FACULTY OF ENGINEERING
AND ARCHITECTURE

COMPUTER VISION GROUP 8

RECOGNITION BASED INDOOR LOCALIZATION

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INTRODUCTION

- Frame processing
- Painting detection
- Painting matching
- Localization
- Conclusion
- Demo

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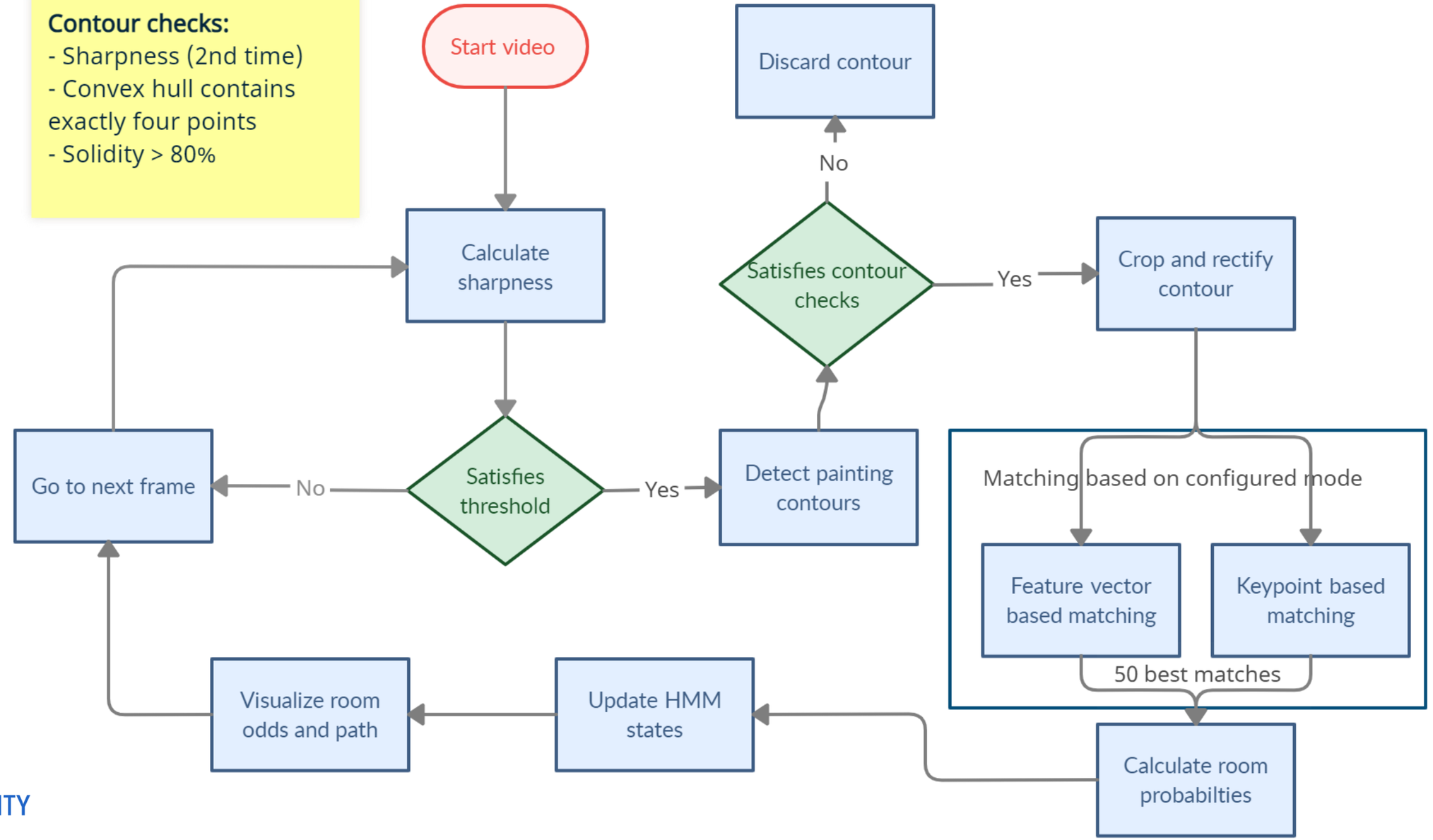
INTRODUCTION

Contour checks:
- Sharpness (2nd time)
- Convex hull contains exactly four points
- Solidity > 80%



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FRAME PROCESSING

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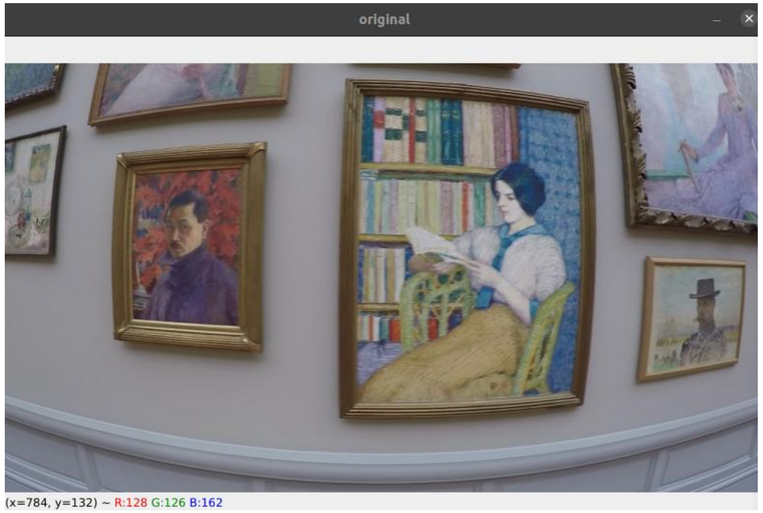
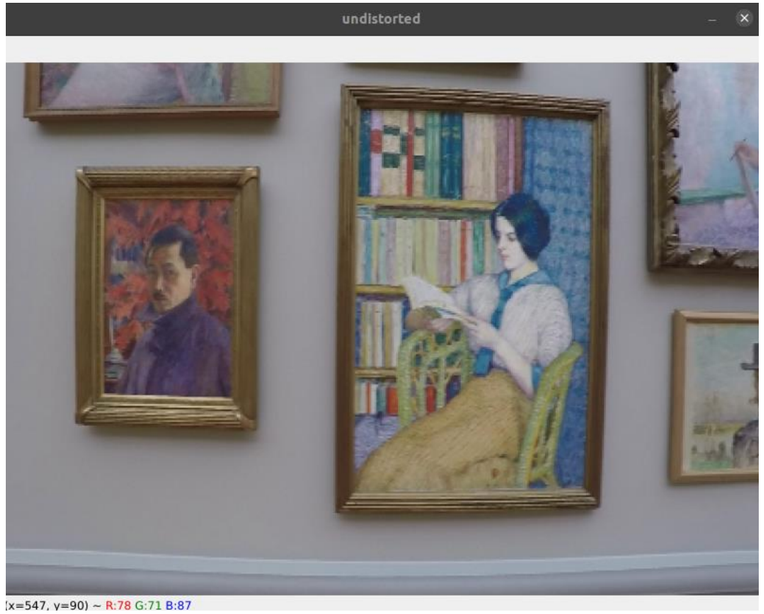
GOPRO CAMERA CALIBRATION

- GoPro: wide-angle lens => radial distortion
- Compensate distortion to …
  - Detect rectangles
  - Rectify paintings
- Chessboard calibration
  - Manually select useful frames
- Correct distorted frames
  - Crop to optimal ROI





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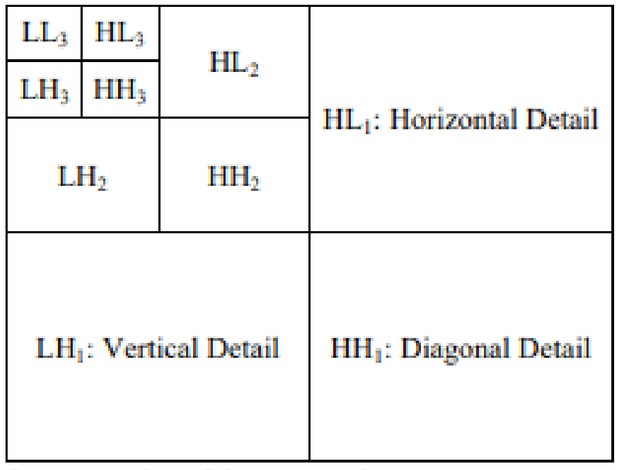
FRAME SHARPNESS

- Discard frames early in the process
  - Prevent processing on every frame
  - Frames affected by motion blur contain less details (impact on keypoint matching)
  - Waste of computational resources
- Evaluate quality of cropped paintings from the frame
  - Impact of sideways perspective
  - Paintings that are far away from the camera

FRAME SHARPNESS

- Image decomposition using the Haar Wavelet Transform
- Pyramid containing three downscaled image versions (result of applying HWT three times in succession)
- Construct edge map on each scale using LH, HL, HH
- Apply max pooling on small subwindows (2x2 => 4x4 => 8x8)



HWT

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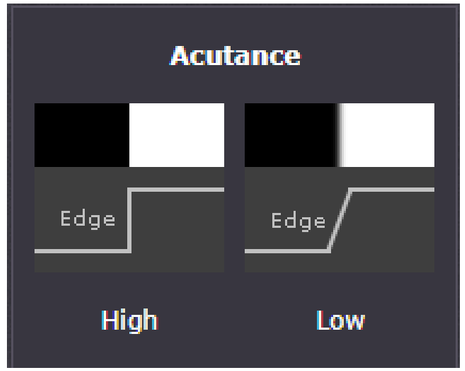
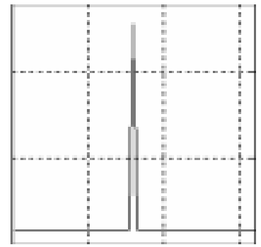
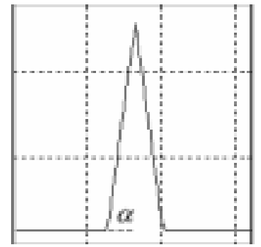
FRAME SHARPNESS

- Blur changes edge type and sharpness
- Group pixels in the edge map as edge point or not
- Classify the type of edge for each edge point
  - Consider all scales: blurred edges recover sharpness when observed in small scale (Gstep => Astep, α closer to 90 degrees)
  - Based on four rules
- Count edge points by type
- Calculate ratio

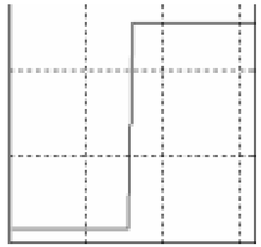




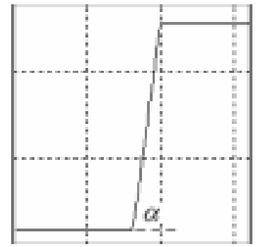
a. Dirac-Structure



b. Roof-Structure



c. Astep-Structure



d. Gstep-Structure

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PAINTING DETECTION

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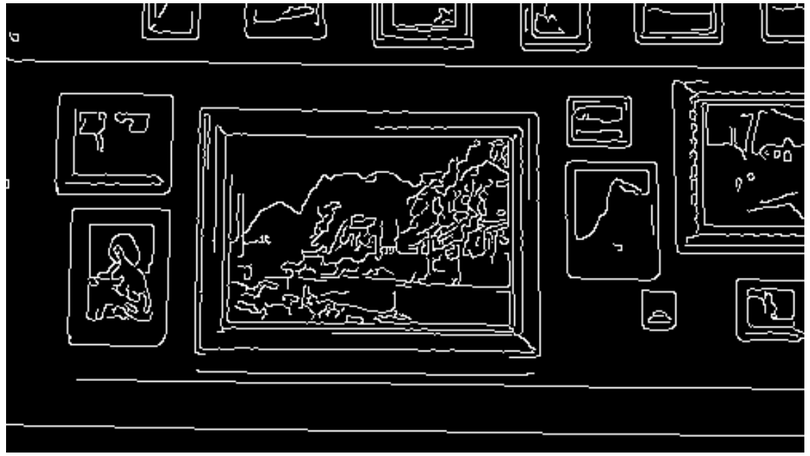
DETECTION PIPELINE

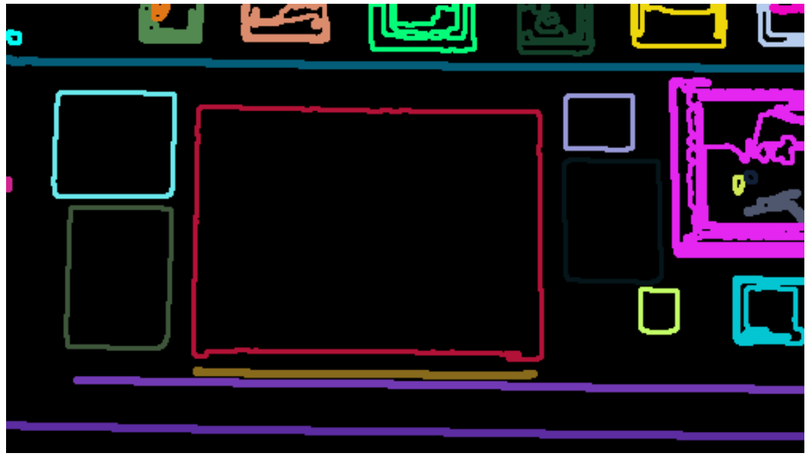
- Gaussian smoothing on grayscale image
- Binary image using Canny and dilate the result
- Find contours in binary image
  - Only outer contours (no children in the tree hierarchy)
  - Approximate polygon on convex hull
  - Number of points in the convex hull (= 4 for quadrilaterals?)
  - Solidity check (compare contour area with convex hull area)
- Crop contours in original image and reevaluate sharpness

DETECTION EXAMPLE

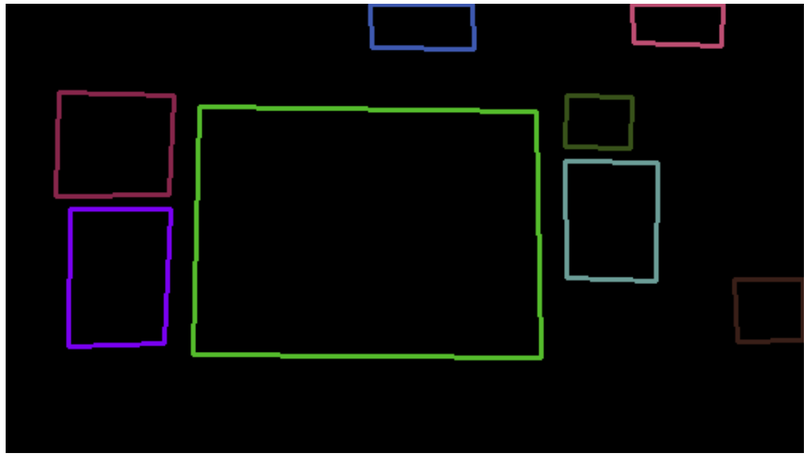
Create edge map



Dilation and contour detection



Apply filter checks



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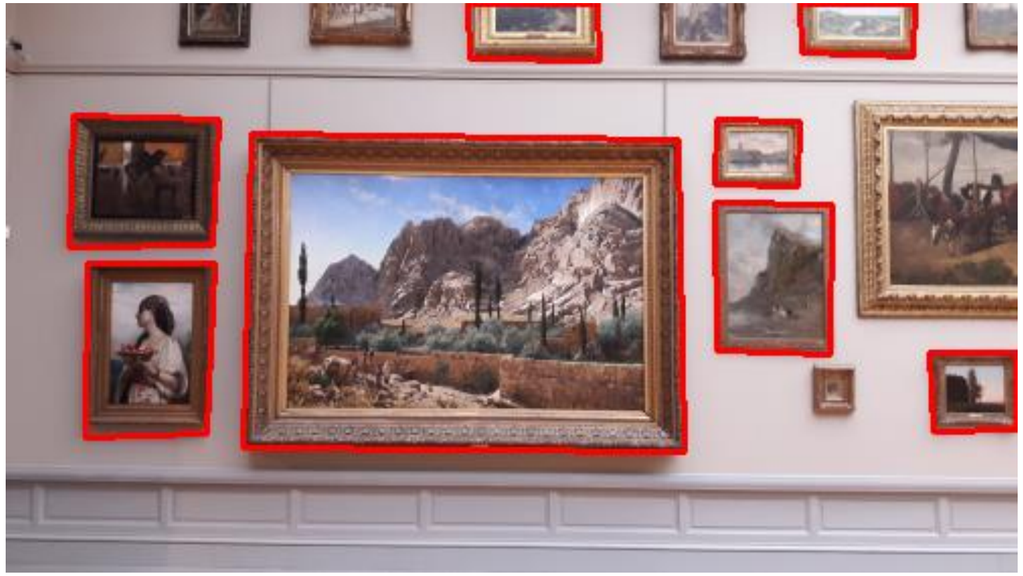
DETECTION EXAMPLE

- Smoothing prevents detection of small details
  (e.g. wire above painting)
- Most prominent paintings detected
- Internal contours detected
  (when frame is missing)
- Irregularities on small paintings



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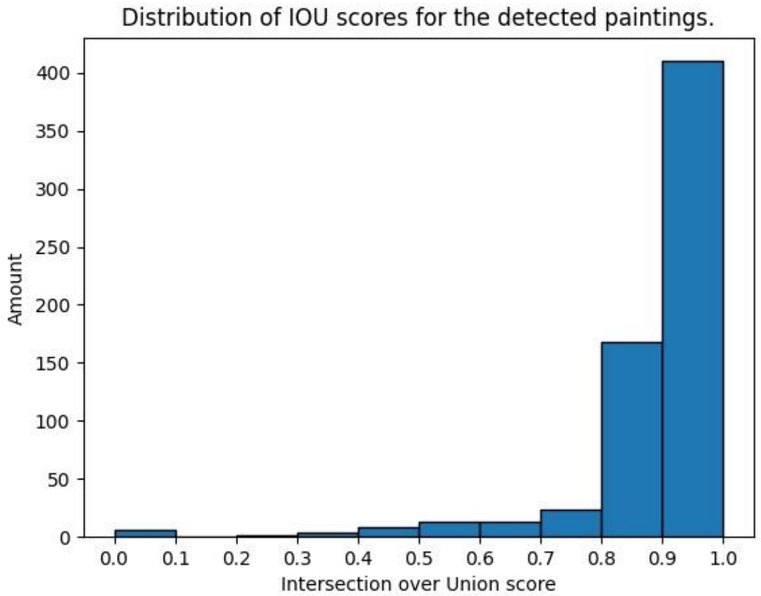
DETECTION BENCHMARK

- 801 paintings in the dataset
  - 646 correctly detected
  - 61 false positives
  - 155 false negatives
- IOU average: 0.89
- Precision: 0.91
- Recall: 0.81
- F1-score: 0.85



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DETECTION BENCHMARKS

False detection

- IOU lower than 0.1
- Contains no paintings

Bad and mediocre detections

- IOU between 0.1 and 0.75
- Bad (partial) detections
- Multiple paintings in contour
- Partially due to dilation

Partial or near complete detection

- IOU between 0.75 and 0.95
- Missing frames
- Contains most painting information
- Shadows under the painting

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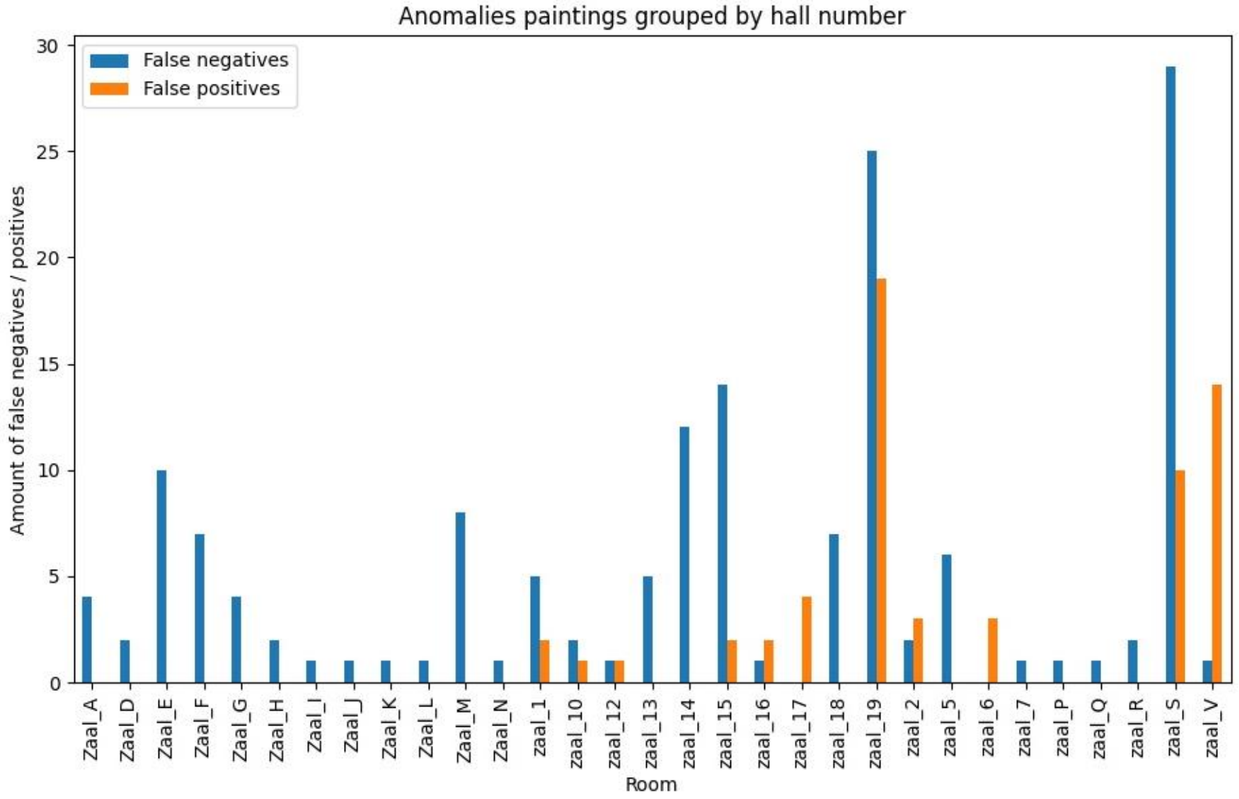
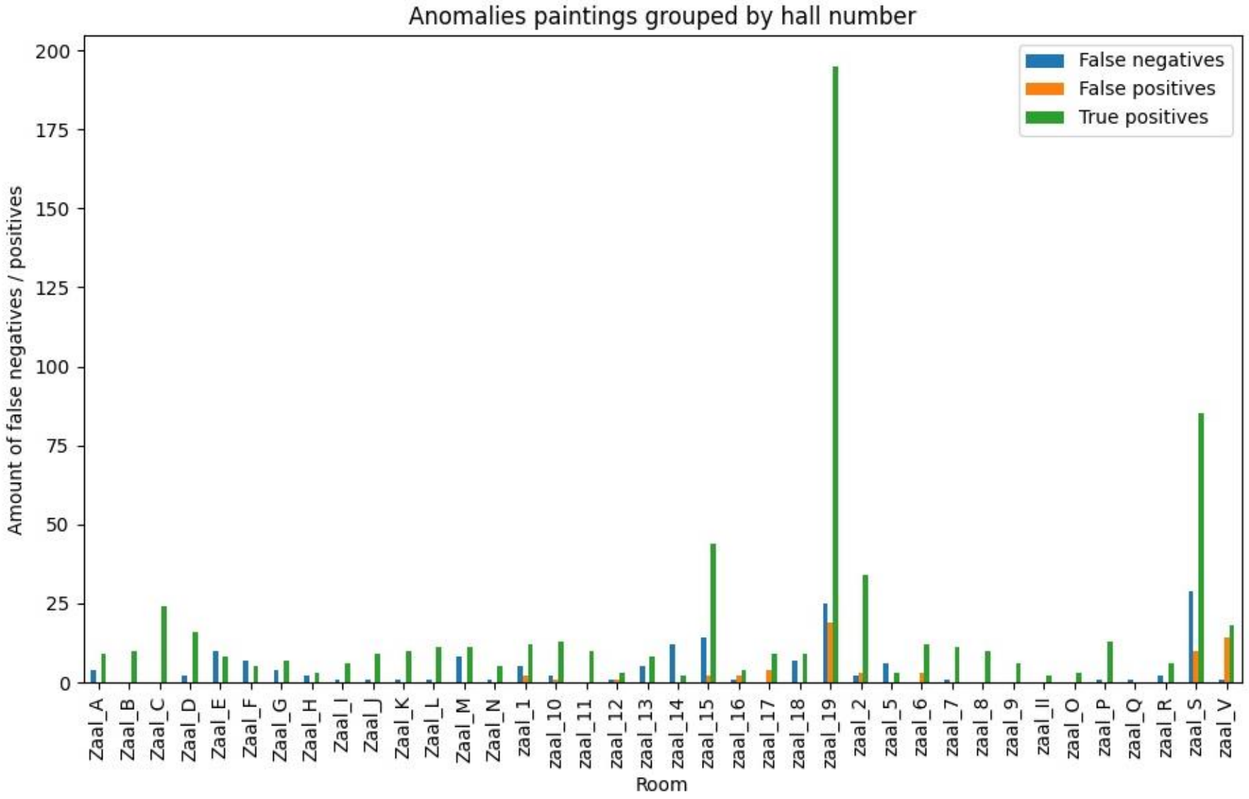
DETECTION BENCHMARKS





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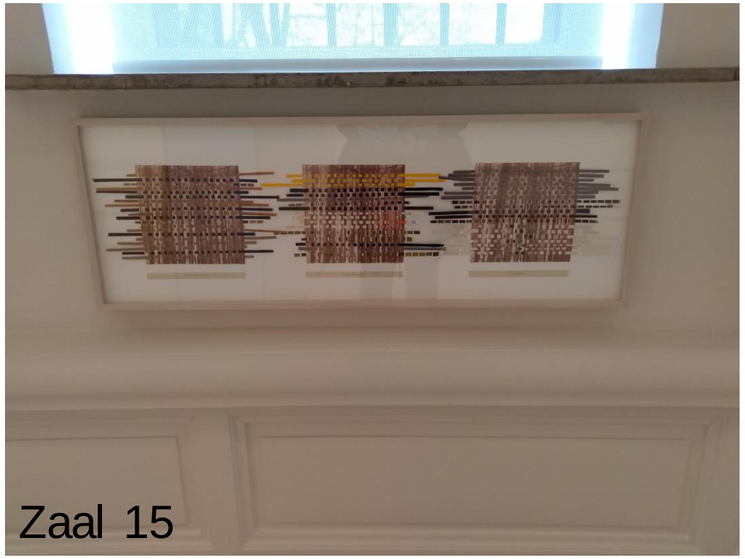
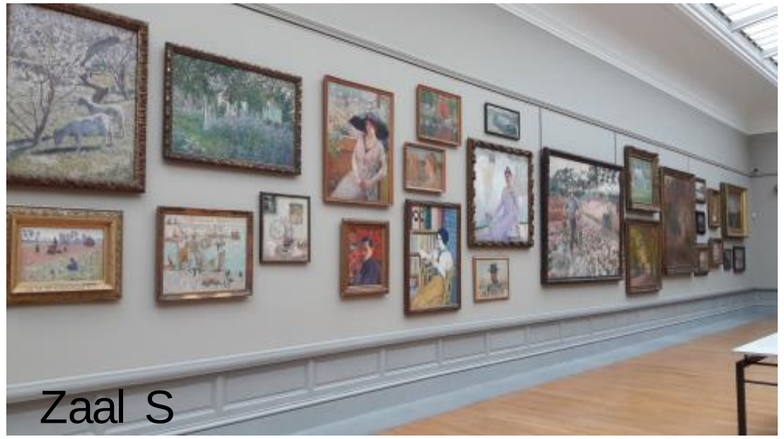
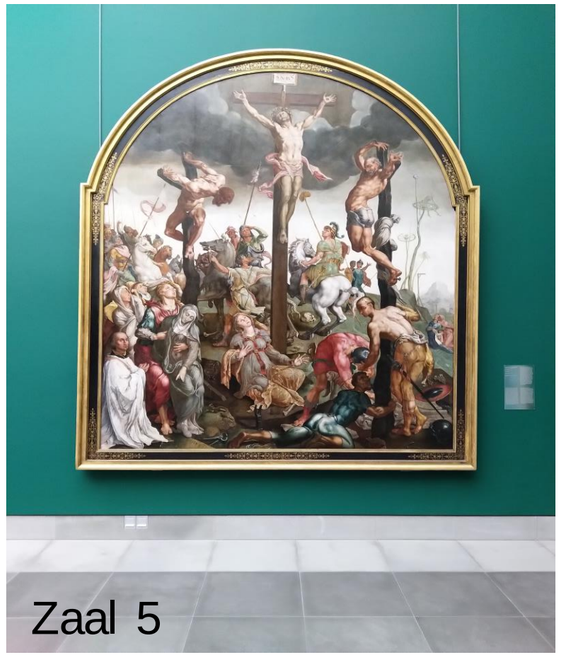
COMMON DETECTION PROBLEMS







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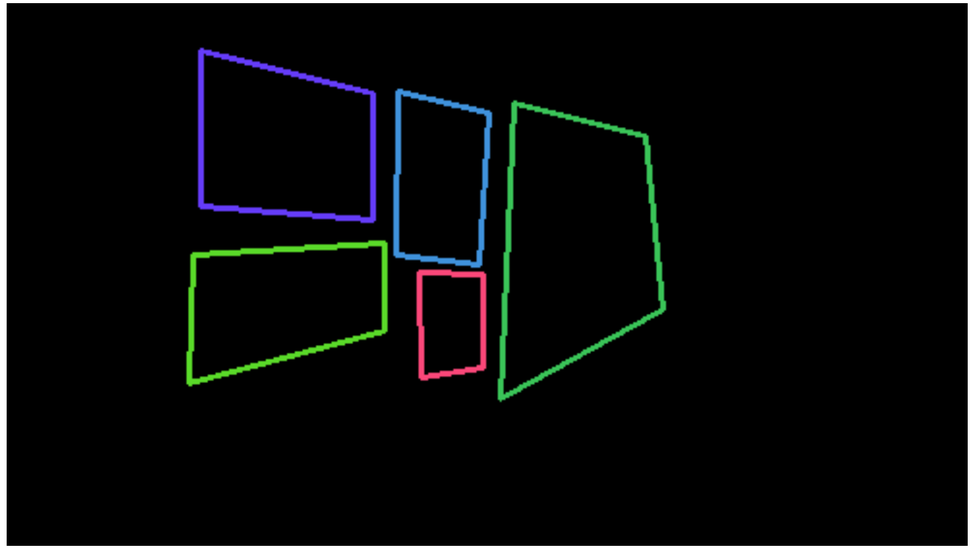
DETECTION IMPROVEMENTS

- Stronger quadrilateral constraints
  - Isosceles trapezoid (may be too specific)
  - Comparison between all four angles
- Compare detected contour shapes
  - Reject if too different
  - Only when X contours detected



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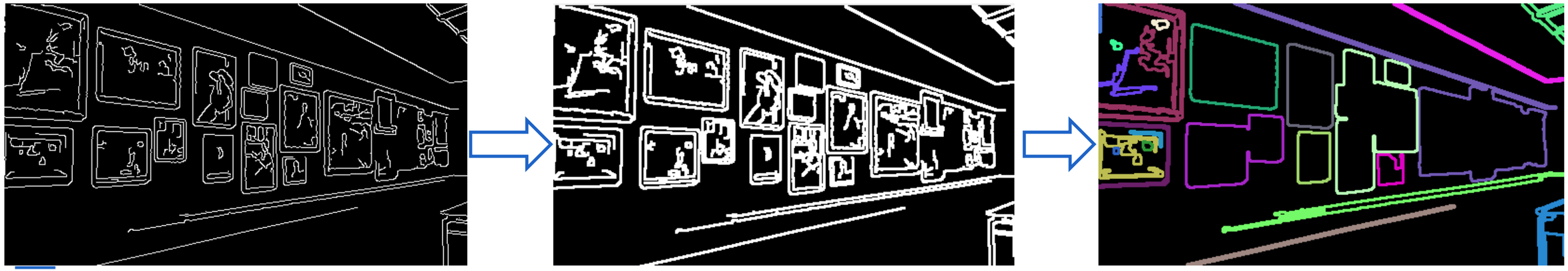
DETECTION IMPROVEMENTS

- Experiment with elliptical paintings
  - Impact of the increased search space on performance
  - Alternative: check if contours are elliptical
- Adaptive dilation behavior
  - Useful when distance between viewer and painting is small
  - Problems when viewed from distance



PAINTING MATCHING

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MATCHING INTRODUCTION

- Keypoint matching
- Feature vector matching

Preprocessing of paintings in database

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KEYPOINT MATCHING

ORB

- Not fully scale invariant
- Shearing and blurry images

KEYPOINT/FEATURE VARIATION CORRECTNESS RESULTS

No. keypoints	Positive matches	Negative matches	Mean score (%)
50	402	35	91.99
100	423	14	96.80
200	424	13	97.03
300	425	12	97.24

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KEYPOINT MATCHING

KEYPOINT/FEATURE VARIATION COMPUTE TIME

No. of keypoints	Compute time (ms)
50	60
100	107
200	238
300	353

DISTANCE DISTRIBUTION AVERAGE VALUES

No. keypoints	Mean	Mean match	Mean no match
50	374.98	302.66	1413.36
100	247.87	229.92	1007.40
200	187.71	173.47	858.89
300	164.64	152.30	819.88

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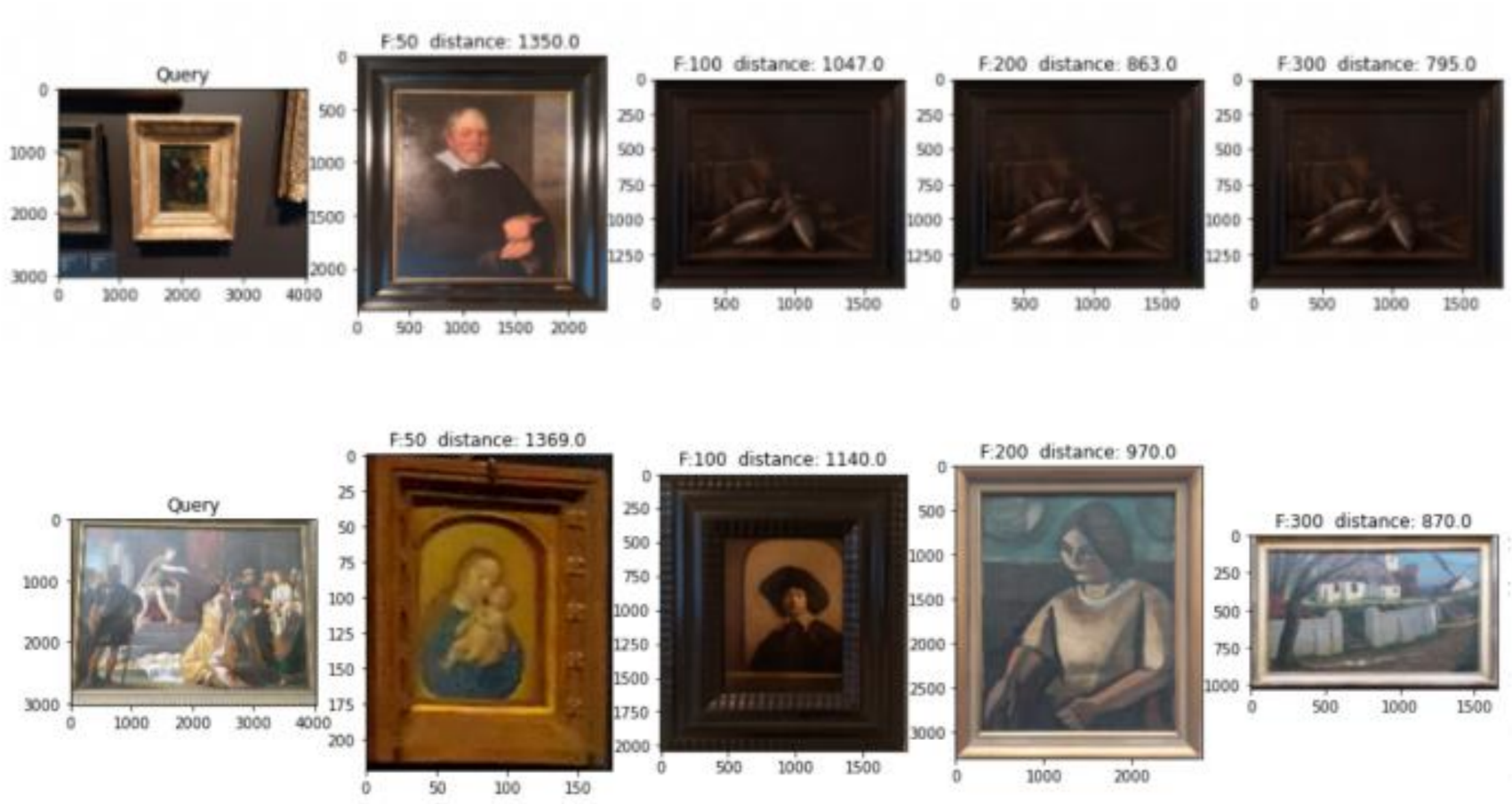
KEYPOINT MATCHING



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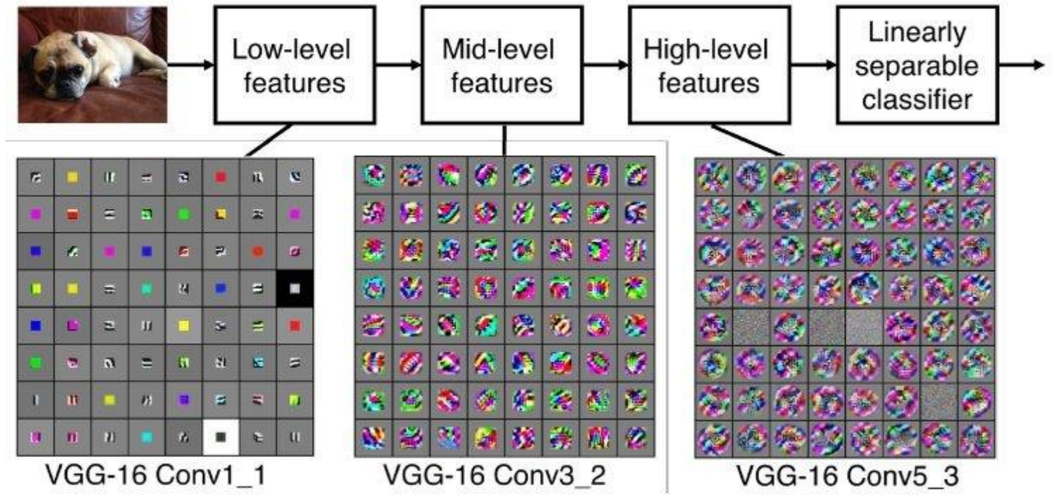
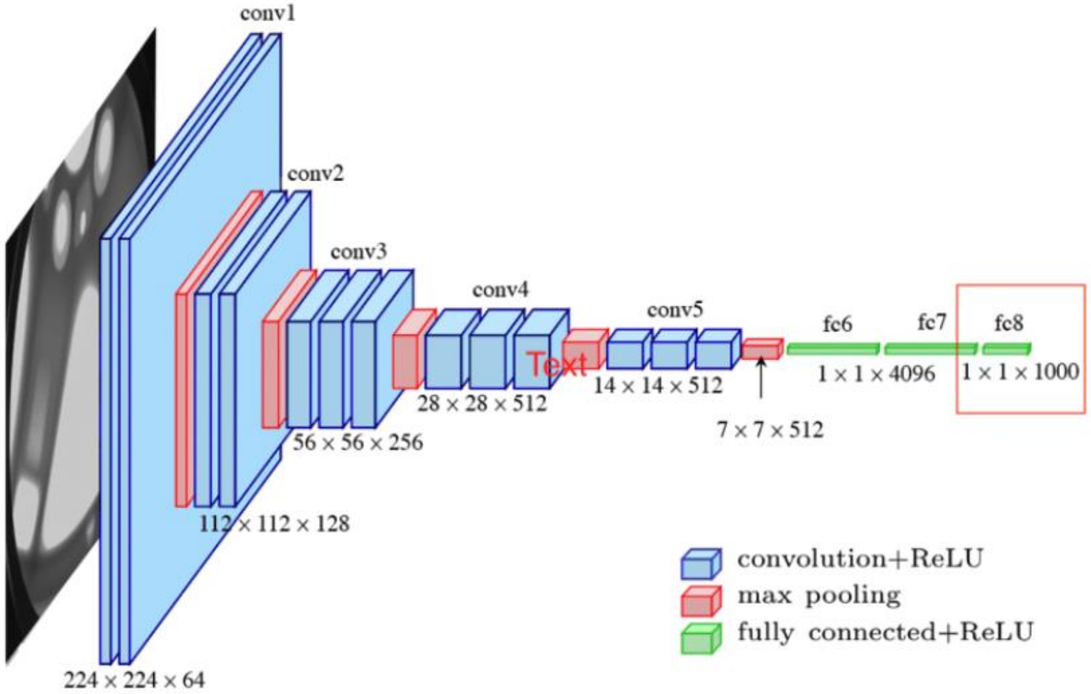
FEATURE VECTOR MATCHING

- VGG16
- Imagenet weights





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FEATURE VECTOR MATCHING

Distance metrics:

- Euclidean
- Cityblock
- Chebyshev
- Cosine

Accuracy (correct vs incorrect matches)

Distance distribution

Difference in distance (first and second match)

Compute time

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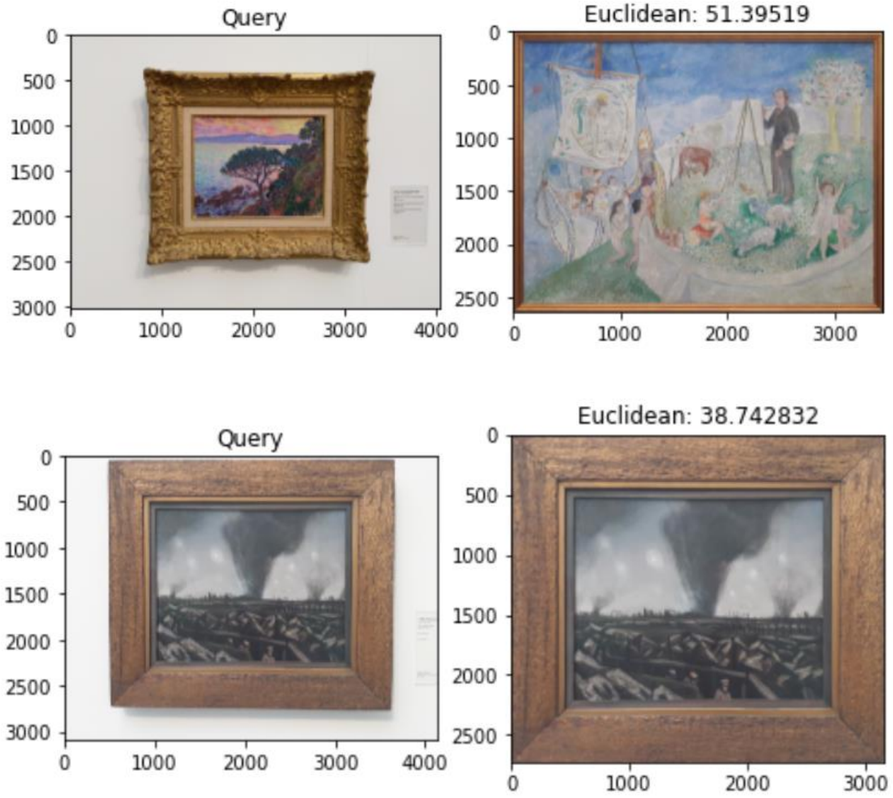
FV-MATCHING DISTANCES

DISTANCE METRIC VARIATION CORRECTNESS RESULTS

Metric	Positive matches	Negative matches	Mean score (%)
euclidean	363	74	83.07
cityblock	358	79	81.92
chebyshev	315	122	72.08
cosine	360	77	82.38

Accuracy (correct vs incorrect matches)



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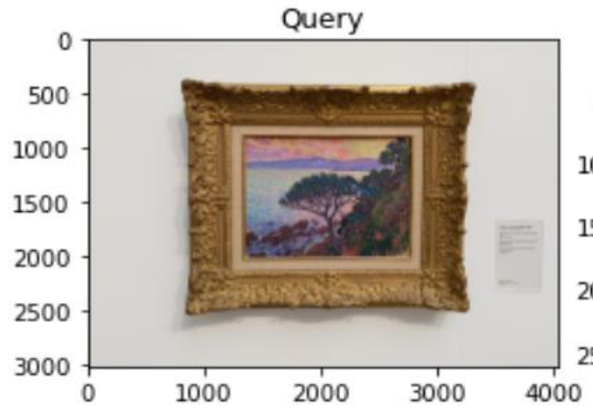
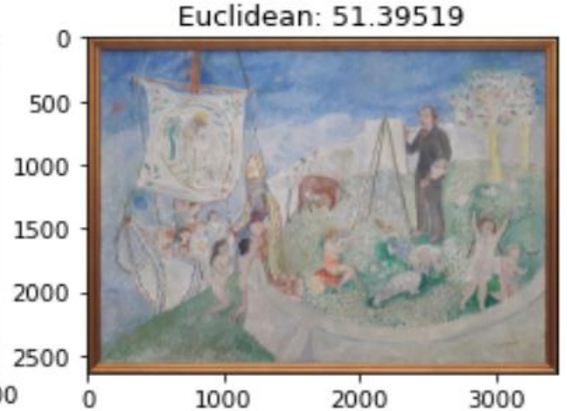
FV-MATCHING DISTANCES

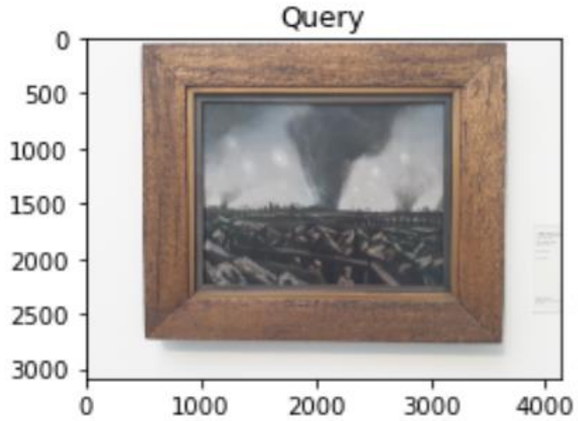
DISTANCE DIST

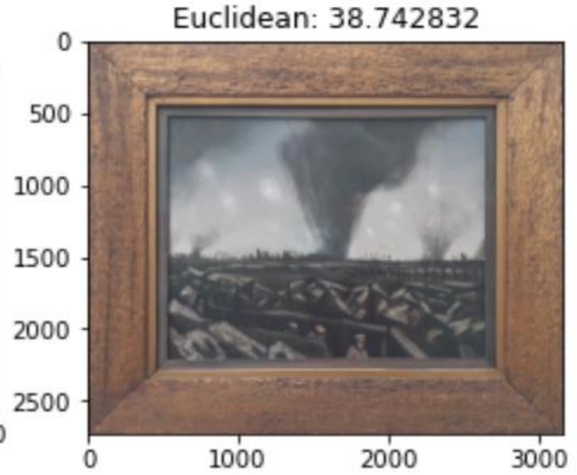
Metric	Mean
euclidean	49.70
cityblock	1420.49
chebyshev	5.22
cosine	0.16

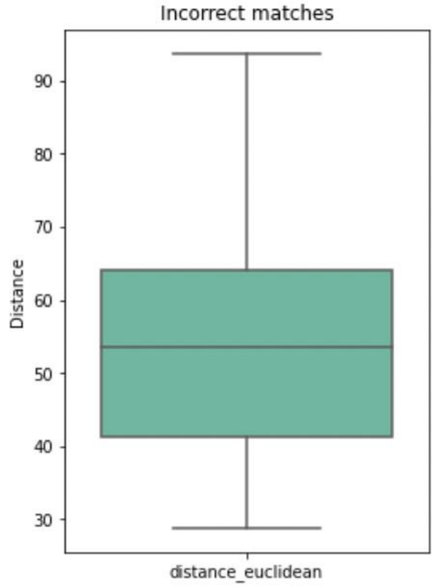
Metric	Outl
euclidean	5
cityblock	9
chebyshev	8
cosine	1











0 outliers

	distance_euclidean
count	74.000000
mean	53.492767
std	15.560075
min	28.766142
25%	41.314603
50%	53.530453
75%	64.106862
max	93.767815

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FV-MATCHING DISTANCES

DIFFERENCE IN DISTANCE DISTRIBUTION AVERAGE VALUES

Metric	Mean match	Mean no match
euclidean	11.64	1.78
cityblock	356.85	54.80
chebyshev	1.02	0.22
cosine	0.08	0.02

Difference in distance (first and second match)

Metric	Relative difference (%)
euclidean	146.95
cityblock	146.75
chebyshev	129.03
cosine	120.00

Query

First match

Second match

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FV-MATCHING DISTANCES

DISTANCE METRIC VARIATION CORRECTNESS RESULTS

Metric	Positive matches	Negative matches	Mean score (%)
euclidean	363	74	83.07
cityblock	358	79	81.92
chebyshev	315	122	72.08
cosine	360	77	82.38

Accuracy (correct vs incorrect matches)

DISTANCE DISTRIBUTION AVERAGE VALUES

Metric	Mean	Mean match	Mean no match
euclidean	49.70	48.92	53.49
cityblock	1420.49	1371.98	1640.33
chebyshev	5.22	5.16	5.38
cosine	0.16	0.14	0.24

Distance distribution

DIFFERENCE IN DISTANCE DISTRIBUTION AVERAGE VALUES

Metric	Mean match	Mean no match
euclidean	11.64	1.78
cityblock	356.85	54.80
chebyshev	1.02	0.22
cosine	0.08	0.02

Difference in distance (first and second match)

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FV-MATCHING COMPUTE TIME

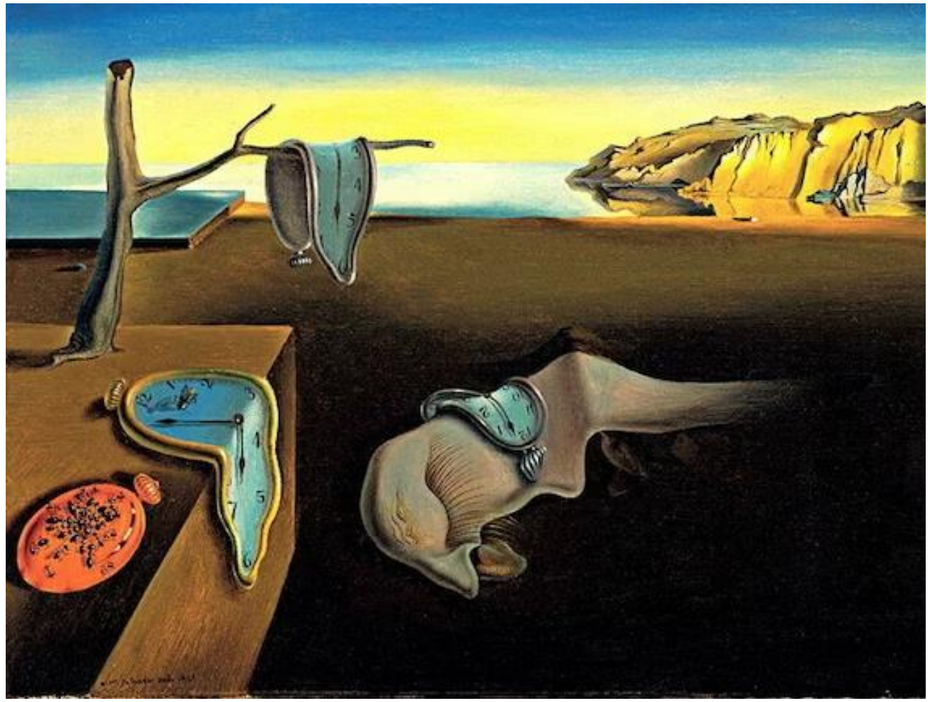

TABLE VIII
COMPUTE TIME DISTANCE METRIC DEPENDENT

Distance metric	Compute time (ms)
euclidean	69.60
cityblock	54.87
chebyshev	221.30
cosine	77.15

DISTANCE METRIC VARIATION CORRECTNESS RESULTS

Metric	Positive matches	Negative matches	Mean score (%)
euclidean	363	74	83.07
cityblock	358	79	81.92
chebyshev	315	122	72.08
cosine	360	77	82.38

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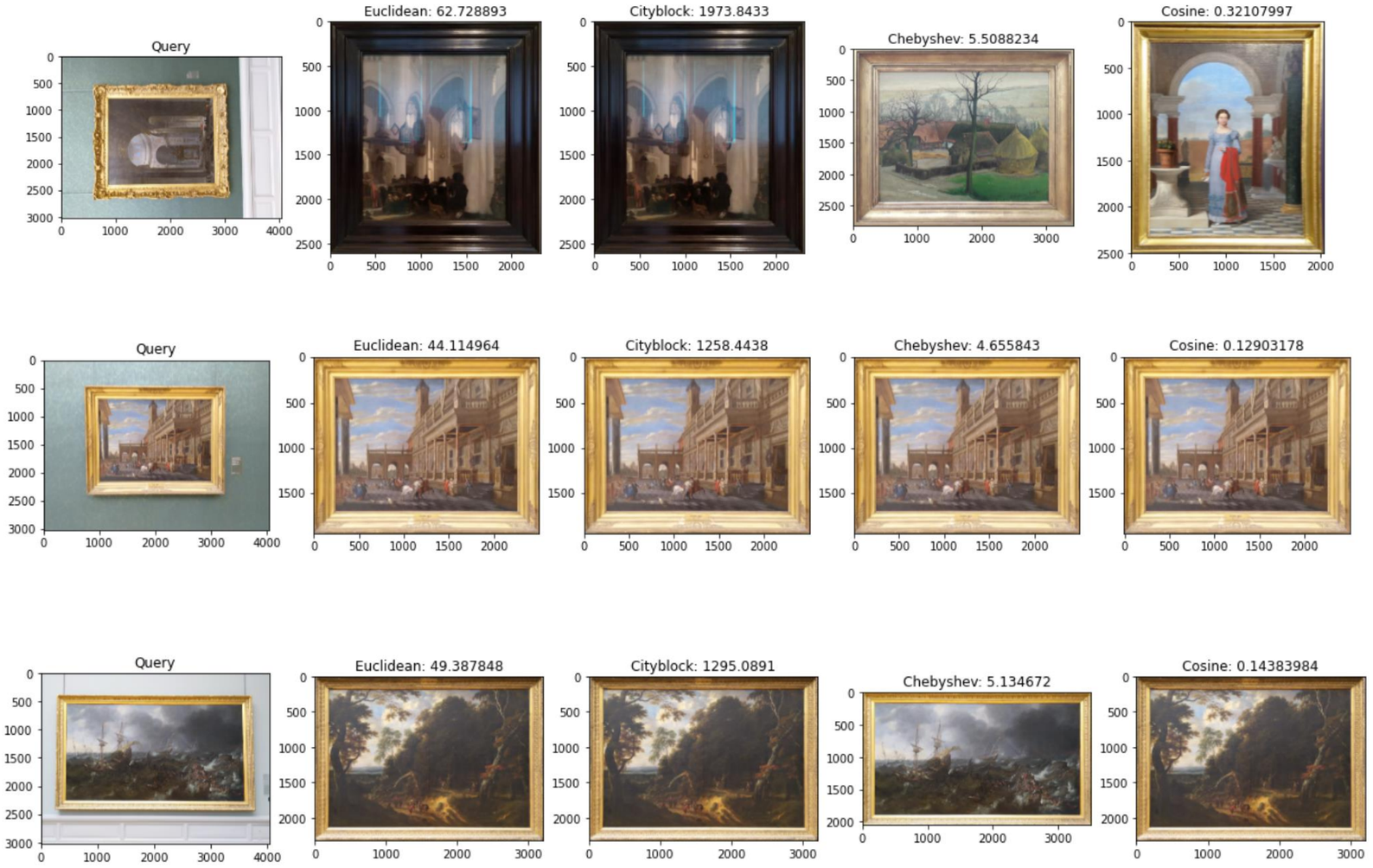
FV-MATCHING EVALUATION



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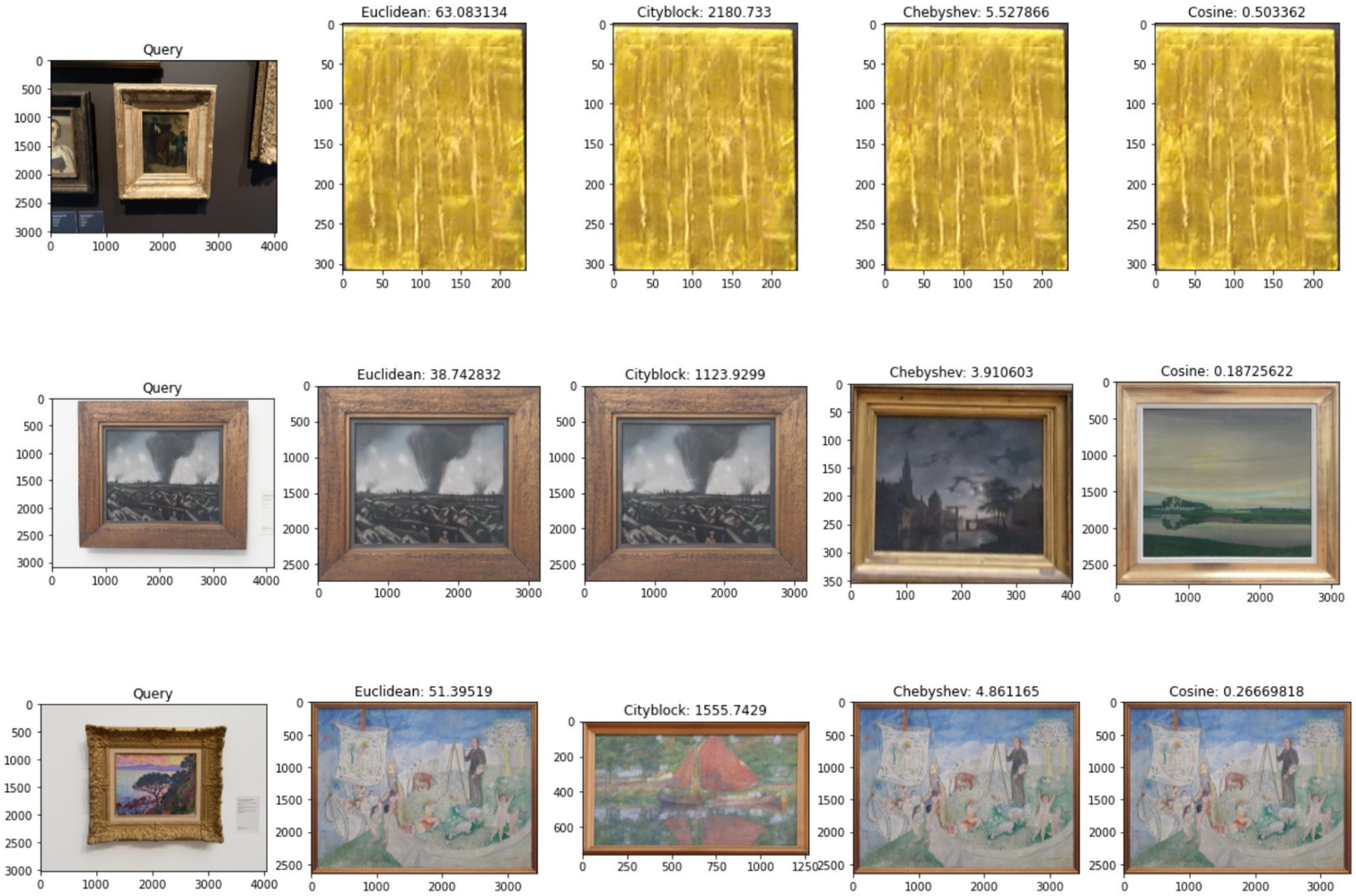
FV-MATCHING EVALUATION



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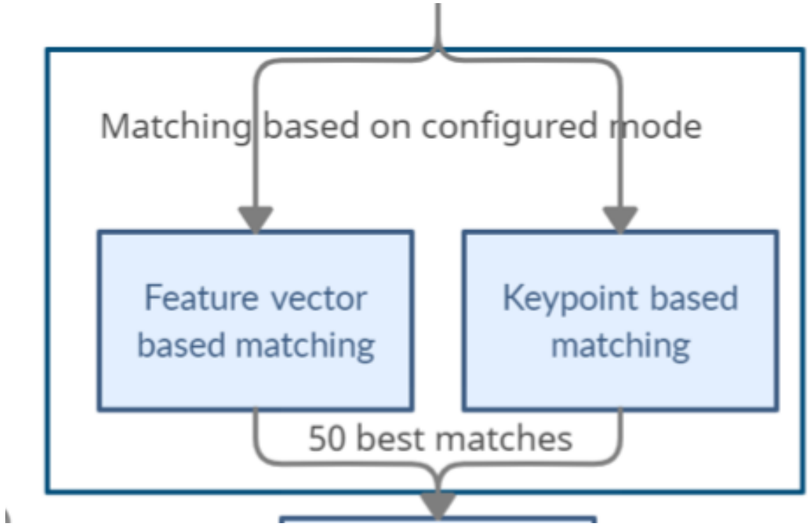
GLOBAL MATCHING EVALUATION

- KM: 100 keypoints/features
- FVM: euclidean/cityblock
- KM -> higher accurate results
- Compute time:

  KPM: 107ms FVM: 54.87-69.60 ms

- Combination
  - Preselection FVM
  - Matching scores KPM



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LOCALIZATION

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LOCALIZATION PIPELINE

- Matching scores to room probabilities
  - Based on soft matches
  - Similar score = similar probability
- Pass through Hidden Markov Model
  - Follow logical path
  - Discourages teleportation
  - Self-correcting
- Visualize localization

MATCHING SCORES TO ROOM PROBABILITIES

- Calculate odds for every room
- Based on soft matches
- Only use best match for a room
- Similar scores = similar probability

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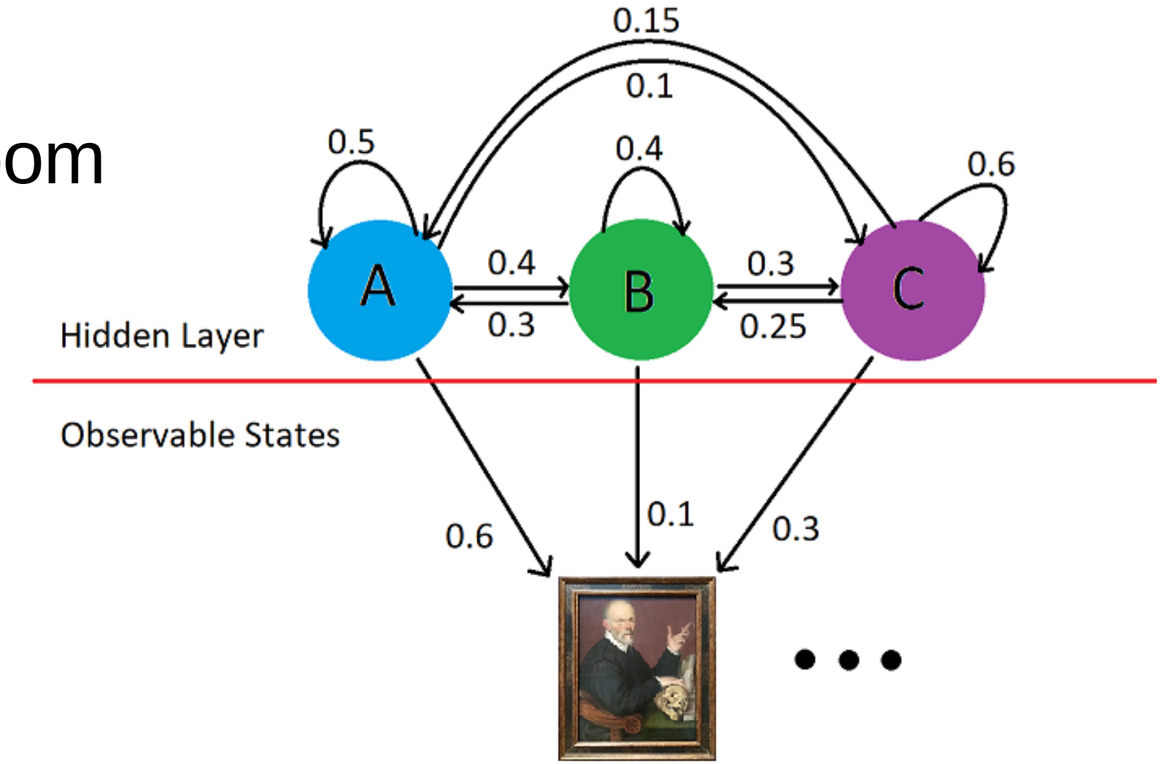
HIDDEN MARKOV MODEL (HMM)

- Hidden Layer
  - Probability of going from one room to another
- Observable States
  - Input frames
  - Probability that frame is located in a certain room



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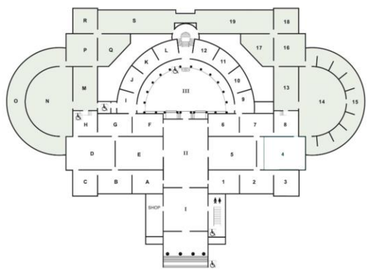
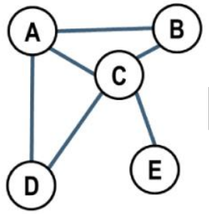
HIDDEN MARKOV MODEL (HMM)

- Hidden Layer probabilities
  - Based on distance between rooms
  - Floorplan → graph → connectivity matrix → distance matrix → probability matrix
  - Gaussian distribution used to obtain probabilities



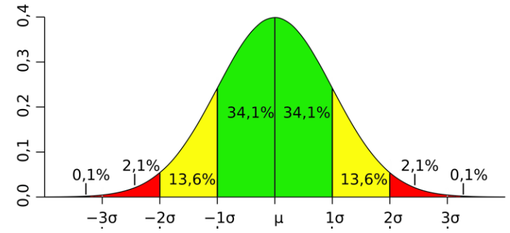


Connectivity Matrix

	A	B	C	D	E
A	0	1	1	1	0
B	1	0	1	0	0
C	1	1	0	1	1
D	1	0	1	0	0
E	0	0	1	0	0

Distance Matrix

	A	B	C	D	E
A	0	1	1	1	2
B	1	0	1	2	2
C	1	1	0	1	1
D	1	2	1	0	2
E	2	2	1	2	0



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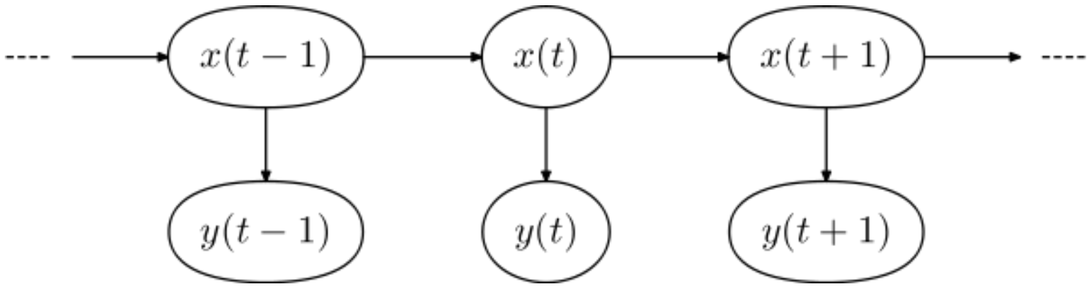
MAKING THE ROOM PREDICTION

- Forward Algorithm
  - Dynamic algorithm
  - Calculates room odds based on the previous prediction
  - Stationary distribution π for first frame
  - $\alpha_t(x_t) = p(y_t|x_t) \sum_{x_{t-1}} p(x_t|x_{t-1})\alpha_{t-1}(x_{t-1})$



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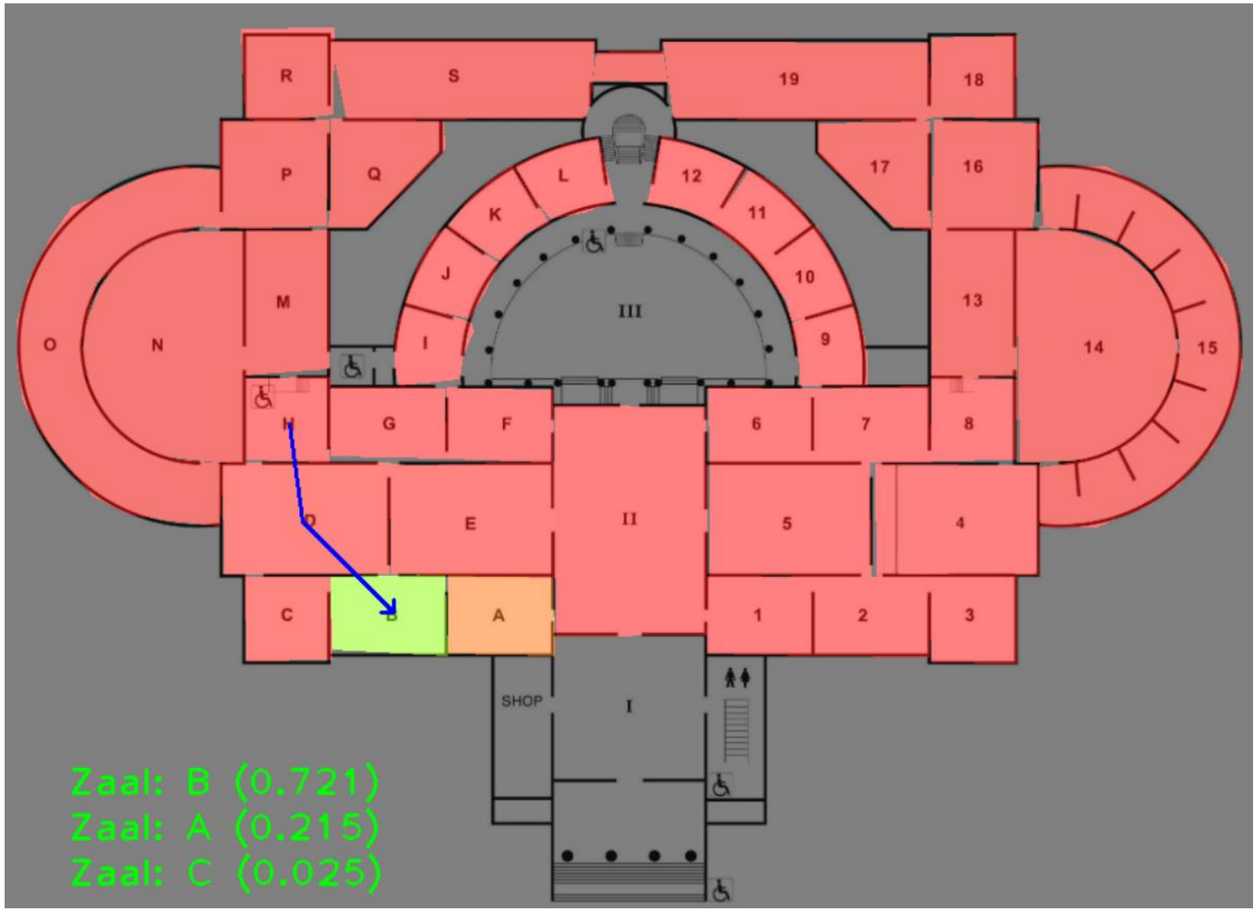
LOCALIZATION VISUALIZATION

- Colored floorplan
- Taken path indicated by arrows



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CONCLUSION

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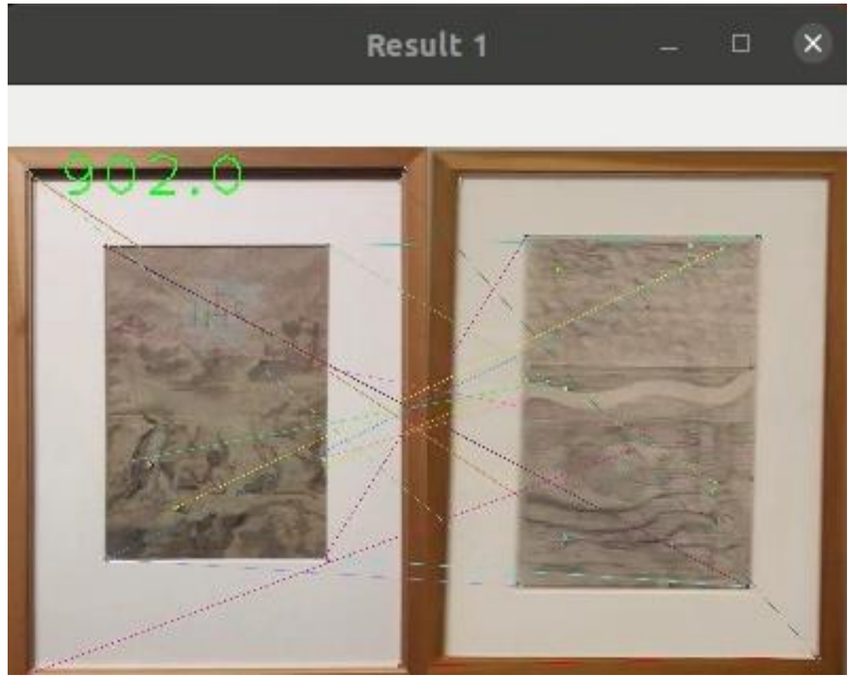
CONCLUSION

- Good performance
  - Time & accuracy
- Challenges
  - Unclear/irregular edges
  - Similar/uniform paintings
- Improvements
  - Multi-threading
  - Wall color matching
  - More robust localisation



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DEMO

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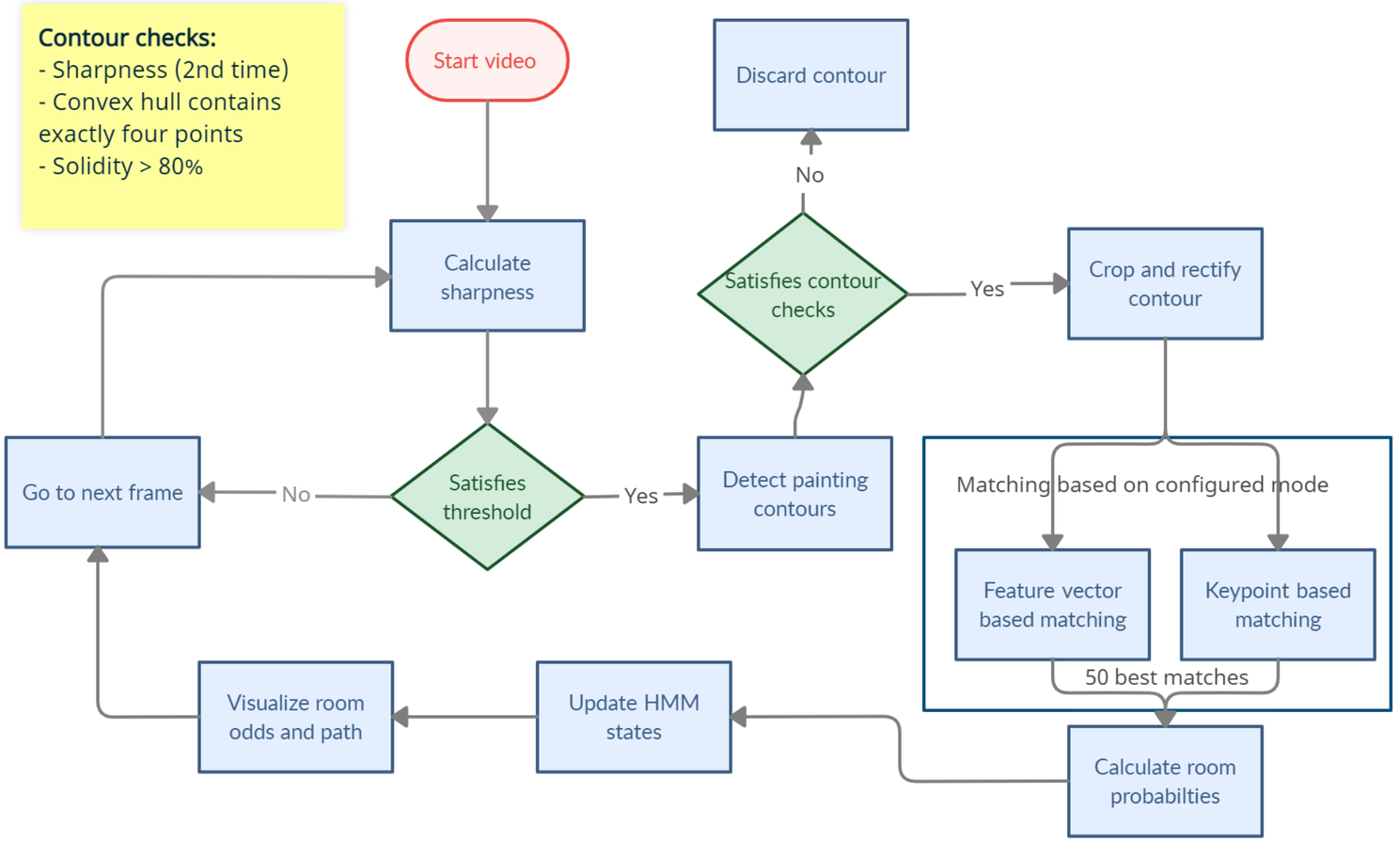
DEMO

- Video: MSK06
  https://ugentbe-my.sharepoint.com/:v:/g/personal/robbe_decorte_ugent_be/EZFbw5refQ5Pi9Lnb1WkTooBMovJ6bKRMKwd7RRAiFZpIQ?e=xcSTGu
- Video: MSK08
  https://ugentbe-my.sharepoint.com/:v:/g/personal/robbe_decorte_ugent_be/EUhITGBuVW9BuHwKCfTzpmMBzYHVEOPmYjcC-aMtiF19mA?e=0qpyK6
- UGent access!

QUESTIONS?



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