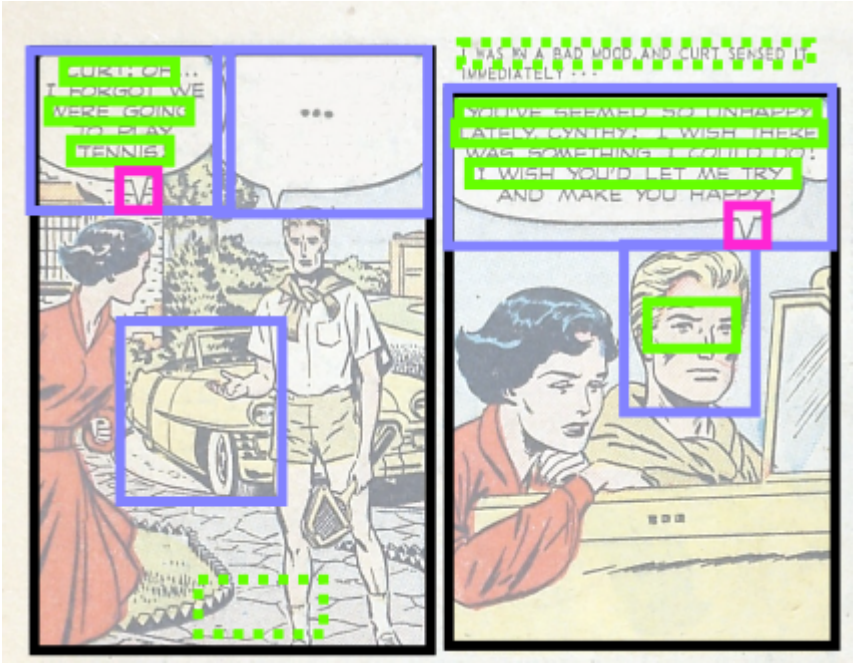


Hypotheses of panels, balloons and text lines

Validation of the hypotheses



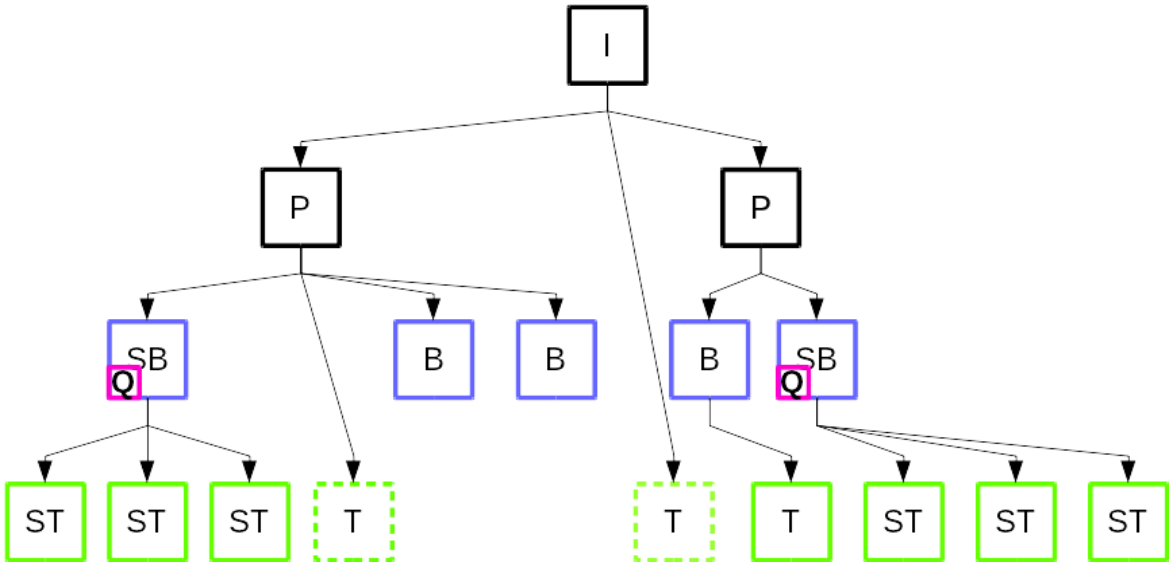
Processing sequence



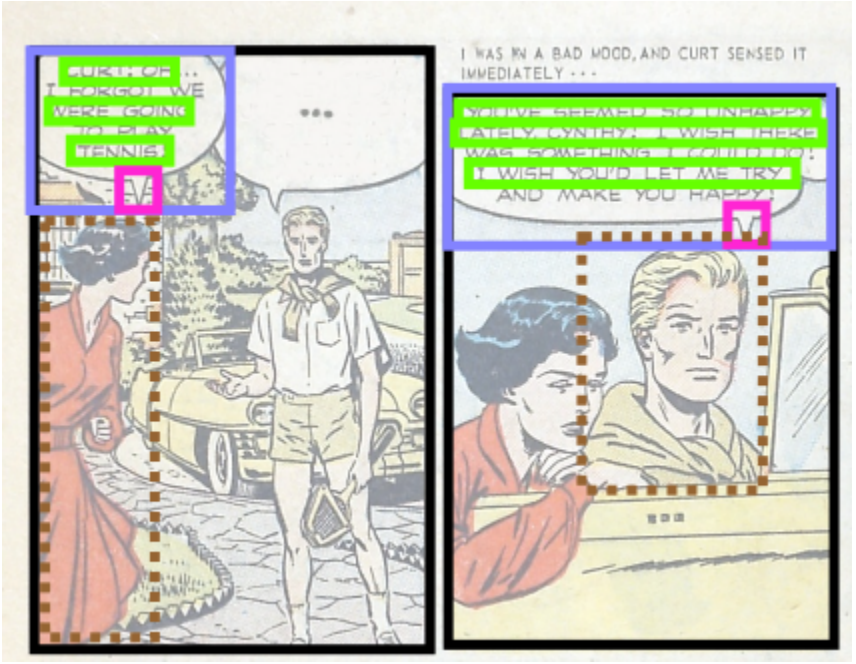
Hypotheses of panels, balloons and text lines

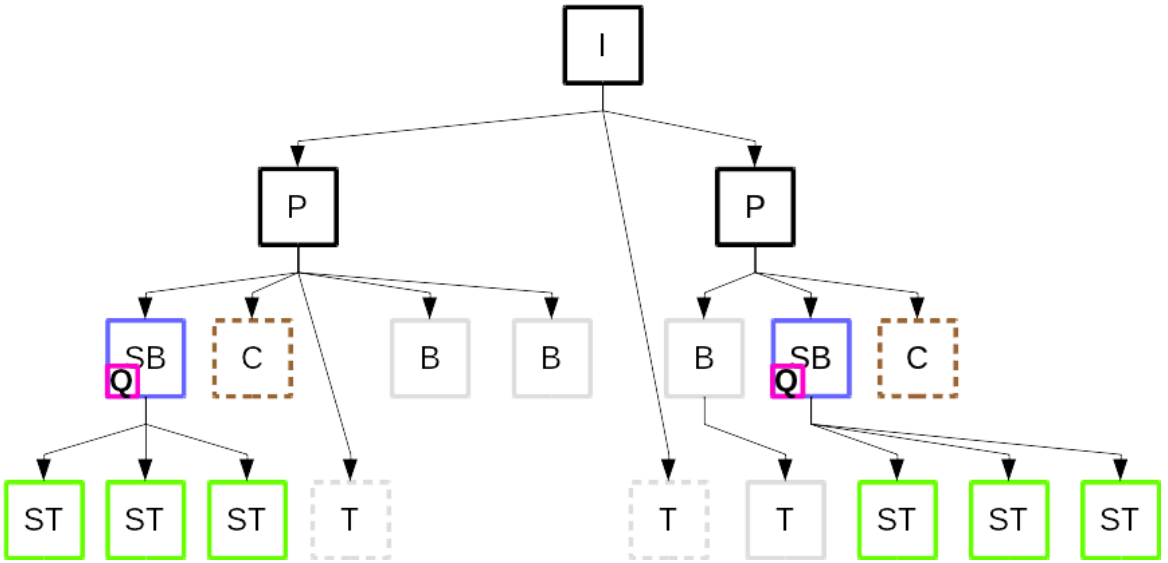
Validation of the hypotheses

Inferences of specific types



Processing sequence



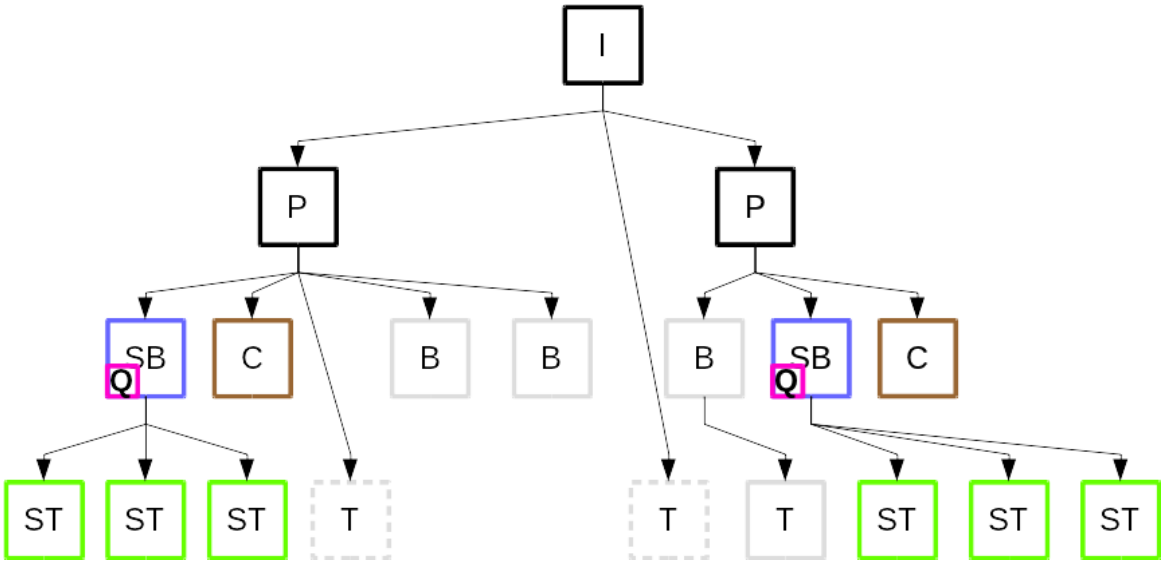


Hypotheses of comic characters

Validation of the hypotheses

Inferences of specific types

Processing sequence

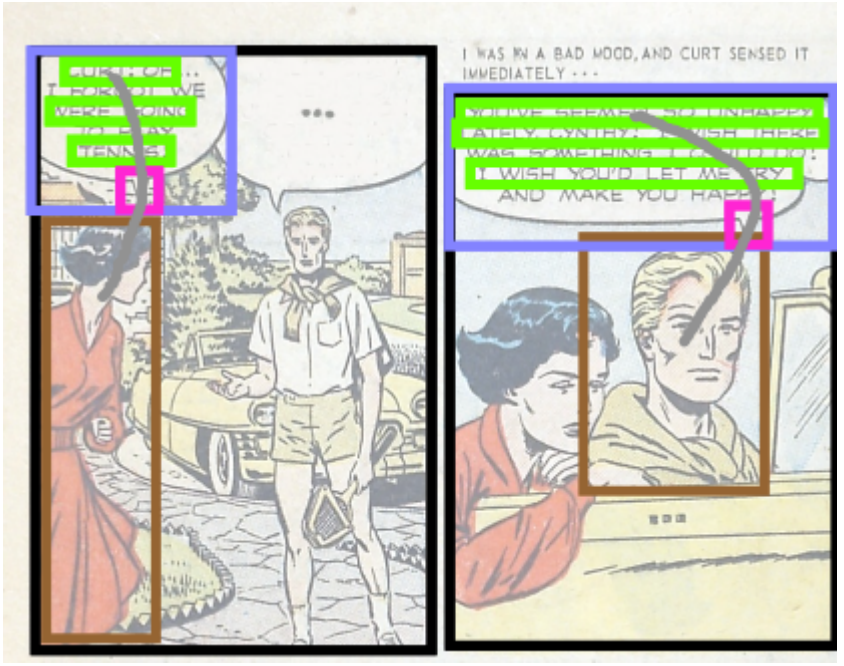


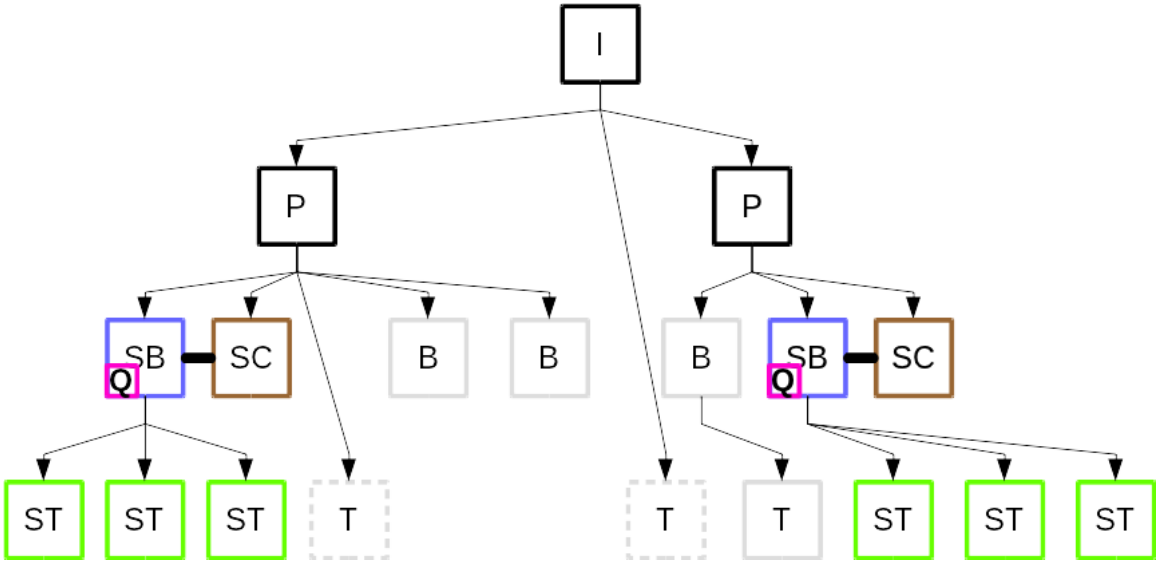
Hypotheses of comic characters

Validation of the hypotheses

Inferences of specific types

Processing sequence





Hypotheses of comic characters

Validation of the hypotheses

Inferences of specific types + semantic links

- Dataset and ground truth
- Evaluations
- Conclusions

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

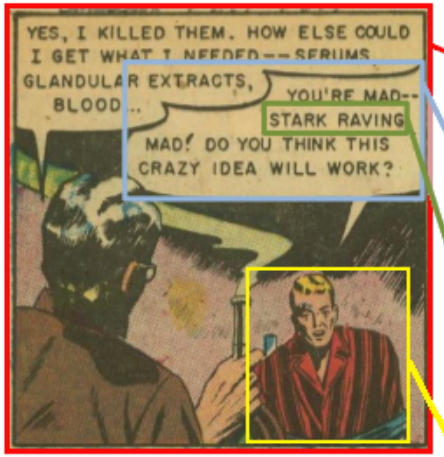
Dataset and ground truth

- 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 »

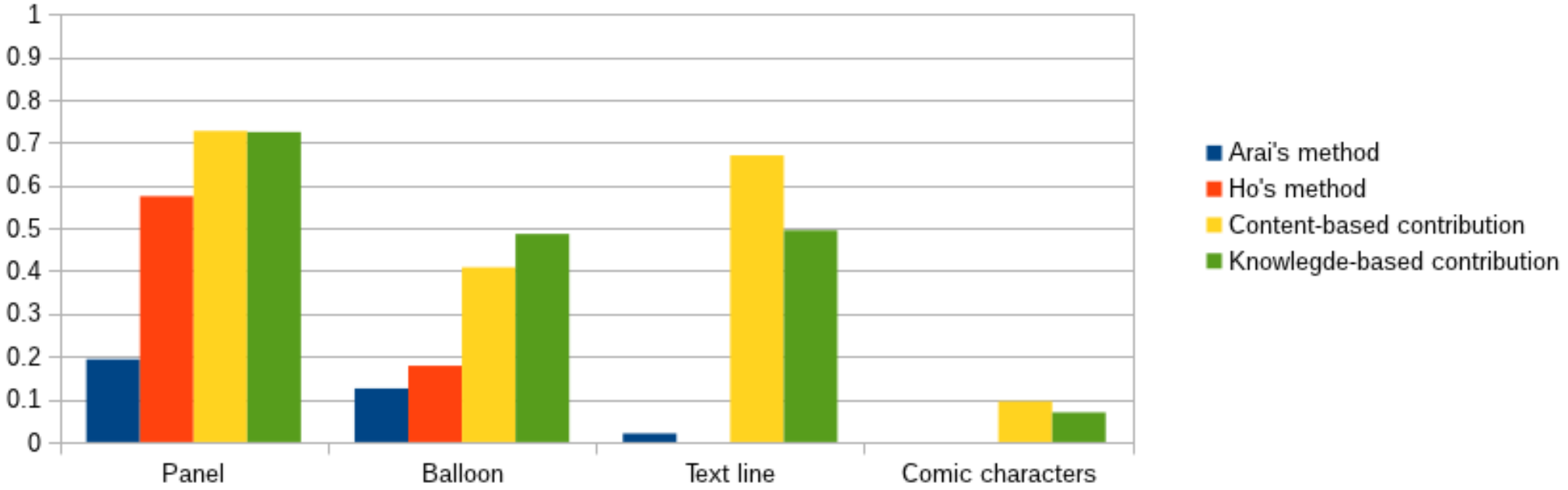
CHARACTER (1550)
LinkedToBalloon: 2

Evaluations

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

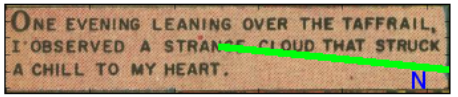
B_p = predicted region
B_{gt} = ground truth region
B_p valid if $a_0 > 0.5$

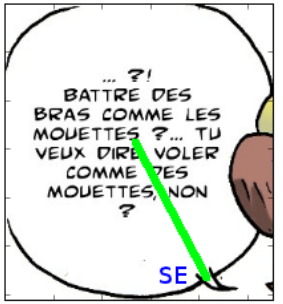
Element localisation results (F-score)



Evaluations

Examples of result





TODO

- Global conclusions
- Global perspectives
- Publications

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

Global conclusions

- Reached objectives
  - Comics image segmentation and understanding
- 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 (TODO: list them all?)
  - National projects (PIA BigData Actialuna + LIP6, ANR EXPION 2015)
  - International project on manga analysis (Campus France SAKURA with Japan)

Global perspectives

- Content extraction
  - Panels: implicit, overlapping and connected
  - Text: recognition
  - Balloon: implicit extraction and evaluation
  - Comic characters: non-speaking and identification
- Content understanding
  - Situation retrieval
  - Object interaction retrieval
  - Label elements from text analysis
- Dataset
  - Increase the number of pages
  - Panel view angle and situation
  - Multi-part comic character segmentation
  - Comic character names and roles

Publications

TODO

Thank you + github + c-r

- Authors, publishers, CIBDI
- Founding: Communauté d'Agglomération de La Rochelle
- Time for demo on easy case with comic character ROI computation?

Complementary information

History of comics art

- Pre-history: painting of animals and hunters in caves [Marx, 2007]
- 1846: Rodolphe Töpffer, the inventor of the “bandes dessinées”
- 1930s: magazine-style comic books production in the US
- 1950s: massive production of manga in Japan (Osamu Tezuka)
- 1971: the term of ninth art is attributed to comics art (Francis Lacassin)
- 1996: explosion of the Internet bubble and webcomics
- 2007: adaptation to social media sites and mobile devices

Pre-history and ancient Egypt

Rodolphe Töpffer, Histoire de Monsieur Cryptogame (1830)

Ted McCall, Robin Hood And Company (1946)

Tezuka Osamu, Manga Classroom (1953)

Marion Montaine, Tu mourras moins bête (2013)

GT validation

Knowledge-driven analysis detail

- Comic character region refinement

Production to interpretation

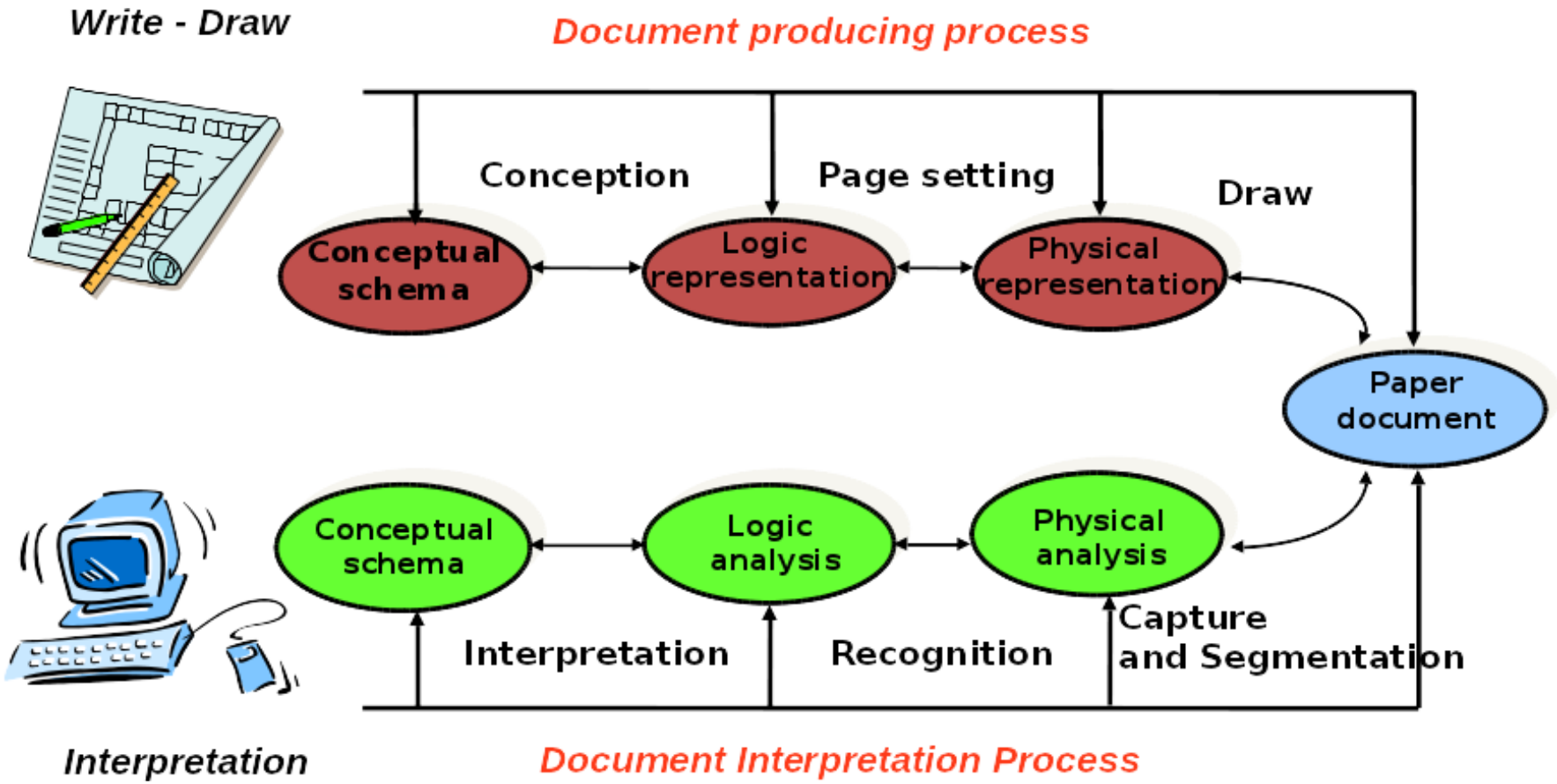


Image source: Handbook of Document Image Processing and Recognition. Springer, 2014