

A Fast and Low Resources Pattern Recognition TSM System for Face Detection

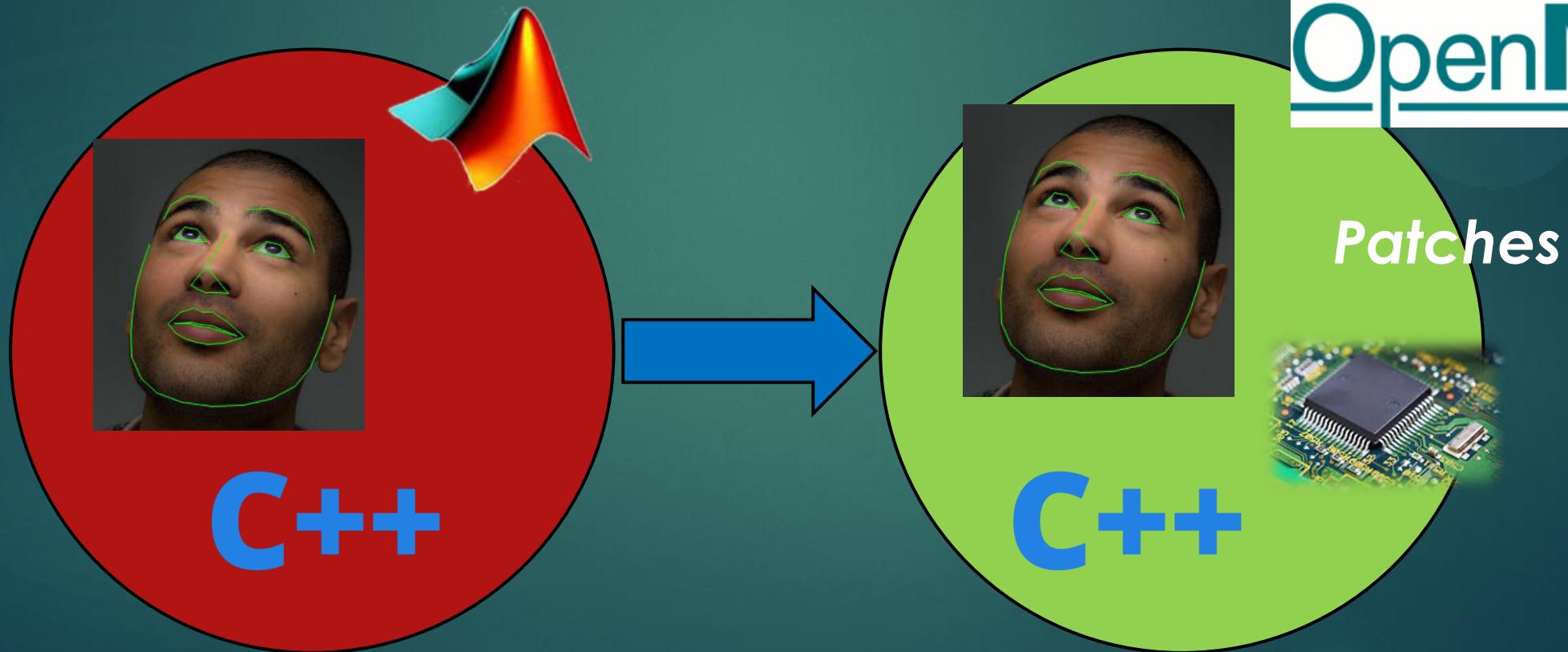
TECHNICAL UNIVERSITY OF CRETE

MICROPROCESSORS AND HARDWARE LABORATORY

PANOS KALODIMAS

A Fast and Low Resources Pattern Recognition TSM System for Face Detection

Master Contribution



A Fast and Low Resources Pattern Recognition TSM System for Face Detection

State of the Art

- ▶ “Face Detection, Pose Estimation and Landmark Localization into the Wild”, Xiangxin Zhu and Deva Ramanan, CVRP 2012
- ▶ “Object Detection with Discriminatively Trained Part Based Models”, Pedro F. Felzenszwalb, Ross B. Girshick, David McAllester and Deva Ramanan, TPAMI 2010
- ▶ TSM Algorithm C++ Implementation, Hang Su, September 2015



A Fast and Low Resources Pattern Recognition TSM System for Face Detection

Related Work on 2012

- ▶ Most Famous Viola Jones Algorithm
- ▶ OpenCV Library
- ▶ Only face Detection
- ▶ No Pose Estimation
- ▶ No Landmark Localization
- ▶ Low Reliability



A Fast and Low Resources Pattern Recognition TSM System for Face Detection

Presentation Contents

- ▶ Short Algorithm Description
- ▶ Algorithm Procedures Description
- ▶ Implementation
- ▶ Multithreading Usage
- ▶ Patches
- ▶ Related Compare

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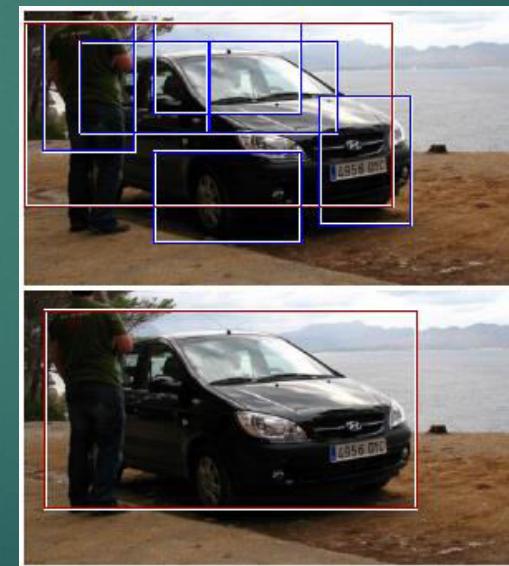
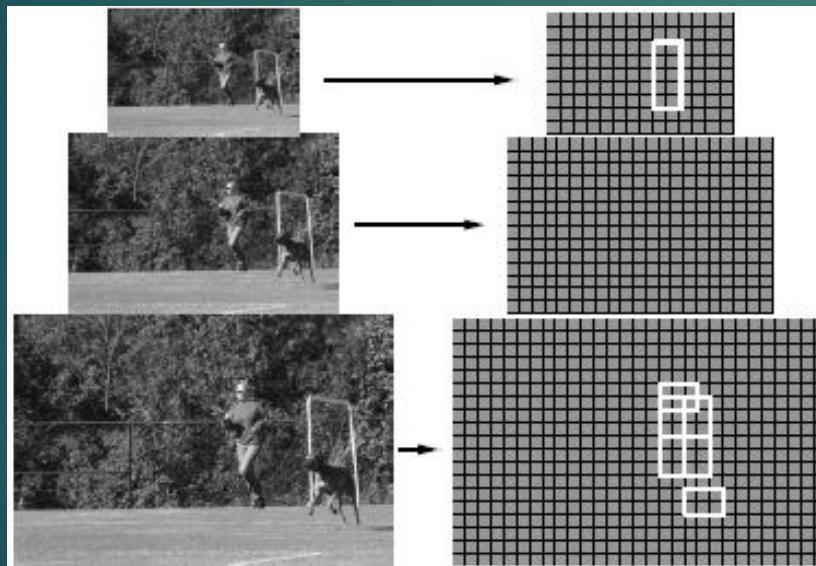
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Short Description

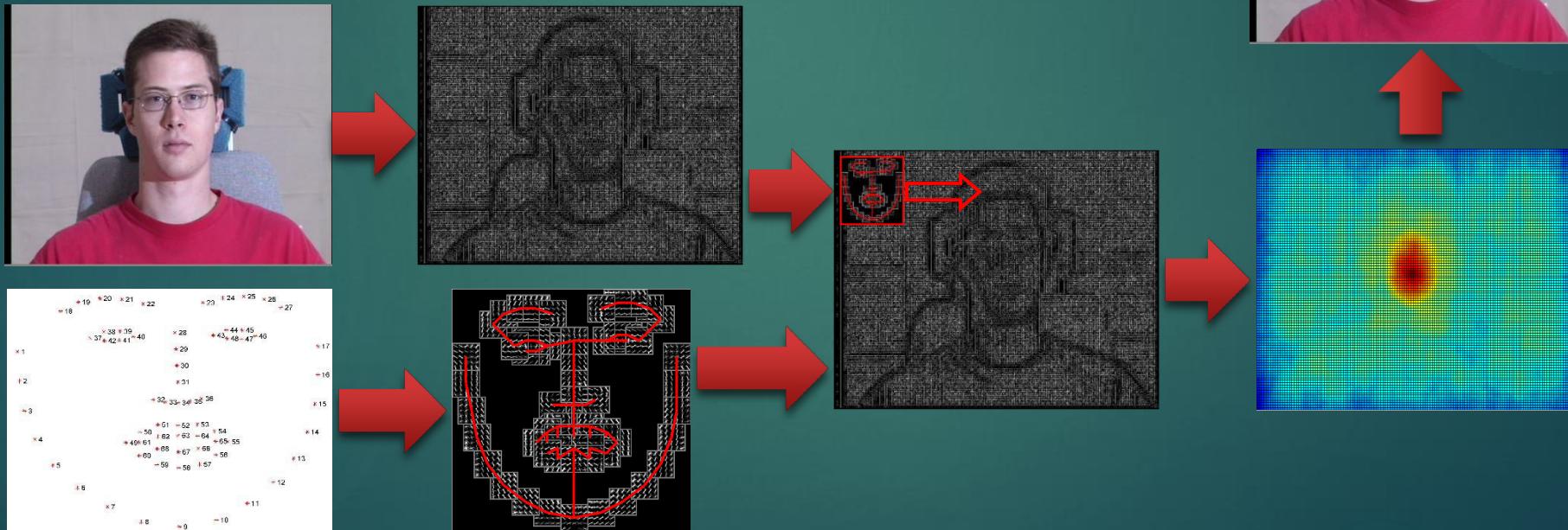
- ▶ “Object Detection with Discriminatively Trained Part Based Models”, Pedro F. Felzenszwalb, Ross B. Girshick, David McAllester and Deva Ramanan, TPAMI 2010



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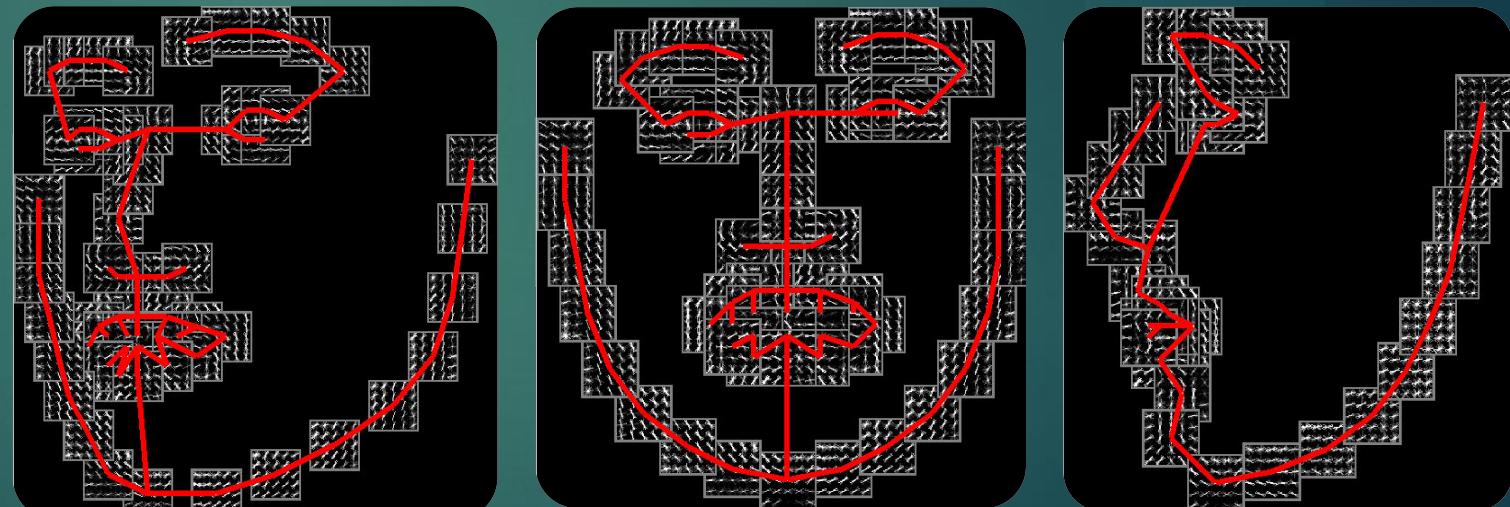
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The Model

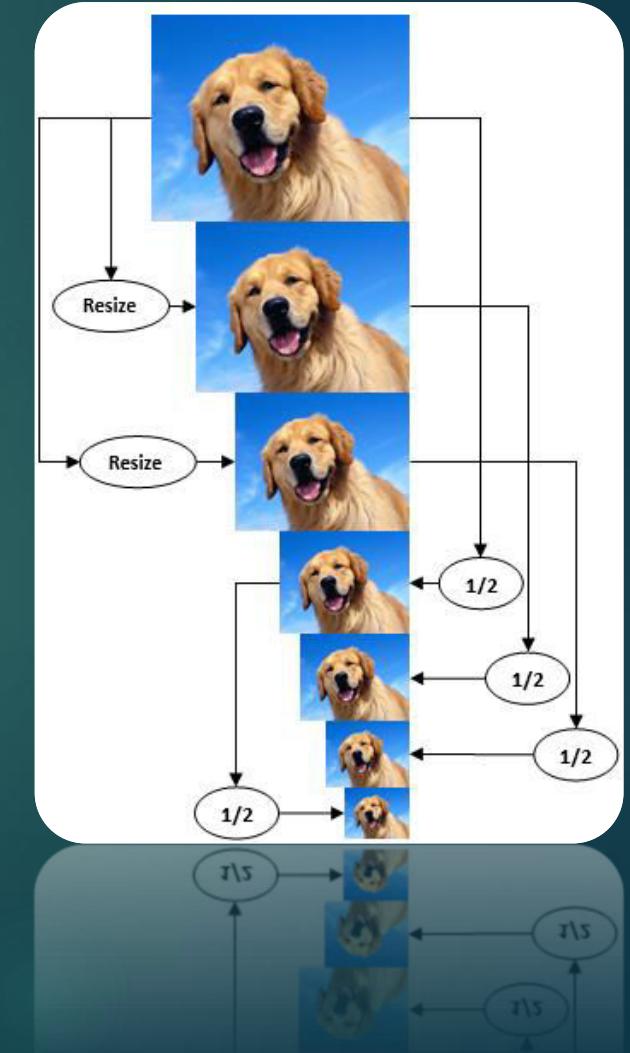
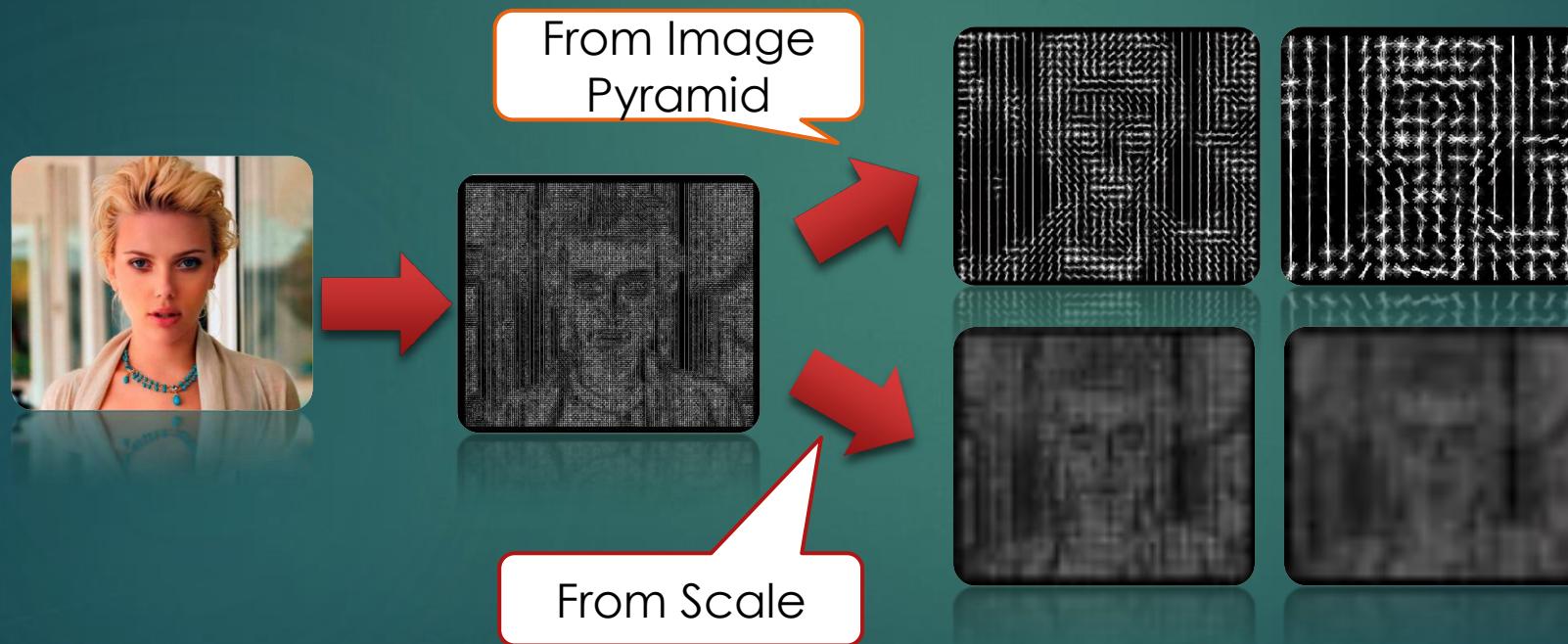
- ▶ 13 Pose Trees (Components) → Tree Structural Model

TSM Components Mutual Parts		Components		
Filters	1-3	4-10	11-13	
99	16/23	68	15/24	
146	39	68	39	



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Features Pyramid



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Convolution

- ▶ Filters Responses
- ▶ $(X \times Y \times 32) \otimes (5 \times 5 \times 32) \rightarrow (X - 4) \times (Y - 4)$

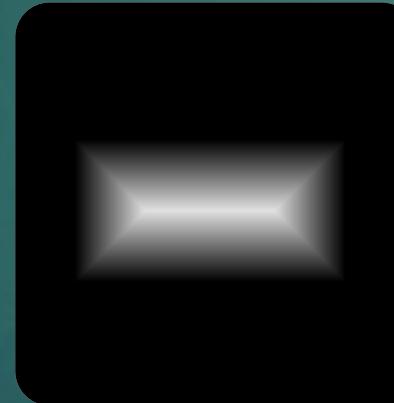
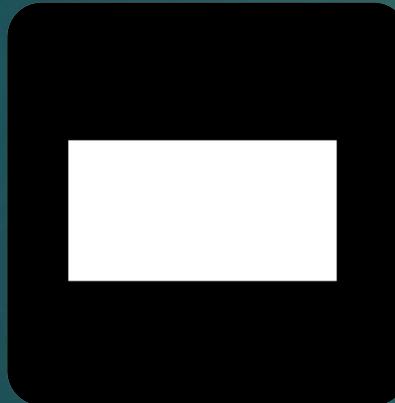


Convolution Procedure Calls			
Image Size	Levels	99 filters Model	146 filters Model
320x240	18	1,782	2,628
640x480	23	2,277	3,358
800x600	25	2,475	3,650
1024x768	27	2,673	3,942
1280x960	28	2,772	4,088

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Distance Transformation Stage

- ▶ P. Felzenszwalb and D. Huttenlocher, “Distance Transforms of Sampled Functions”, Theory of Computing, Vol. 8, No. 19, September 2012

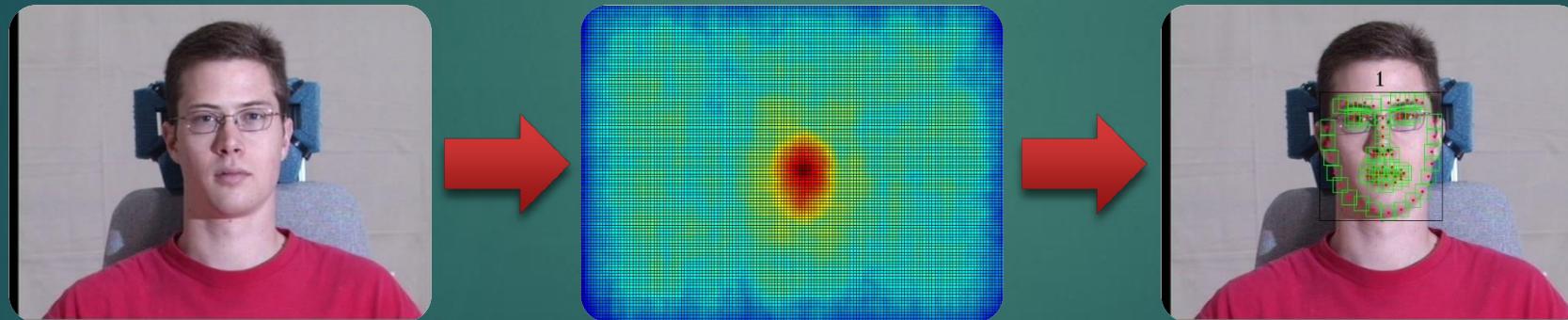


DT Scores Arrays		
Image Size	Levels	DT Scores
320x240	18	25,092
640x480	23	32,062
800x600	25	34,850
1024x768	27	37,638
1280x960	28	39,032

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Find & Backtrack

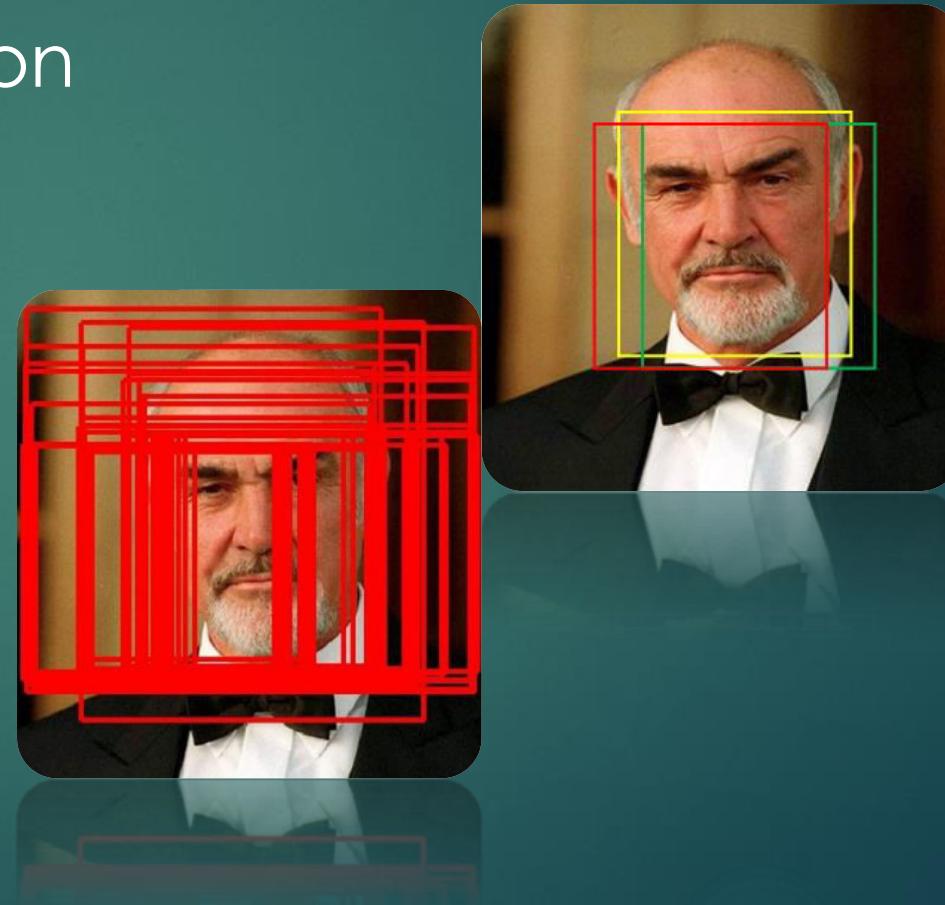
- ▶ Find the pixels with values greater than a Threshold variable
- ▶ Backtrack Estimates the Landmark Locations



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Non-Maximum Suppression

- ▶ Noise Removal
- ▶ One Face – Multiple Detections
- ▶ One Face – Multiple Scales
- ▶ One Face – Multiple Poses



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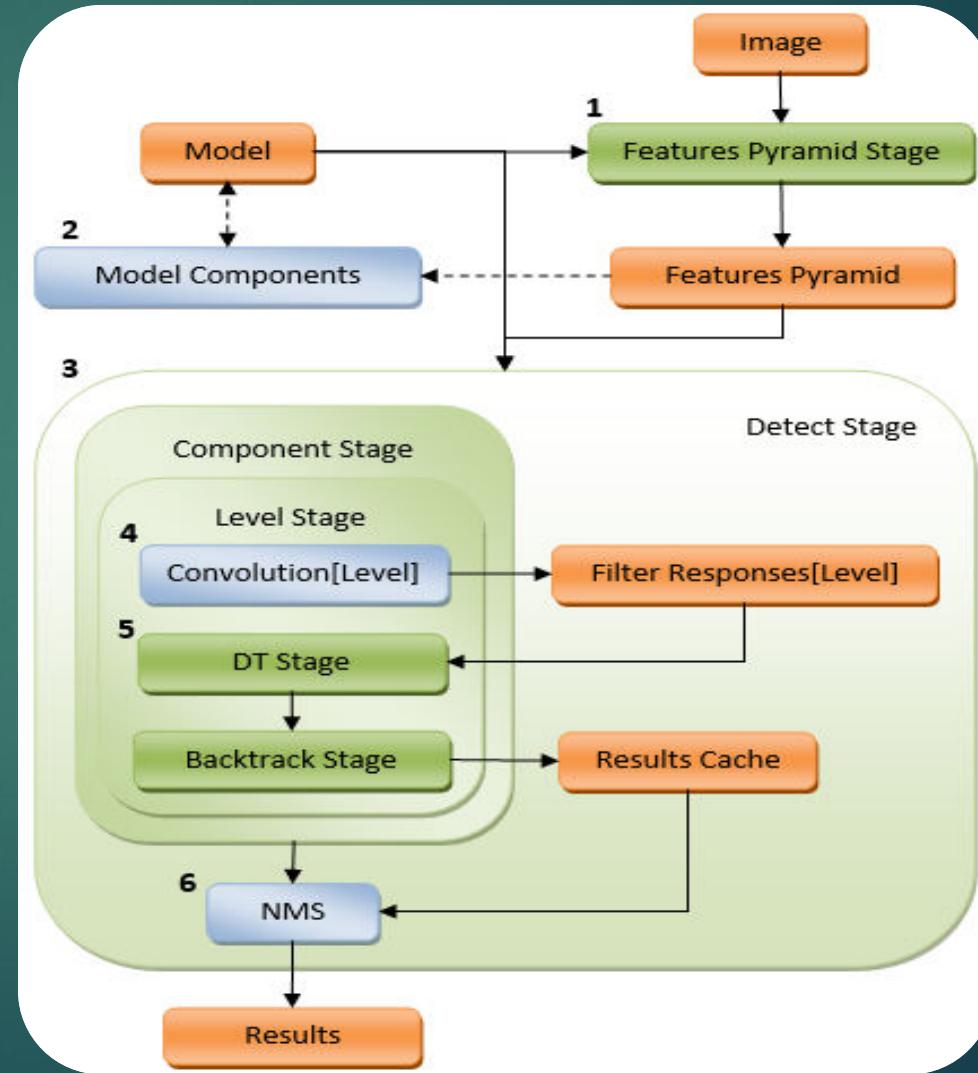
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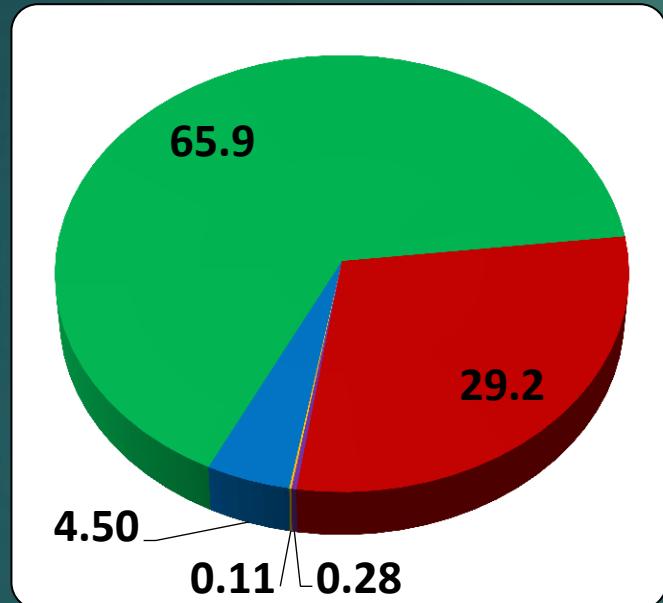
Version 1.1

- ▶ The Original Version
- ▶ Absolut Conversion from Matlab to C\C++

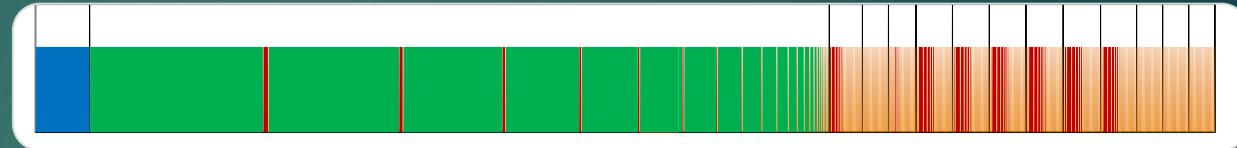


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Version 1.1 Profile



Time Profile

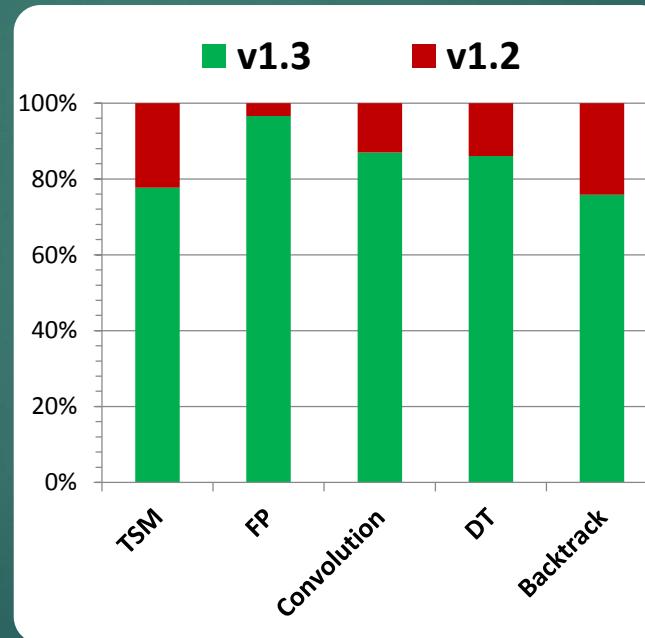


Max Memory Profile

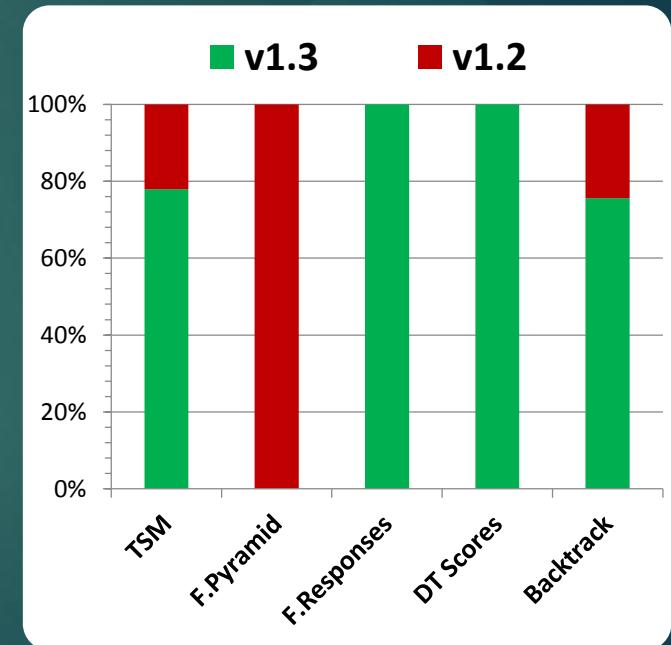
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Version 1.x Improvements

	Time	Mem
All	-20.3	-72.3
F. Pyramid	-0.08	-11.8
Convolution	-8.78	0
DT	-4.23	0
Backtrack	-0.07	-10.5
Double 2 Float	-7.22	-50.0



Time %

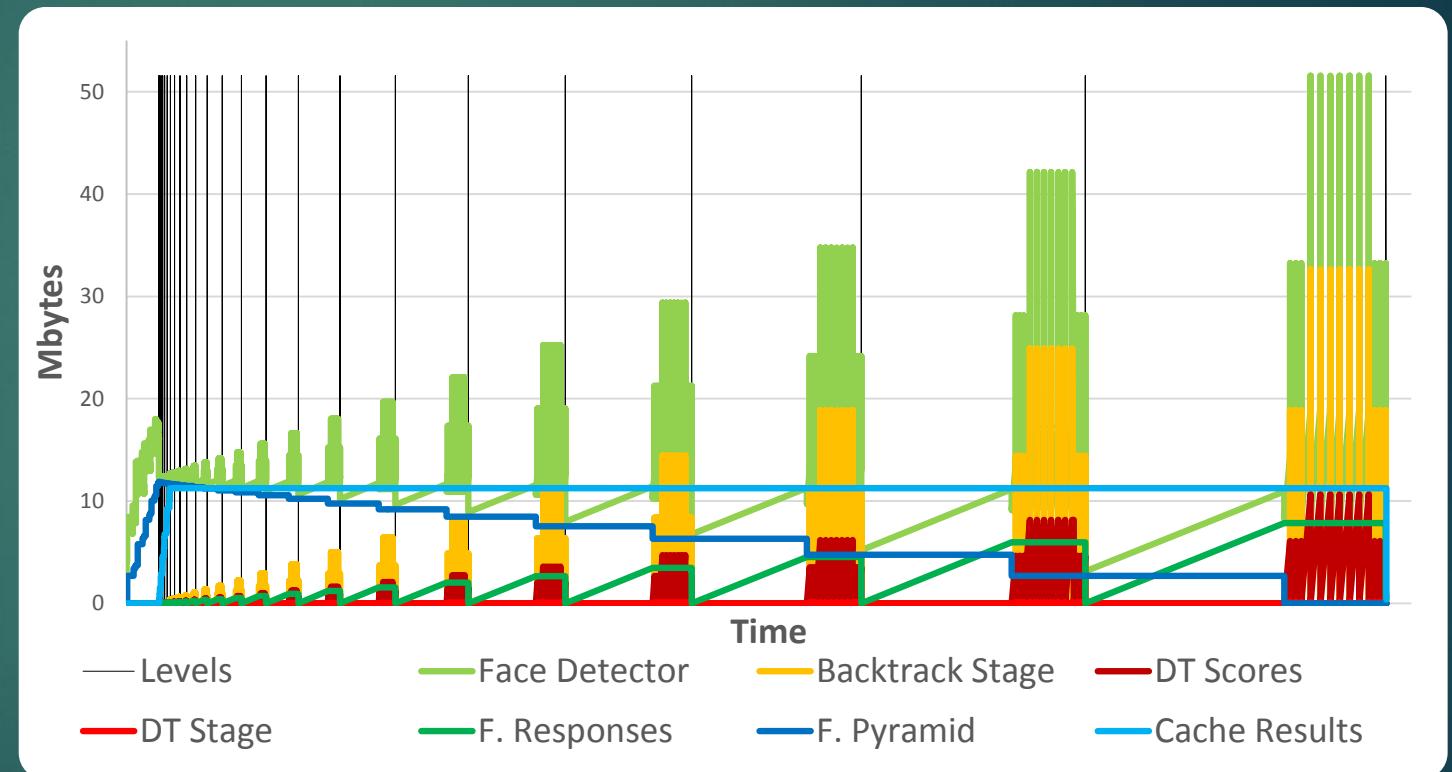


Memory

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Version 2

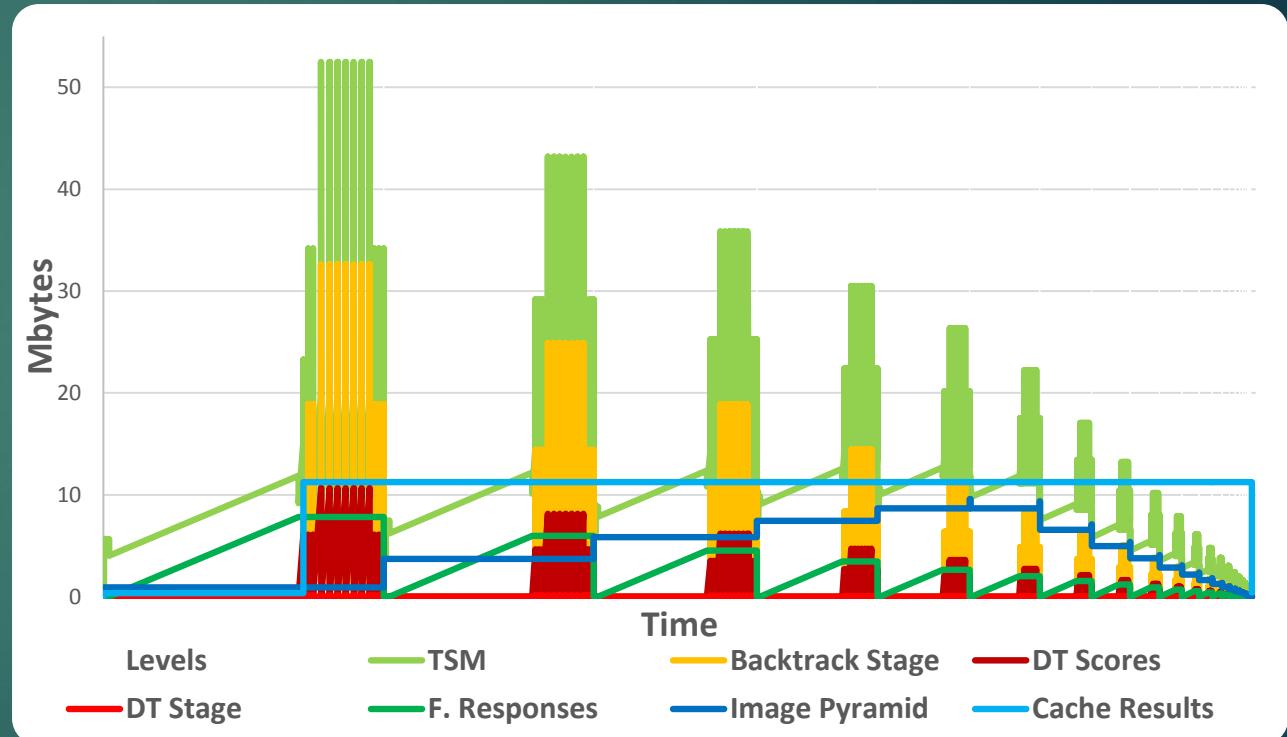
- ▶ Memory usage optimization
- ▶ Less -33.7% Max Memory



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Version 3

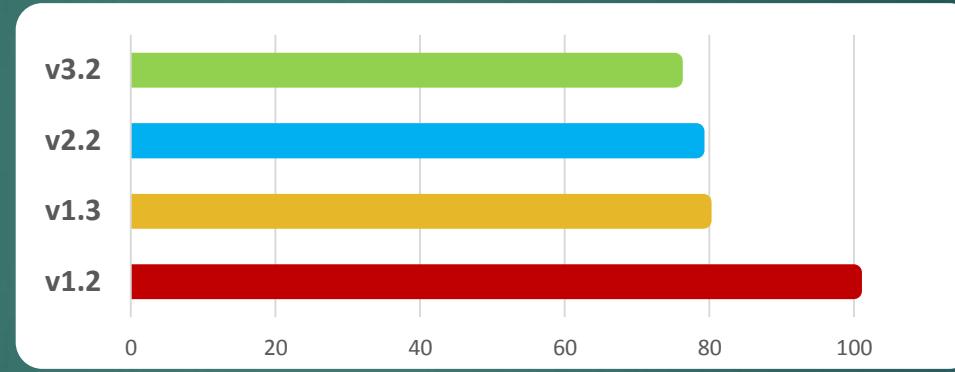
- ▶ Data Locality Optimization
- ▶ Less -3.5% execution time



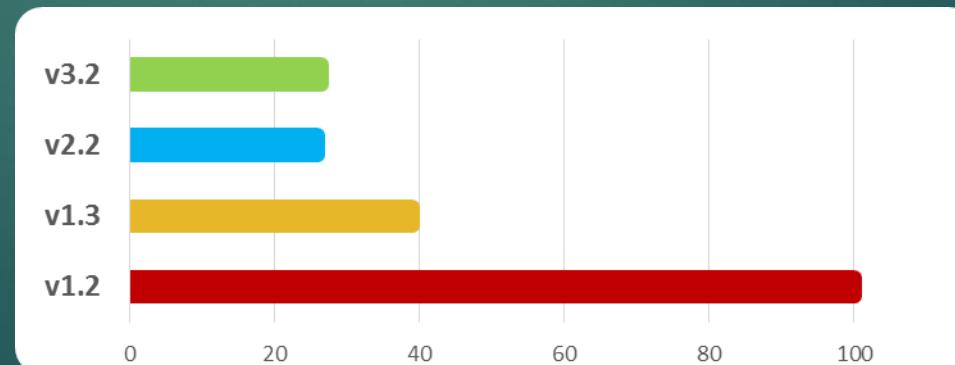
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All Versions – Execution Time

Time	
v1.1	100
V1.3	79.2
v2	78.2
v3	75.2



Max Memory	
v1.1	100
v1.3	38.9
v2	25.8
v3	26.3



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All Versions – Max Memory Requirements

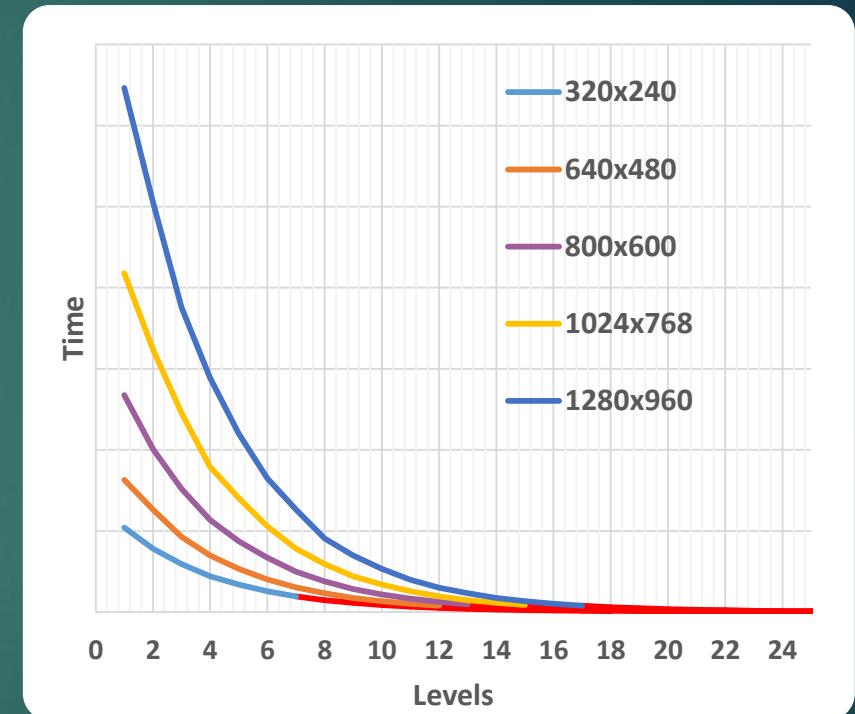
TSM Algorithm All Versions Max Memory Requirements (Mbytes)					
Version	320x240	640x480	800x600	1024x768	1280x960
v1.1 (double)	70	265	409	664	1030
v1.1	35	132	205	332	515
v1	21	78	121	196	304
v2	14	52	80	130	202
v3	14	53	81	132	206

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Short Pyramid

- ▶ Reduce the number of levels of Image Pyramid
- ▶ Gain only -4.6% of time

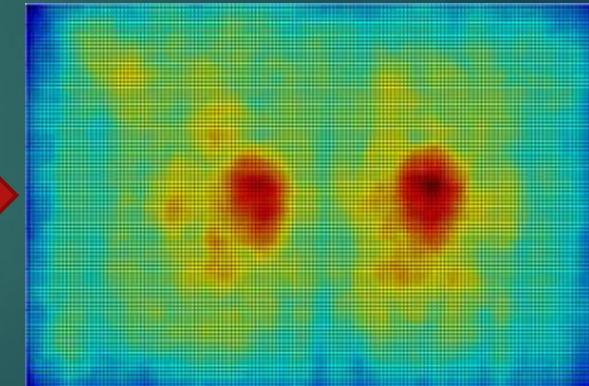
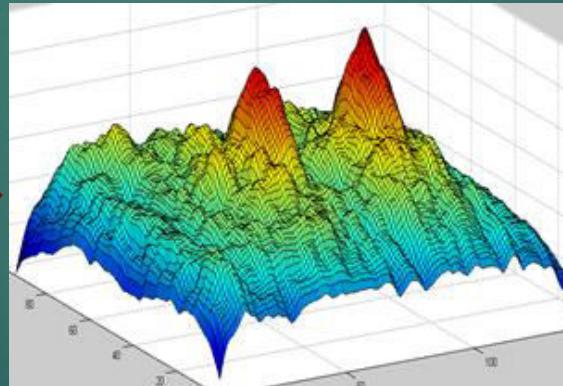
$$Levels_{pyramid} = \left\lfloor \log_2 \left(\frac{Height_{image}}{Height_{min}} \right) \cdot \text{interval} \right\rfloor$$



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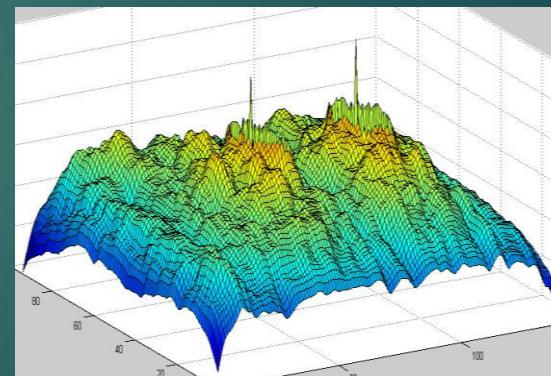
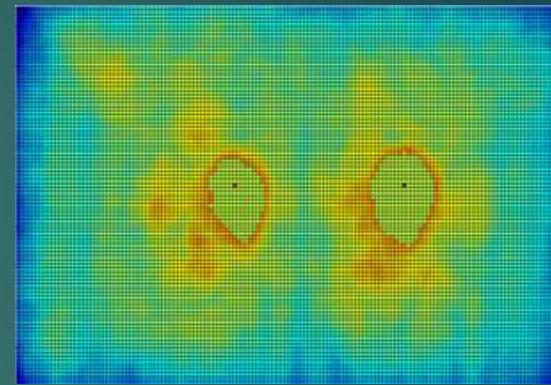
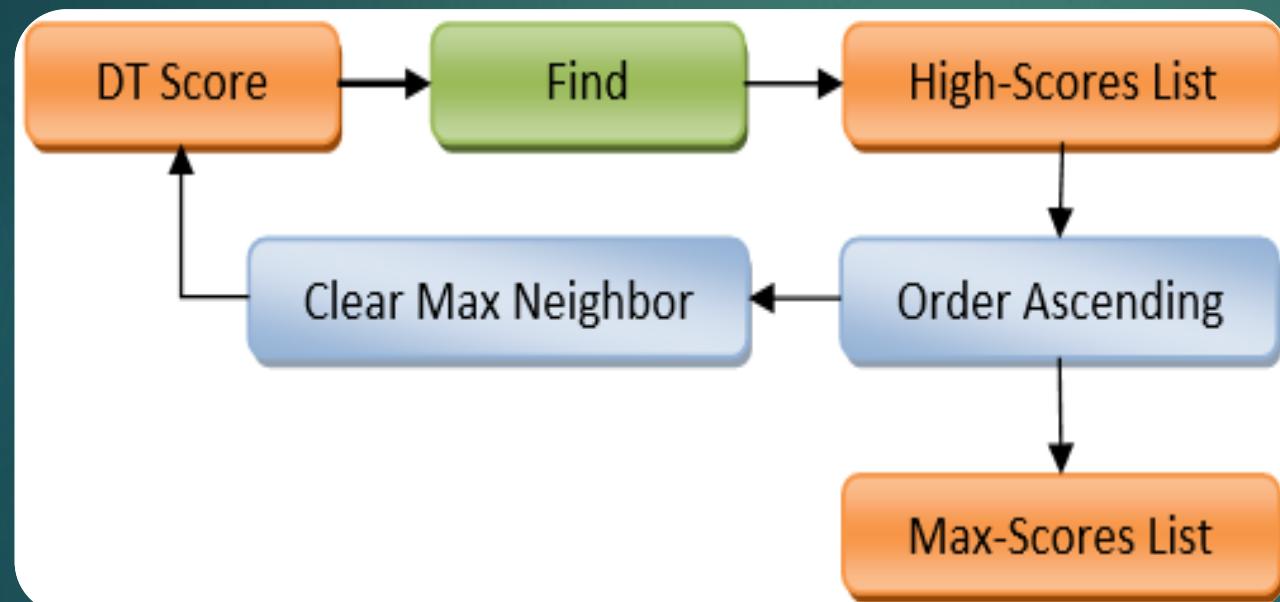
Find v2.0

- ▶ The DT procedure returns peaks of High-Scores
- ▶ Search Space reduce



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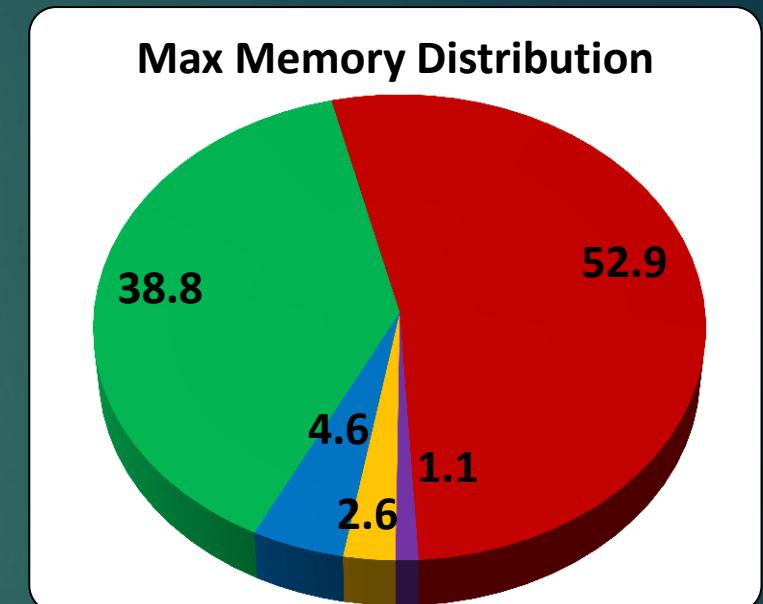
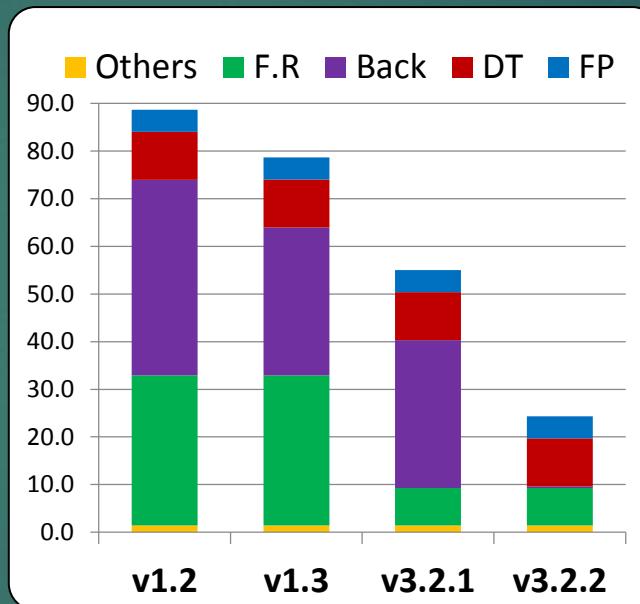
Find v2.0



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Find v2.0 vs v1.0

- ▶ Max Memory less for -61,6% more
- ▶ Total -89,9% Max Memory Reduction



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Multi-threading

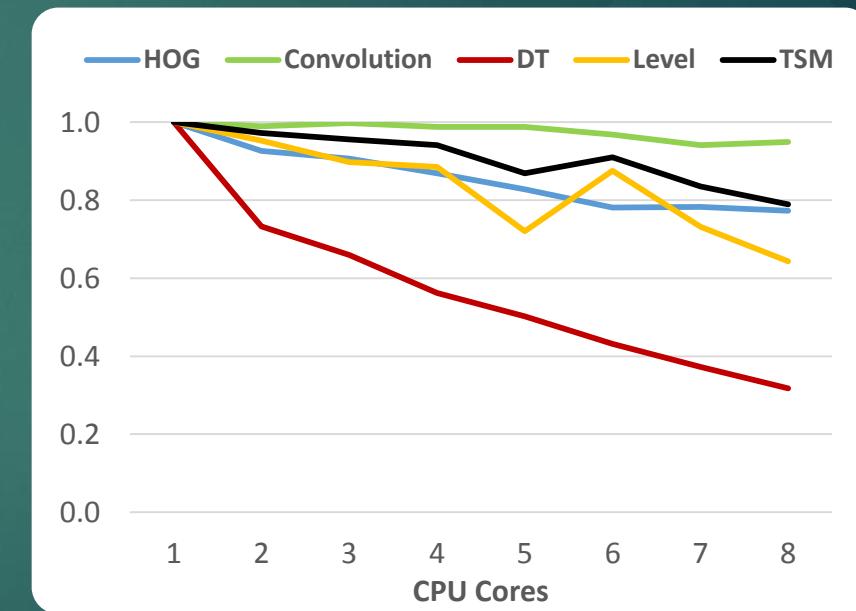
- ▶ Usage of OpenMP (OMP)
- ▶ Reduces Execution Time
- ▶ Increases Memory Consumption



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HOG Procedure OMP

Execution Time Speedup					
CPUs	HOG	Conv	DT	Level	TSM
2	x1.9	x2.0	x1.5	x1.9	x1.9
3	x2.7	x3.0	x2.0	x2.7	x2.9
4	x3.5	x4.0	x2.2	x3.5	x3.8
5	x4.1	x4.9	x2.5	x3.6	x4.3
6	x4.7	x5.8	x2.6	x5.3	x5.5
7	x5.5	x6.6	x2.6	x5.1	x5.8
8	x6.2	x7.6	x2.5	x5.1	x6.3



Efficiency

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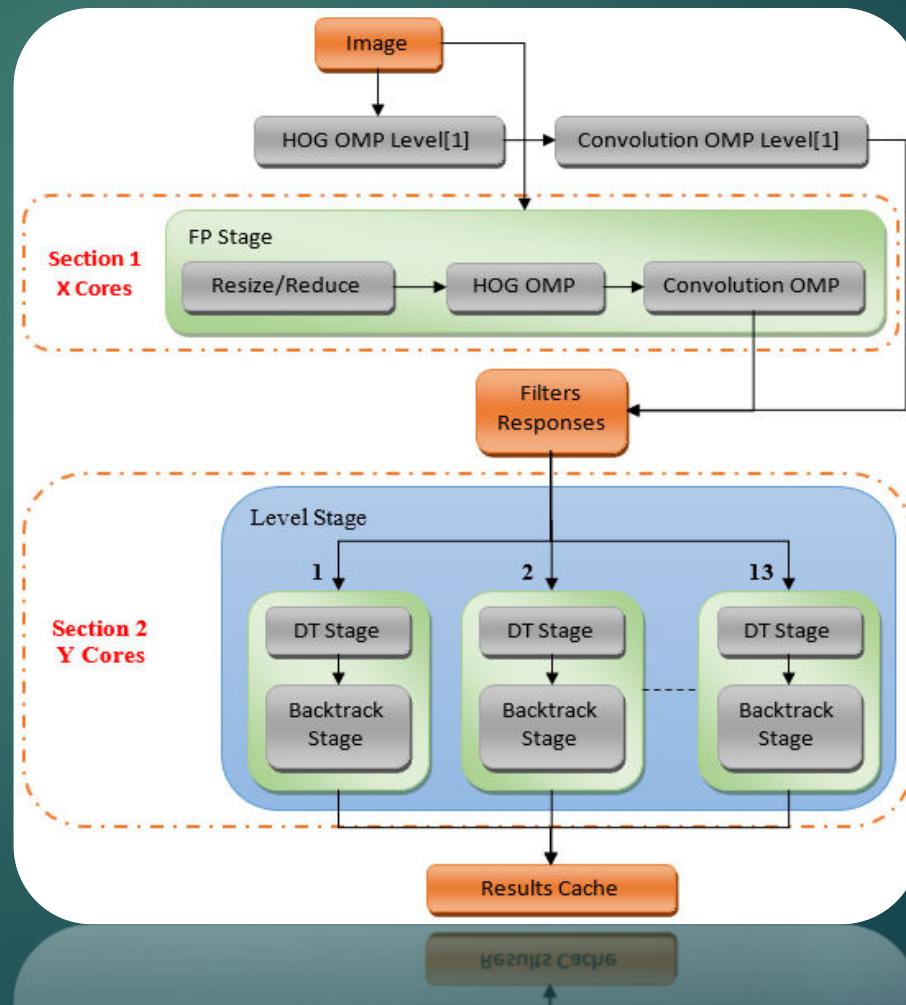
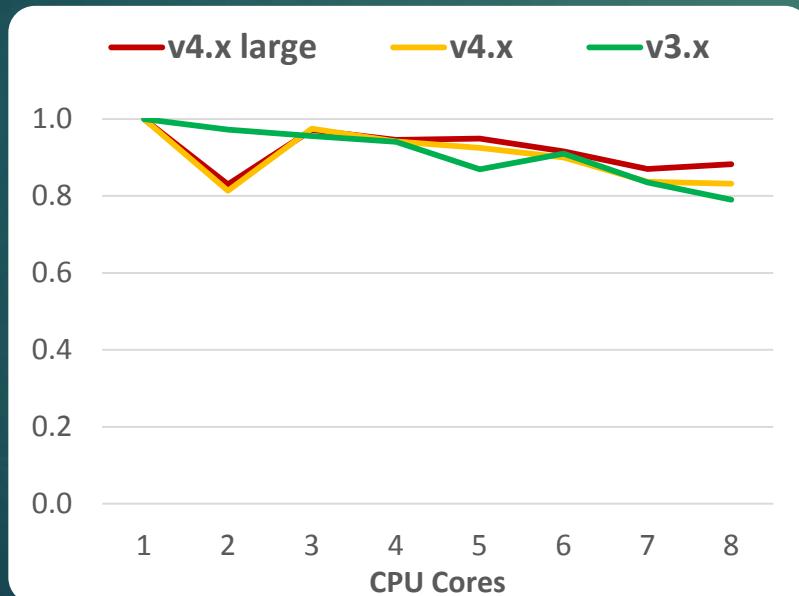
Version 3.2.2 – Max Memory Consumption

TSM v3.2.2 OMP Max Memory Consumption (Mbytes)						
CPUs	320x240	640x480	800x600	1024x768	1280x960	Average
1	5,5	20	31	50	78	
2	8,3	31	48	78	121	+54.0 %
3	11	42	65	106	164	+108 %
4	14	53	82	133	207	+162 %
5	17	64	99	161	250	+216 %
6	19	75	116	188	293	+270 %
7	22	86	133	216	336	+324 %
8	25	96	150	244	379	+378 %

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Version 4

- ▶ Uses the best OMP efficiency for less Max Memory



TSM v4.1.2 vs v3.2.2	
Image	3200x2400
Time	89.8%
Memory	30.8%
Memory v3.2	2,427 Mb
Memory v4.1	749 Mb

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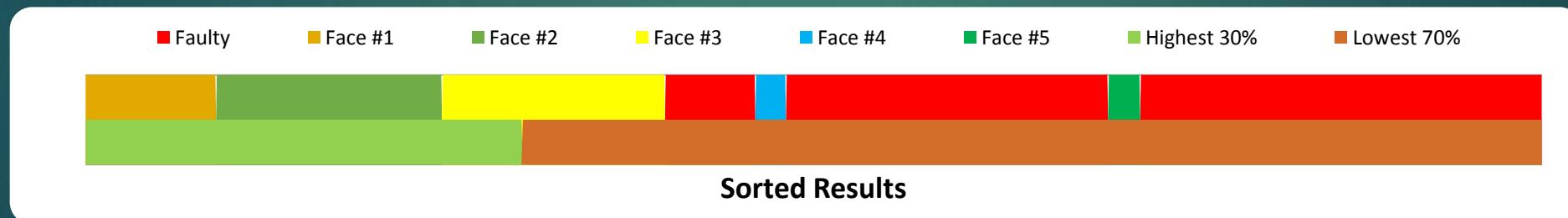
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NMS Limit Patch

- The NMS Procedure rejects the bottom 70% of the results cache detections as noise



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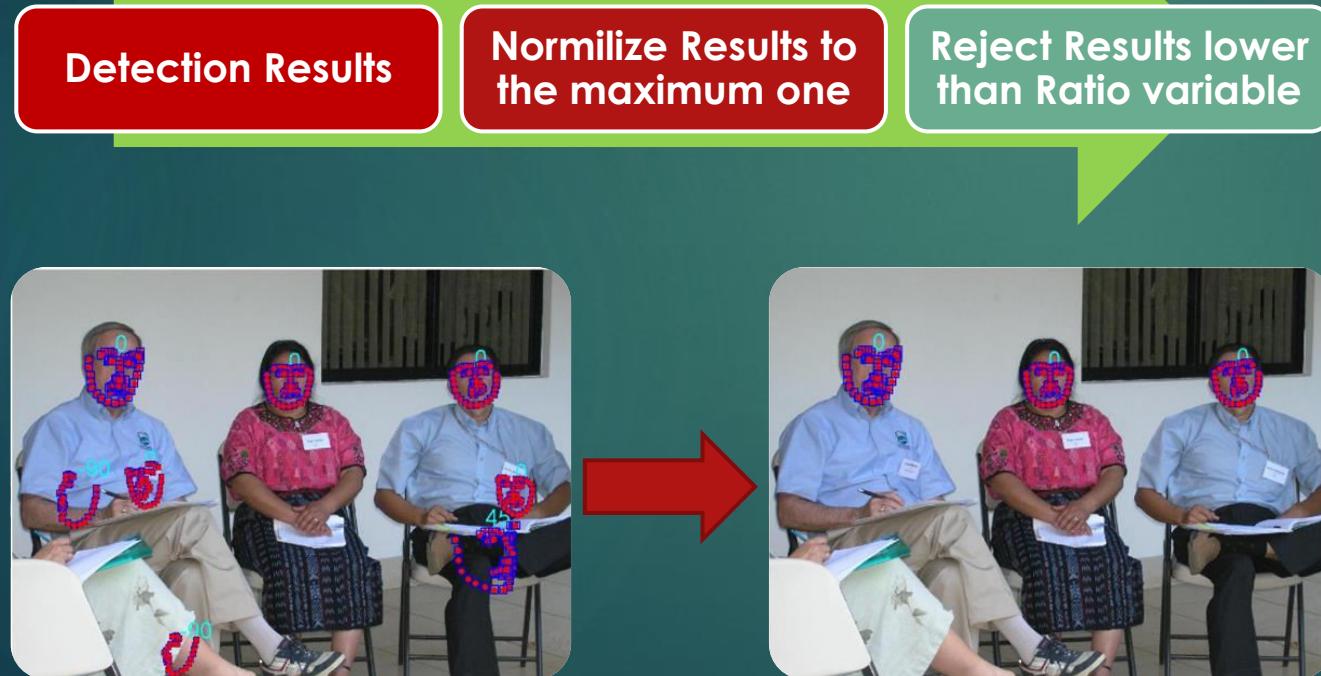
NMS Limit Patch

- ▶ Disables the NMS Limit of 70%

	NMS Limit Results using 99 Filters Model							
Threshold	-0.70	-0.65	-0.60	-0.55	-0.50	-0.45	-0.40	-0.35
NMS Limit	70%							
Detected	89.1	87.8	86.1	82.9	82.5	82.1	80.8	-
Fake	21.8	15.3	10.6	8.27	4.93	3.27	1.82	-
Reliability	71.4	75.8	78.1	77.1	79.1	79.8	79.6	-
Fake/Real	15.0	10.9	4.25	1.84	1.57	1.08	0.82	-
NMS Limit	0%							
Detected	93.2	91.2	90.4	88.2	85.5	84.8	83.1	80.3
Fake	47.9	36.7	23.9	16.4	9.50	6.37	3.95	2.59
Reliability	50.2	59.6	70.4	75.2	78.4	80.2	80.4	78.7

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Dynamic Threshold Patch



NMS Limit Patch vs Original (%)

Thresh	Ratio	Reliability		Efficiency	
		Patch	Origin	Patch	Origin
-0.70	25%	73.5	71.4	90.6	89.1
-0.65	25%	76.6	75.8	88.2	87.8
-0.60	20%	79.1	78.1	85.7	86.1
-0.55	15%	81.2	77.1	82.9	82.9
-0.50	10%	80.5	79.1	82.9	82.5
-0.45	0%	80.2	79.8	84.8	82.1

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Speed up Proposals

- ▶ Avoid Levels – Great Speedup
- ▶ Avoid Filters – Good Speedup
- ▶ Avoid Components (Poses) – Small Speed up
- ▶ Execution Time vs Reliability
- ▶ 1-2% loss of Reliability is OK

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Stable Speed up

- ▶ Canvas Patch
- ▶ Pyramid Interval Reduce
- ▶ 68 Filters Model (-30%)

Level	%
1	25.0
2	18.8
3	14.1
4	10.5
5	7.91
6	5.93
7	4.45
8	3.34
9	2.50
10	1.88
11	1.41

Interval	4	3
Time	-20.6%	-37.8%
Reliability	-5 %	-15 %
Image Size	Face Size	
320x240	41.7	
640x480	20.8	
800x600	16.7	
1024x768	13.0	
1280x960	10.4	

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Special Case Speedup

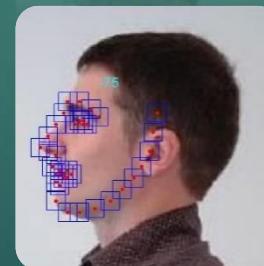
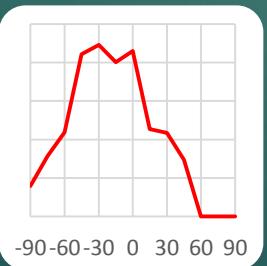
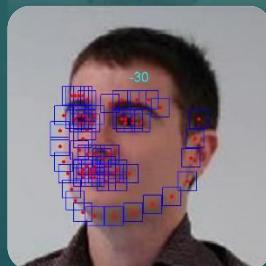
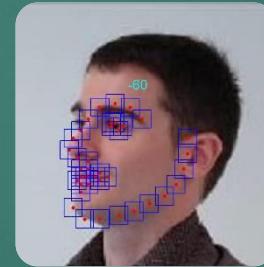
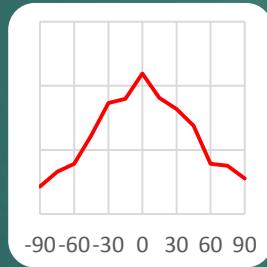
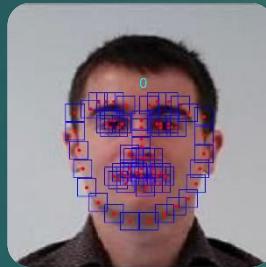
- ▶ Empty images
- ▶ Same Scale or Direction faces
- ▶ Less Computation Time
- ▶ Less energy consumption
- ▶ More work in the same time
- ▶ Same work in less time



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Detection Components Patch

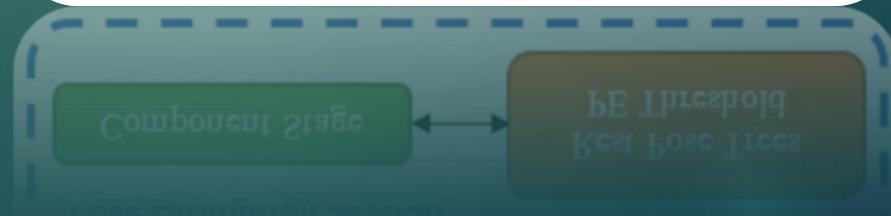
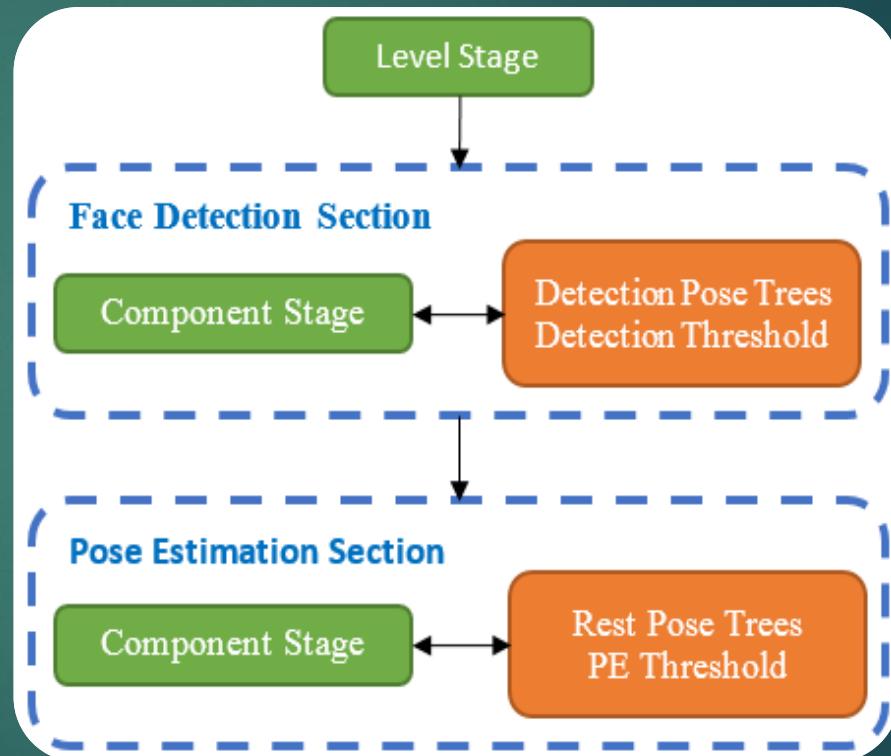
- ▶ Close pose angles return similar results



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Detection Components Patch

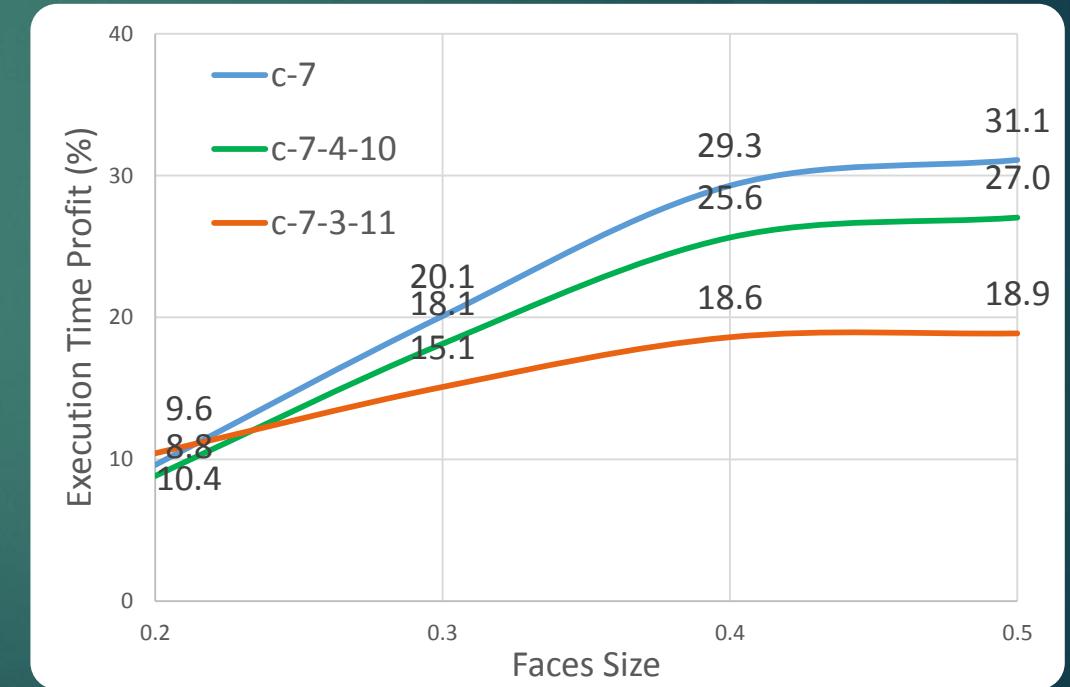
- ▶ Separates detection procedure from Pose Estimation
- ▶ Choose detection Components



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Detection Components Patch

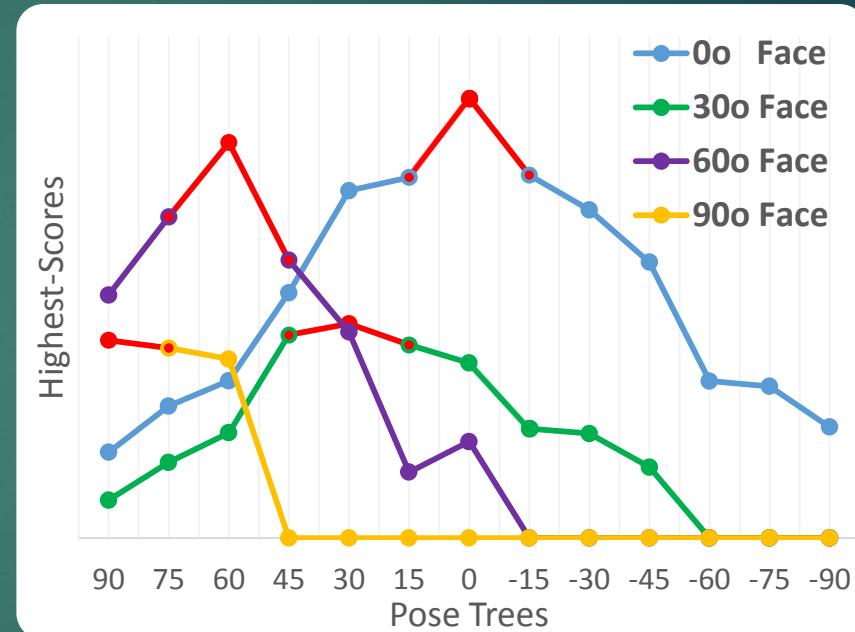
DC Pose	Efficiency	Reliability	No face
DC-1-68	84.0	79.4	40.9
DC-3-99	84.8	80.4	23.1
DC-3-68	84.4	79.8	35.0
Original	82.1	79.9	-



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Fast Pose Estimation

- ▶ The right pose tree gets the highest score
- ▶ Near pose trees creates peaks

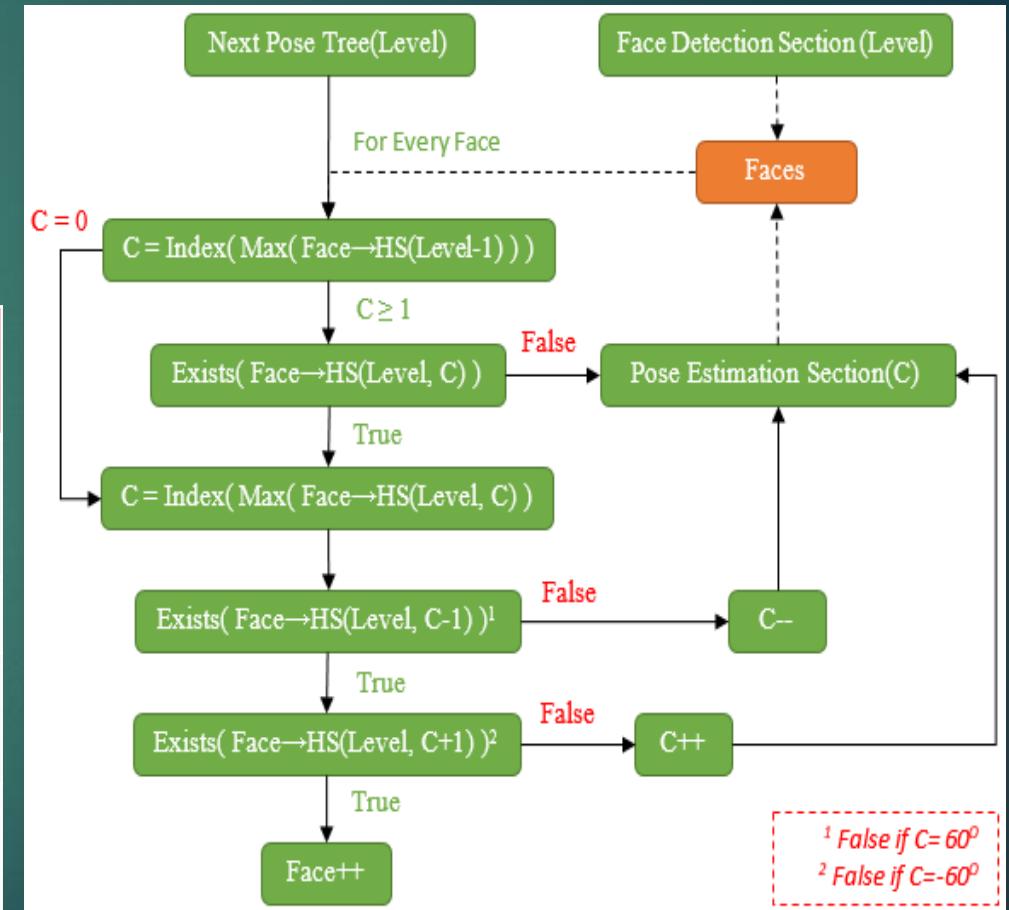


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FPE – Pose Peak Detection

► Decision Flow

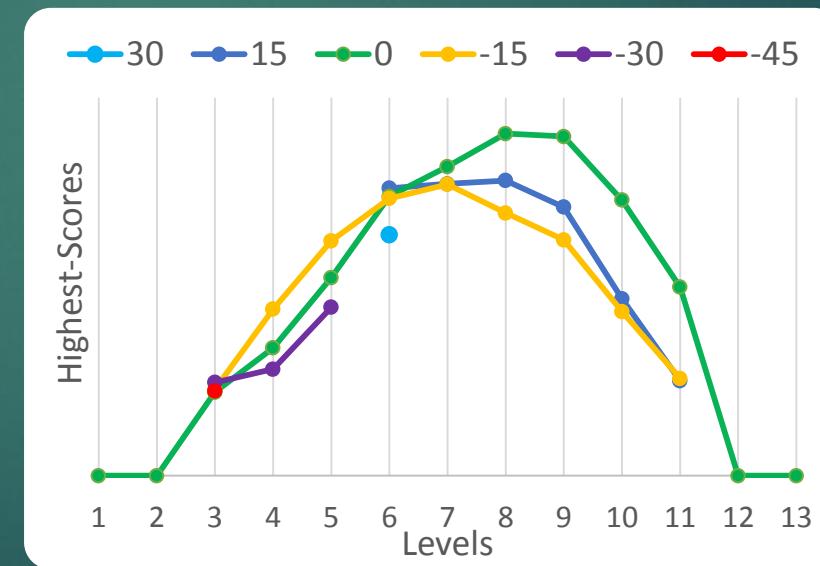
PPD Patch Components Stage Execution Times per Pose				
	VAR(All)	AVG(All)	AVG($-45^\circ \leq & \leq +45^\circ$)	AVG($-60^\circ \geq & \geq +60^\circ$)
DC-1-68	2.85	5.62	4.29	7.17
DC-3-68	0.24	5.38	5.14	5.67
DC-3-99	0.85	5.38	6.00	4.67



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FPE – Pose Peak Detection

► Patch Example

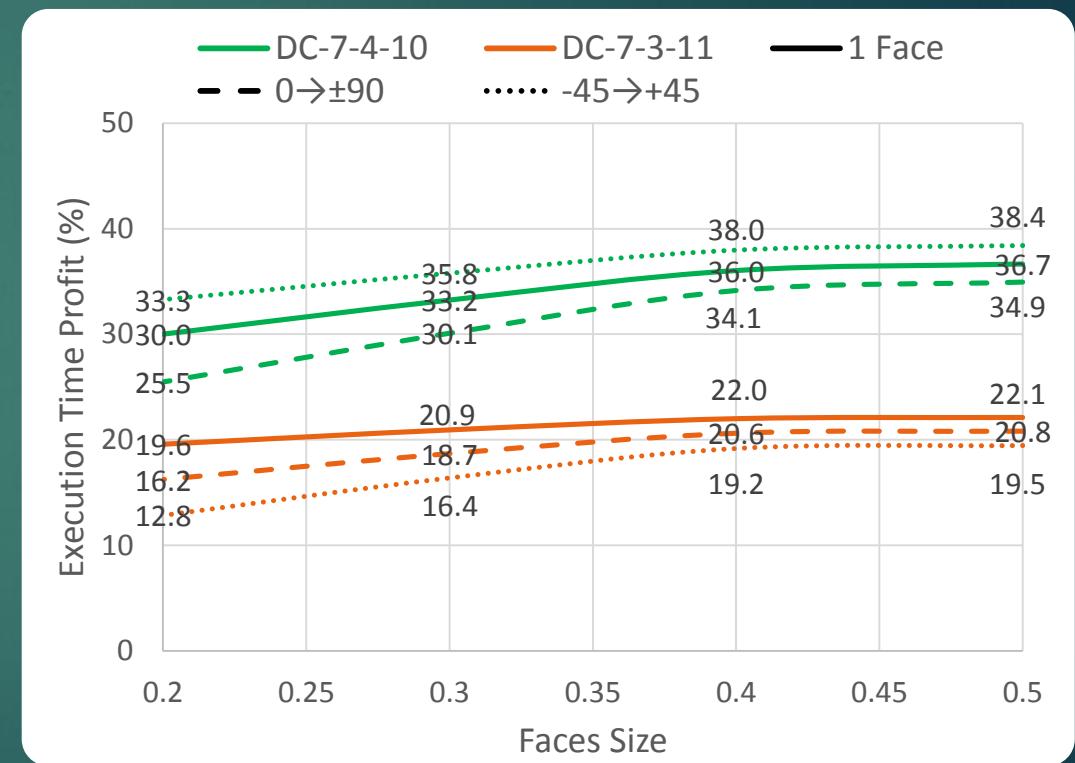


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FPE – Pose Peak Detection

► Pose Estimation loss at -1%

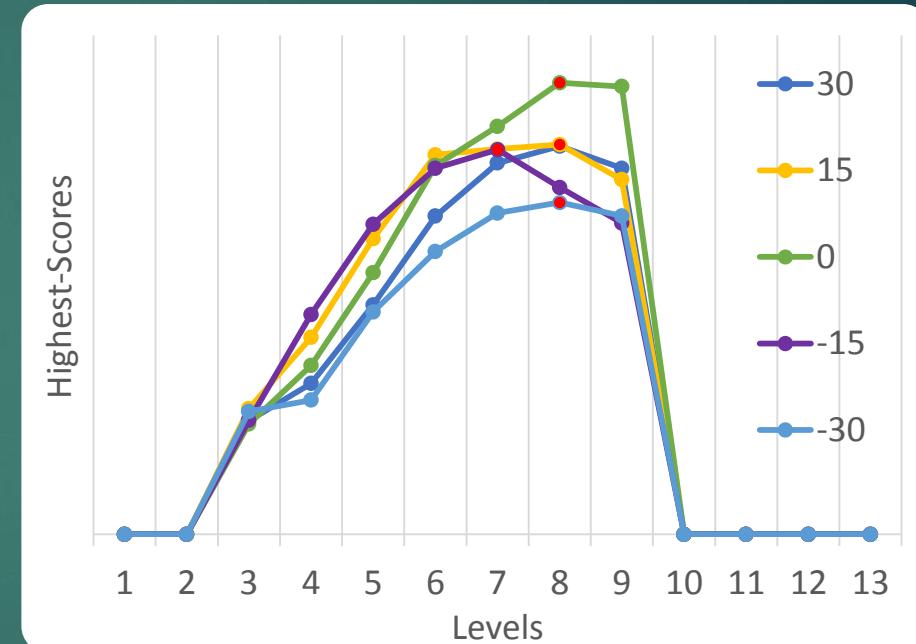
DC Pose	Efficiency	Reliability	Time Profit
DC-1-68	78.8	75.5	44.6
DC-99	84.6	80.5	23.4
DC-3-68	78.4	79.9	42.5
Original	82.1	79.9	-



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FPE – Level Peak Detection

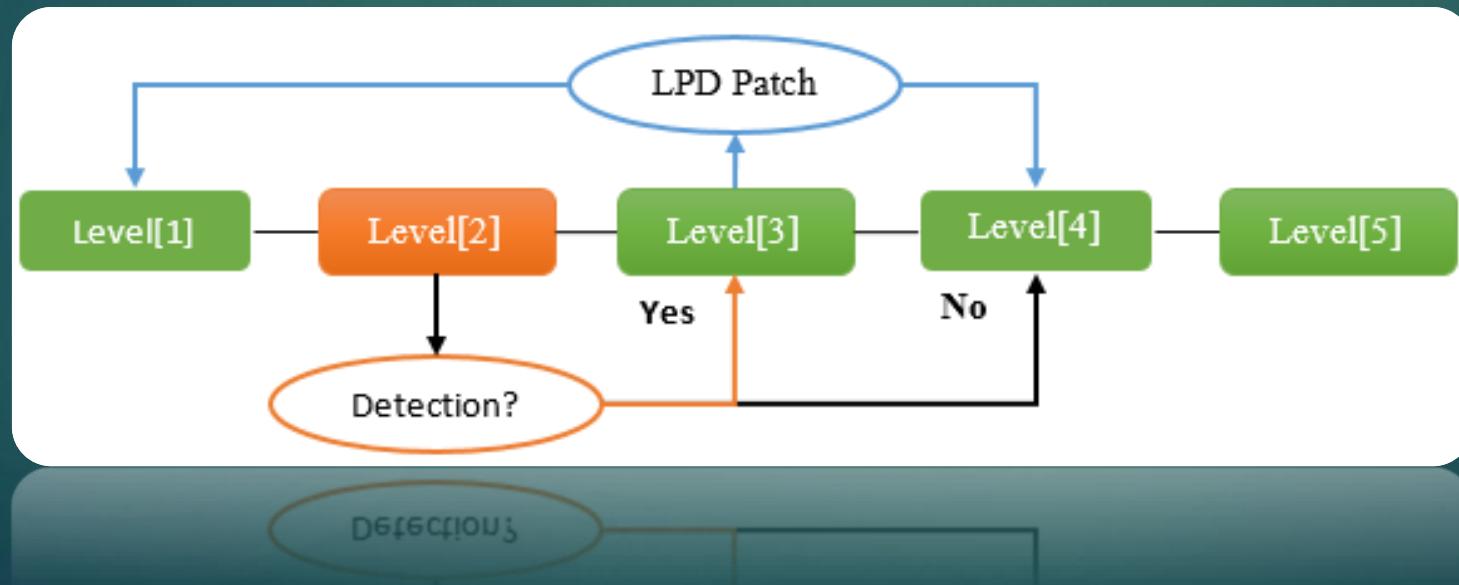
- ▶ The right level brings the highest score
- ▶ Near levels creates peaks
- ▶ Less than 2% time profit
- ▶ No Reliability loss



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Fast Pyramid Pass Patch

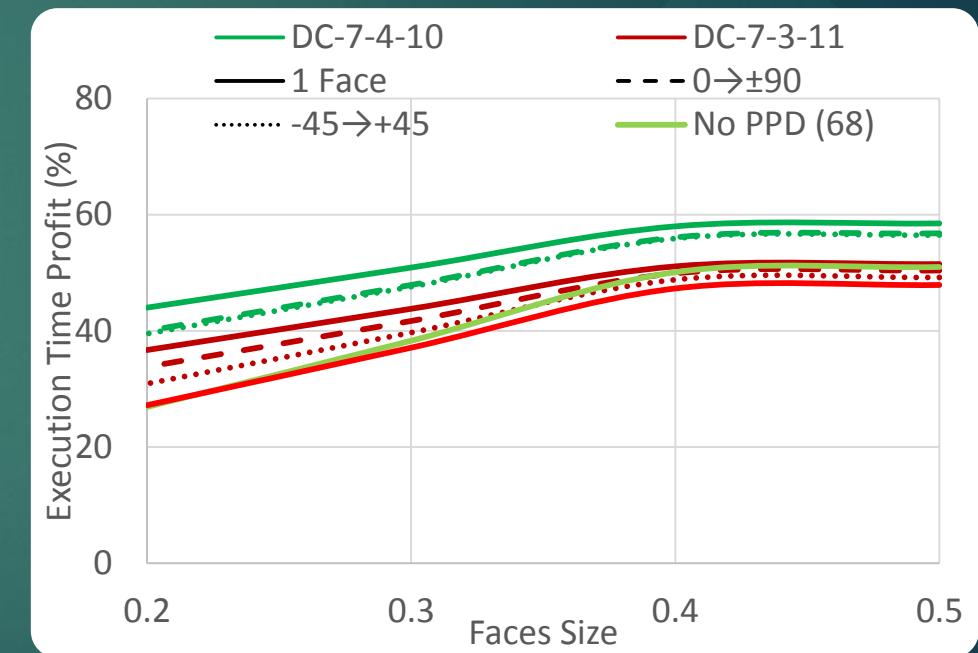
- ▶ Level stage executed every two (step) levels
- ▶ Can be combined with Level Peak Detection



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Fast Pyramid Pass Patch - Results

	DC Pose	Efficiency	Reliability	No face
LPD	DC-99	84.8	80.2	60.4
	DC-3-68	84.2	80.1	65.4
FPE	DC-99	84.8	81.0	60.6
	DC-3-68	82.5	78.3	69.9
	Original	82.1	79.9	-



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Presentation Contents

- ▶ Short Algorithm Description
- ▶ Algorithm Procedures Description
- ▶ Implementation
- ▶ Multithreading Usage
- ▶ Patches
- ▶ Related Compare

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Related Compare

Tests Hardware Specifications			
	System 1	System 2	System 3 (Zedboard)
CPU Model	Intel Core i7-4600U @2.70GHz	Intel Core 2 Duo T8100 @2.10GHz	Dual Core ARM Cortex-A9 @866MHz
CPU Cores	4	2	2
RAM Memory	8 GB	4 GB	512 MB
Operating System	VM Ubuntu 15.04 (no GUI)	Ubuntu 14.04 (no GUI)	Ubuntu 12.04 (no GUI)
v3.2.2/Creators[25]	-56.3 %	-57.2 %	-63.4 %

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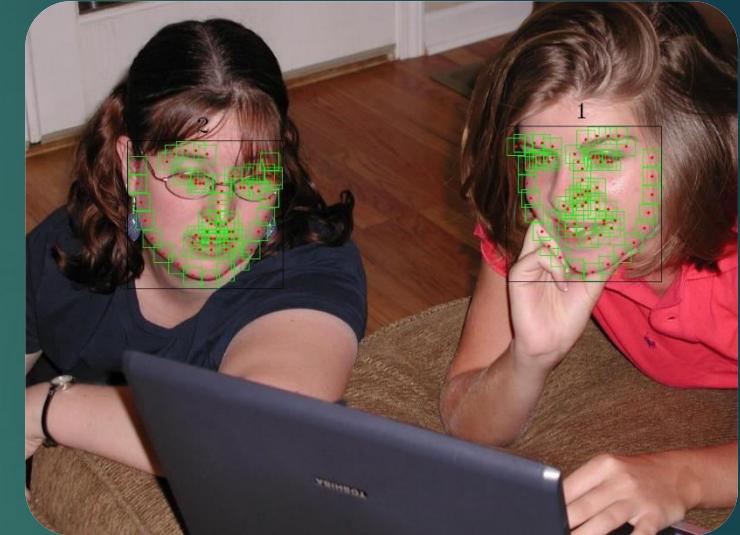
Related Compare

TSM v3.2.2 vs Creators Execution Time (%)							
System	CPU Cores	320x240	640x480	800x600	1024x768	1280x960	Average
1	1	-50.9	-38.6	-32.5	-31.7	-29.4	-36.6
	2	-61.6	-46.1	-42.1	-41.4	-39.6	-46.2
	3	-61.6	-49.9	-50.4	-47.4	-47.6	-51.4
	4	-65.2	-53.2	-55.5	-54.1	-53.4	-56.3
2	2	-76.5	-54.4	-52.7	-52.5	-49.6	-57.2
3	2	-76.6	-56.7	-56.9	Out of memory	Out of memory	-63.4

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Related Summary

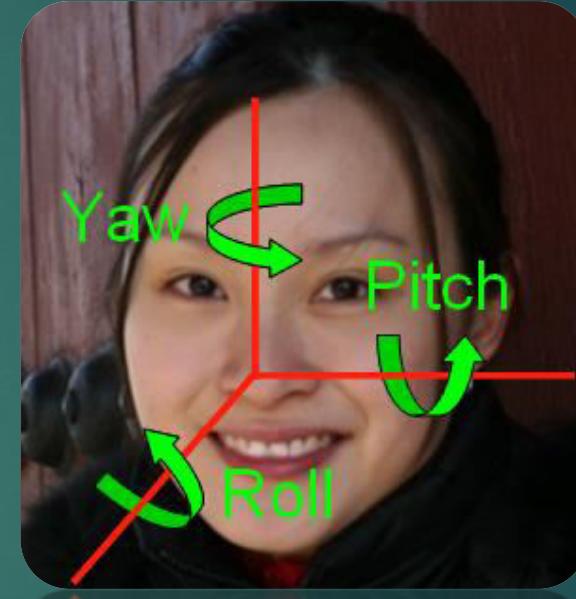
- ▶ Most Just Face Detection
- ▶ Most Frontal Faces Only
- ▶ Some Pose Estimation
- ▶ Very Few 68 Landmark Localization
- ▶ None Full Angle Pose Estimation & 68 Landmark Localization



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Future Work

- ▶ Separate Face Detection and Pose Estimation
- ▶ Complete Pose Estimation
- ▶ Better Landmark Localization
- ▶ General Object Detection



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Questions?

