Implementing a Library to Calculate Surrogate Safety

A software library to calculate PET and speed values of road users

By: Mohammad Hossein Nazemi

Overview

1) Introduction	Traffic Safety, SSA and SSM, PET and Speed, Our Contribution
2) Background	Literature Review, Similar Approaches, Shortcomings of Other Works
3) Approach	PET Detection and Calculation Module, Average and Momentary Speed Module
4) Validation	PET Validations and Experiments, Speed Validation Experiment

Introduction

Traffic Safety, SSA and SSM, PET and Speed, Our Contribution

Traffic Safety

Picture is from: https://www.chicagotribune.com/autos/sc-auto-motormouth-1018-story.html

Traffic Safety – Problems of Crash Data

1. Do not happen that frequently

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Traffic Safety – Problems of Crash Data

1. Do not happen that frequently
2. Do not include useful information

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Traffic Safety – Problems of Crash Data

1. Do not happen that frequently
2. Do not include useful information
3. Hard to differentiate between random occurrence or statistical crashes

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Traffic Safety – Problems of Crash Data

1. Do not happen that frequently
2. Do not include useful information
3. Hard to differentiate between random occurrence or statistical crashes
4. Do not show the behavior of road users before the crash

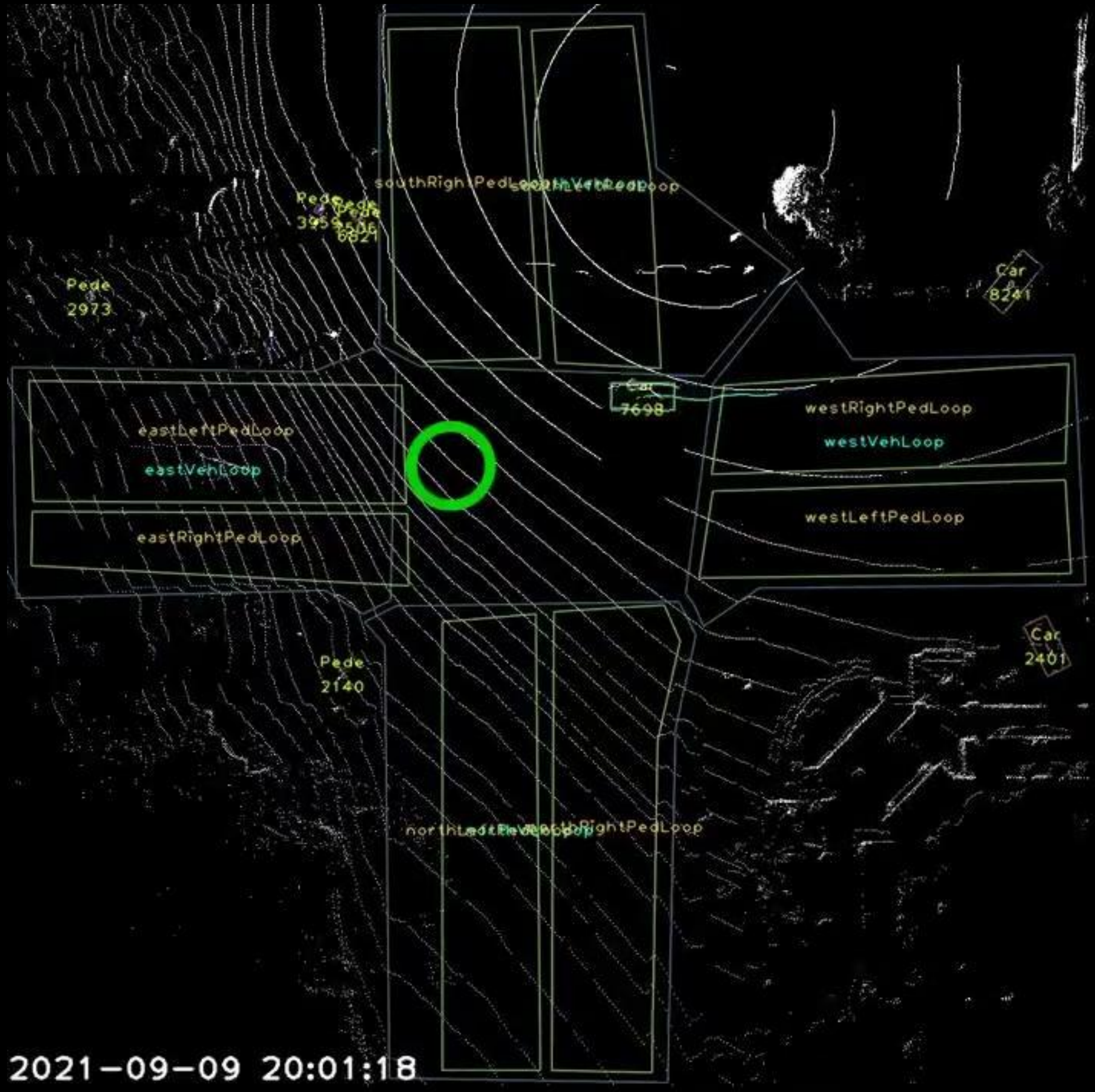
Picture is from: https://www.chicagotribune.com/autos/sc-auto-motormouth-1018-story.html

Surrogate Safety Analysis

- Various surrogate safety measures like PET, TTC, deceleration rate, and Speed
- Studies showed the relations between surrogate safety measures and crash data
- In this work we focused on two measures, PET and Speed

Picture is from: https://umanitoba.ca/extended-education/programs-and-courses/business-and-management-programs/business-analysis

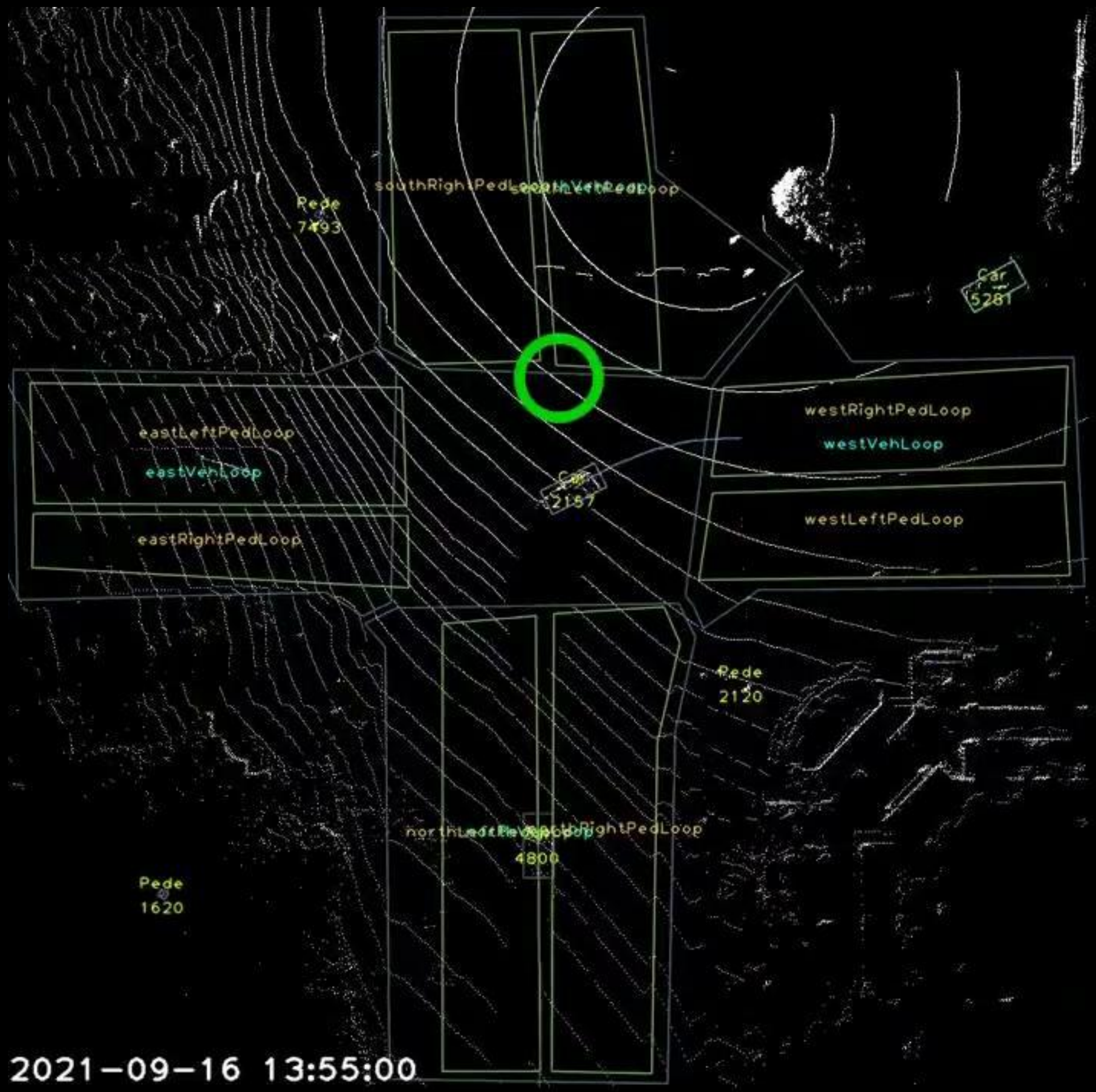
Post Encroachment Time (PET)



Speed

From BlueCity Sensors

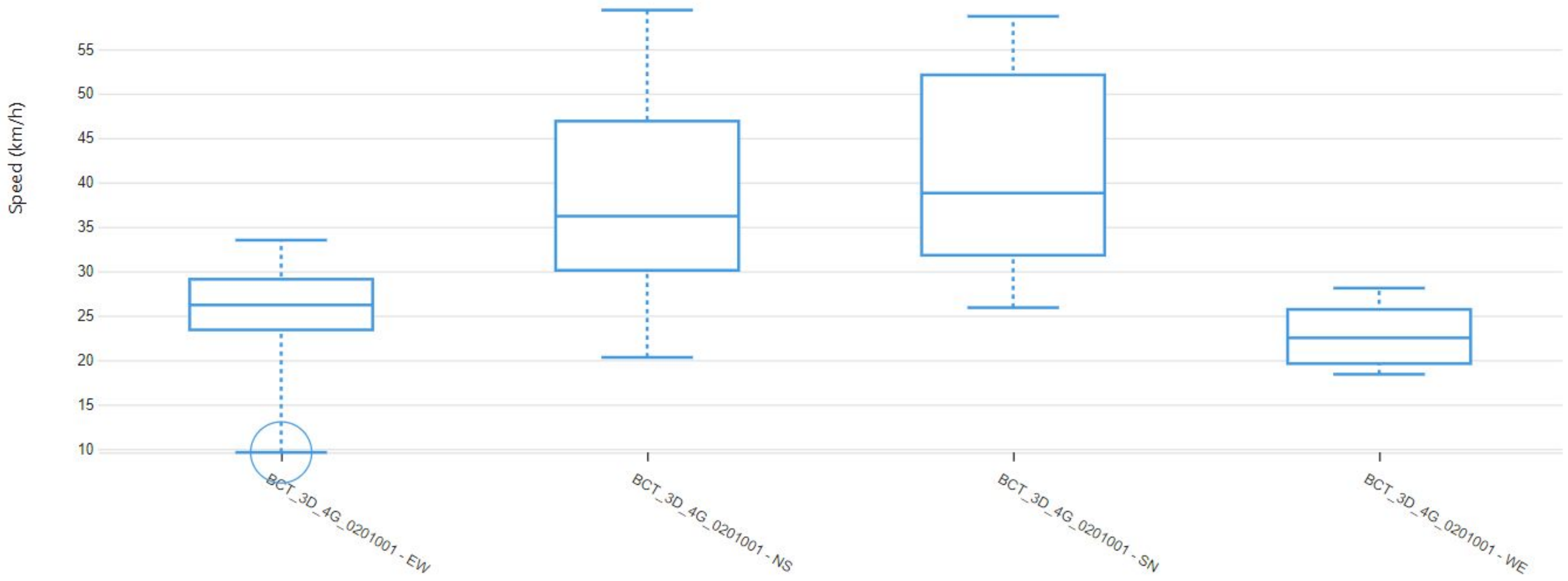
Speed



From BlueCity Sensors

Speed

1. Momentary Speed
2. Average Speed



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What We Have Done

- Automated PET Detection and Calculation Module

Characteristics

What We Have Done

- Automated PET Detection and Calculation Module

Characteristics

- Decoupled

What We Have Done

- Automated PET Detection and Calculation Module

Characteristics

- Decoupled
- Realtime/Continuous

What We Have Done

- Automated PET Detection and Calculation Module

Characteristics

- Decoupled
- Realtime/Continuous
- Precise

What We Have Done

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- Decoupled
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- Generalized

What We Have Done

- Automated PET Detection and Calculation Module

Characteristics

- Decoupled
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- Precise
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- Easy to use

What We Have Done

- Automated PET Detection and Calculation Module

Characteristics

- Decoupled
- Realtime/Continuous
- Precise
- Generalized
- Easy to use
- Fault tolerant

What We Have Done

- Automated PET Detection and Calculation Module
- Momentary and Average Speed Calculation Module

Characteristics

What We Have Done

- Automated PET Detection and Calculation Module
- Momentary and Average Speed Calculation Module

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What We Have Done

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What We Have Done

- Automated PET Detection and Calculation Module
- Momentary and Average Speed Calculation Module

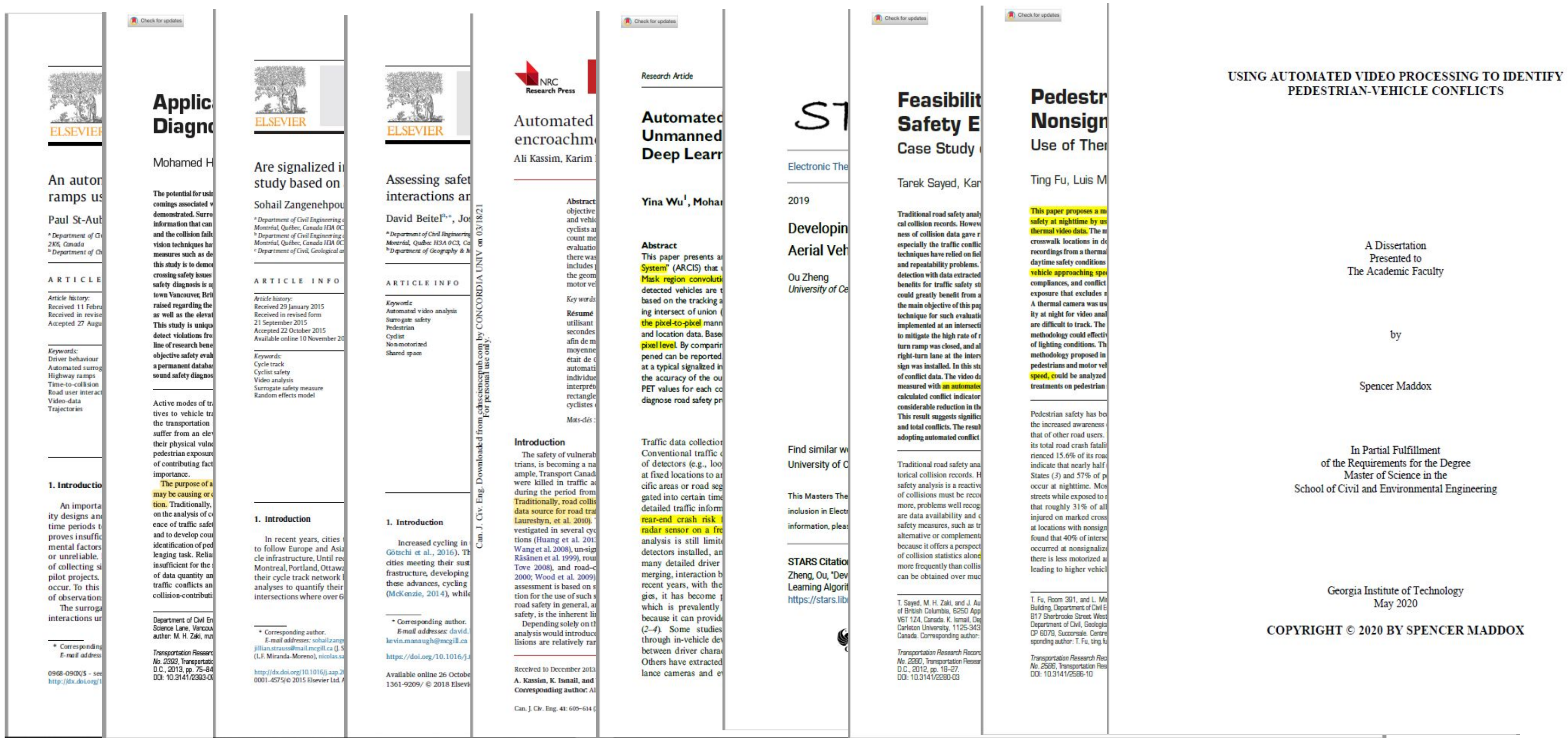
Characteristics

- Decoupled
- Realtime/Continuous
- Easy to use

Background

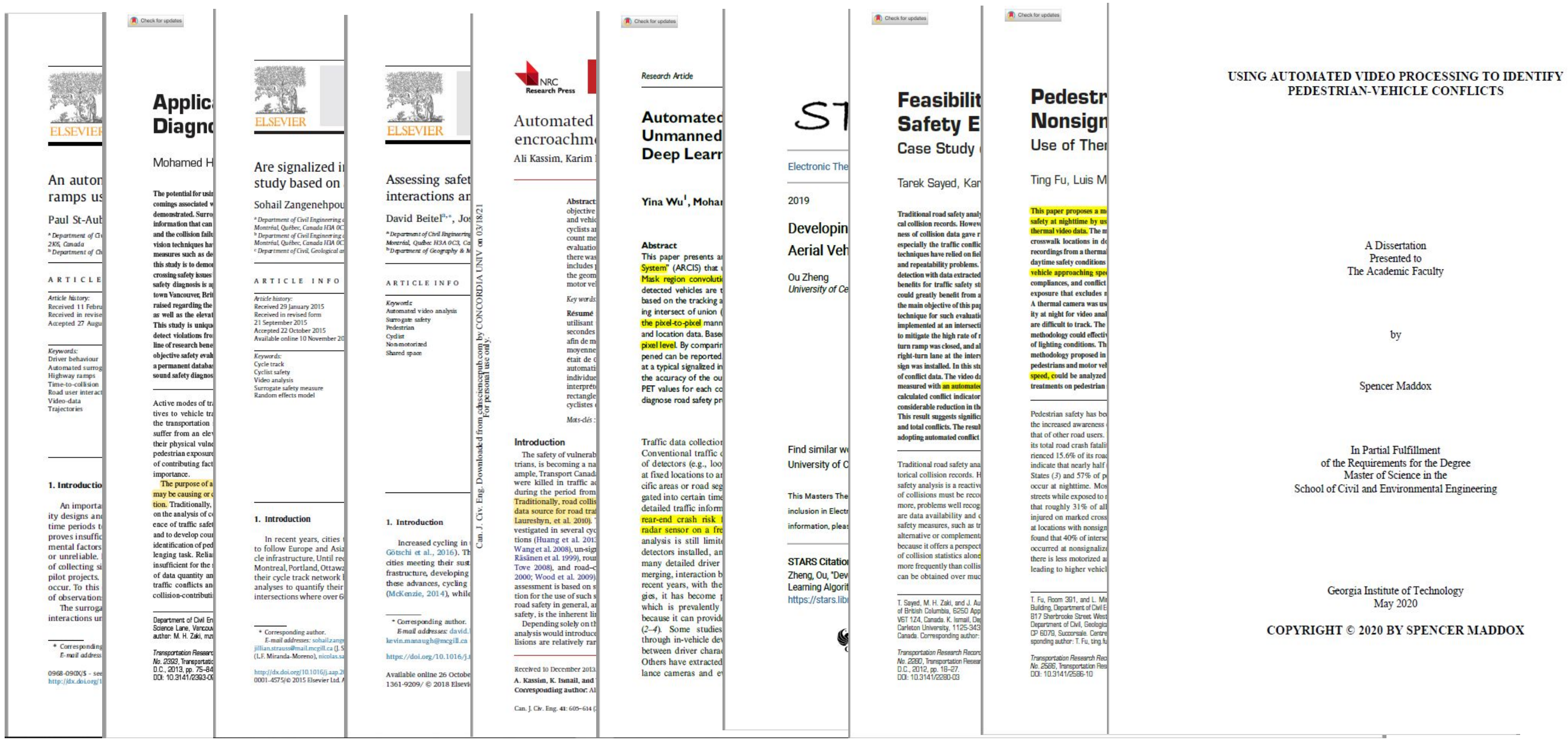
Literature Review, Related Works

Case Studies



Case Studies

- Decoupled
- Realtime/Continuous
- Precise
- Generalized
- Easy to use
- Fault tolerant

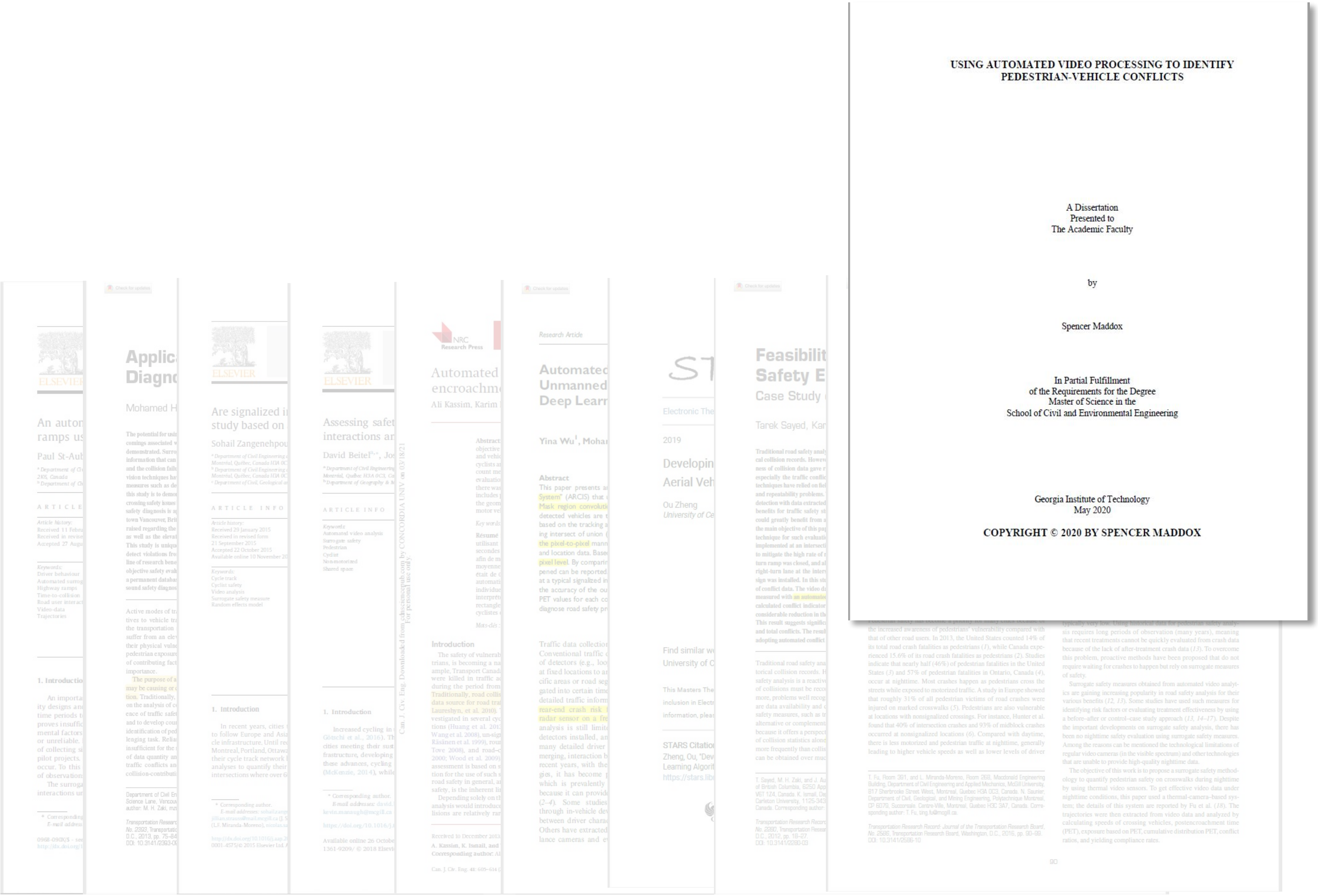


Case Studies

- Focus on the Automated SSM Module

Case Studies

- Focus on the Automated SSM Module
- Decoupled



Case Studies

- Focus on the Automated SSM Module
- Decoupled
- Realtime/Continuous

Case Studies

- Focus on the Automate Module
- Decoupled
- Realtime/Continuous
- Precision

Case Studies

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- Decou
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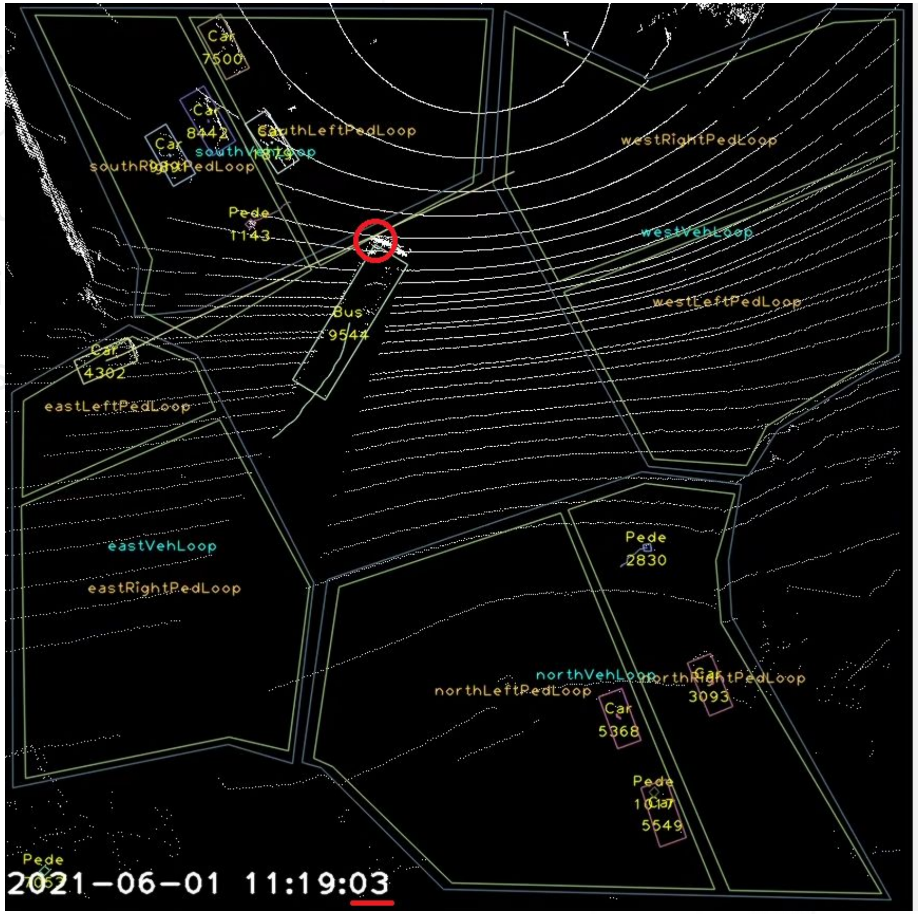
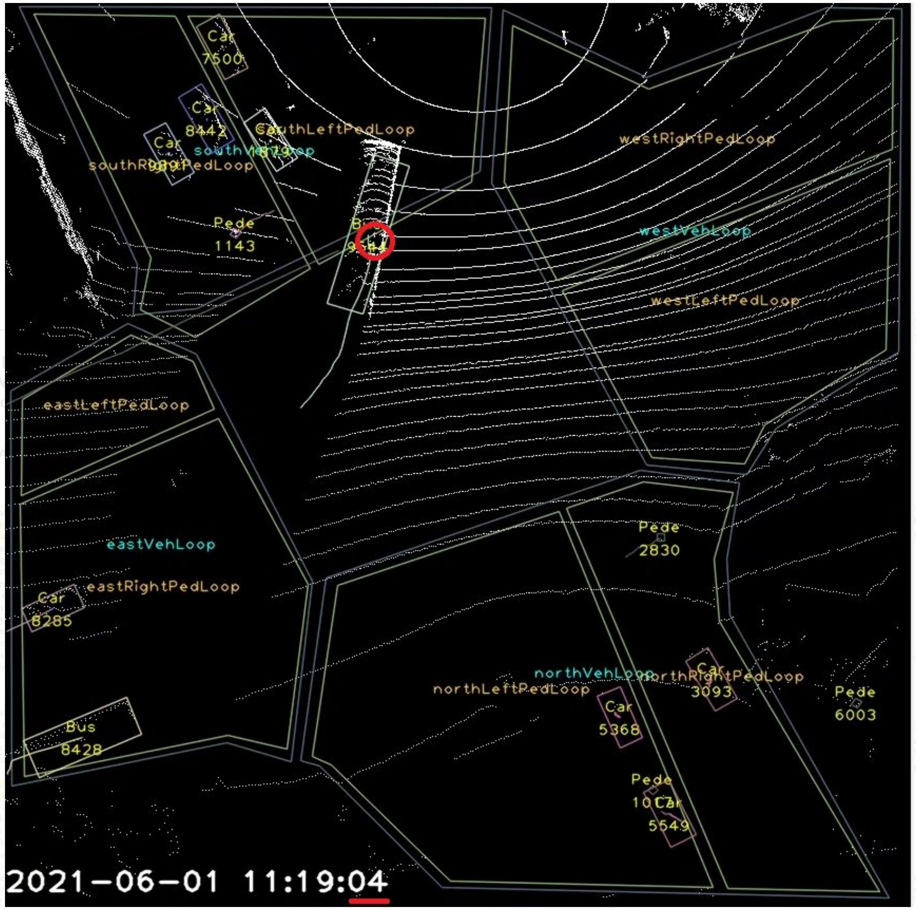
- Precis





Case Studies

- Focus on the Automate Module
- Decoupled
- Realtime/Continuous
- Precise

Case Studies

- Focus on the Automated SSM Module
- Decoupled
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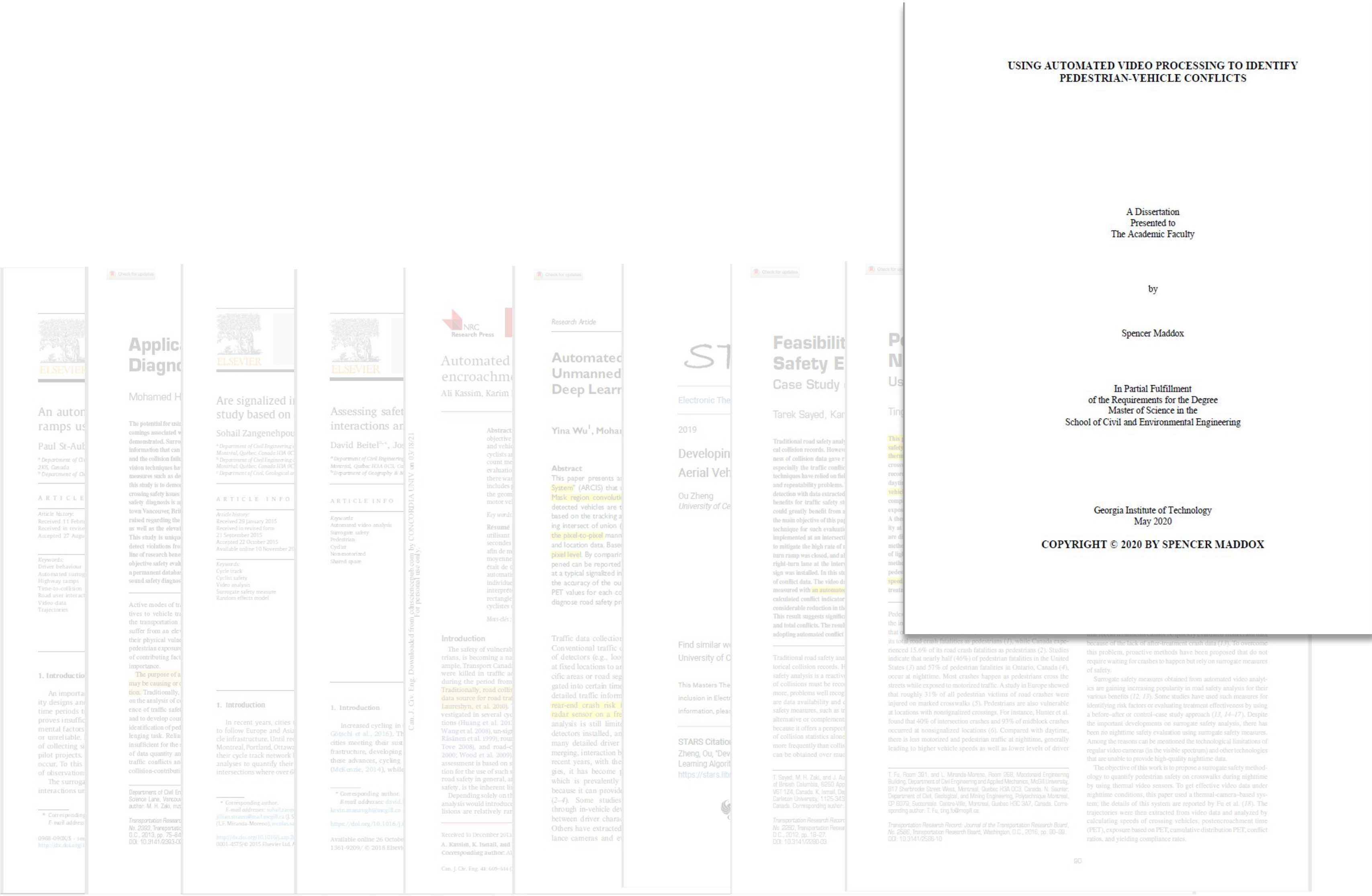
- Precise
- Generalized



Case Studies

- Focus on the Automated SSM Module
- Decoupled
- Realtime/Continuous
- Precise
- Generalized
- Easy to use

Case Studies

- Focus on the Automated SSM Module
- Decoupled
- Realtime/Continuous
- Precise
- Generalized
- Easy to use
- Fault tolerant

Case Studies

- Focus on the Automated SSM Module
- Decoupled
- Realtime/Continuous
- Precise
- Generalized
- Easy to use
- Fault tolerant
- Combination of multiple SSMs

Approach

Serializer, PET Module, Noise Cancelation Modules, Momentary Speed Module, Average Speed Module

PET

Serializer, PET Module, Noise Cancelation Modules

Speed

Momentary Speed Module, Average Speed Module

PET

Serializer, PET Module, Noise Cancelation Modules

Speed

Momentary Speed Module, Average Speed Module

PET: Characteristics

1. Decoupled
2. Realtime/Continuous
3. Precise
4. Generalized
5. Easy to use
6. Fault tolerant

PET: Characteristics

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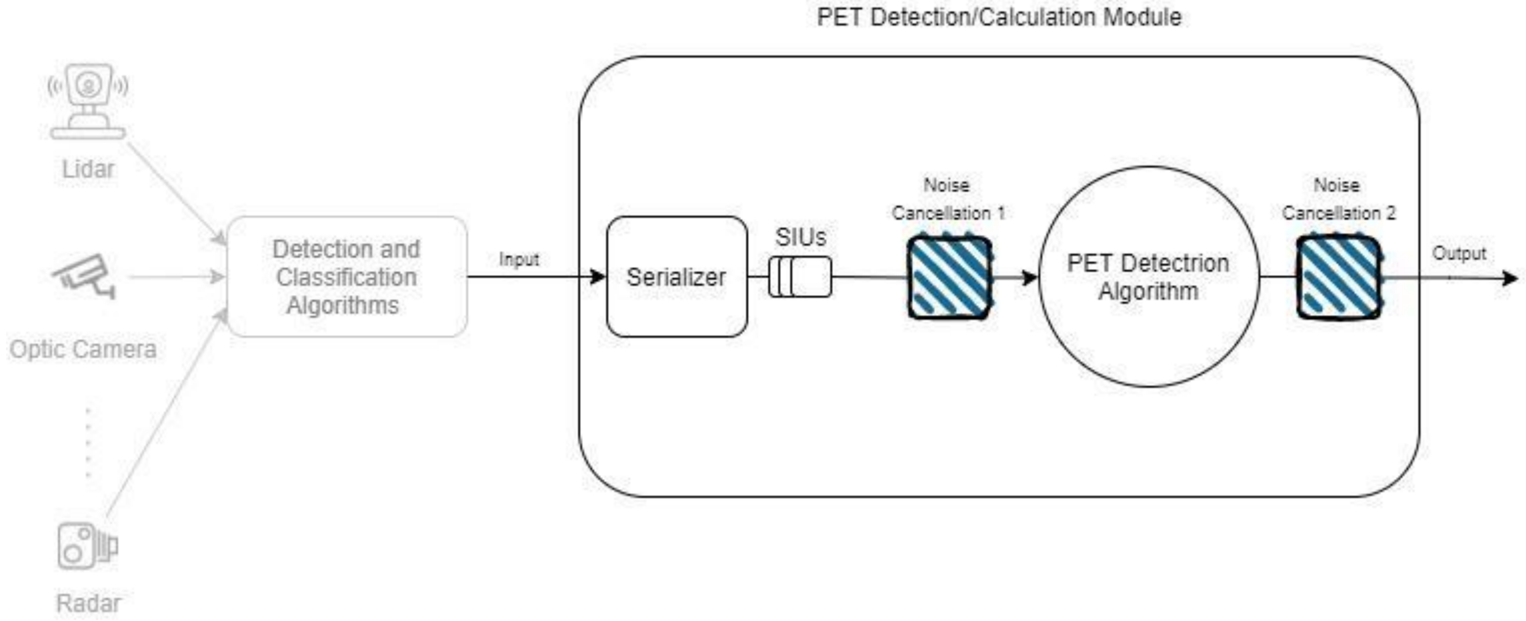
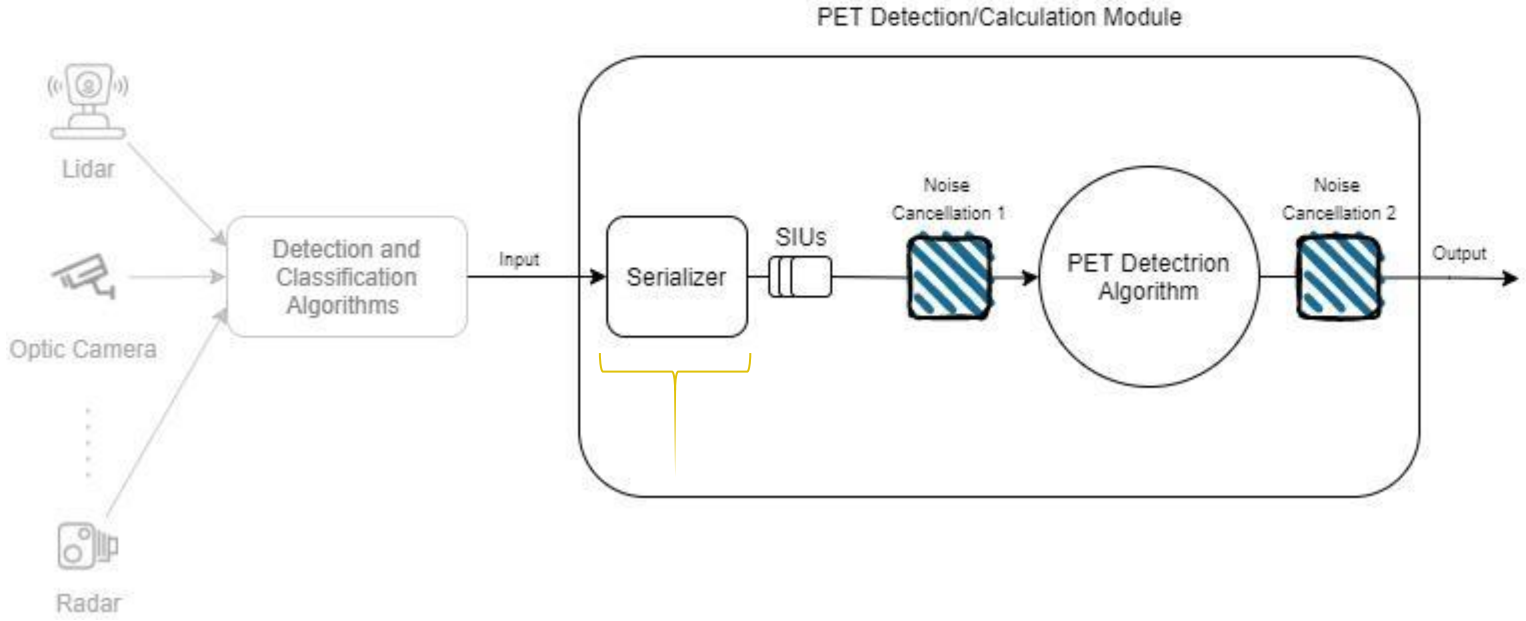


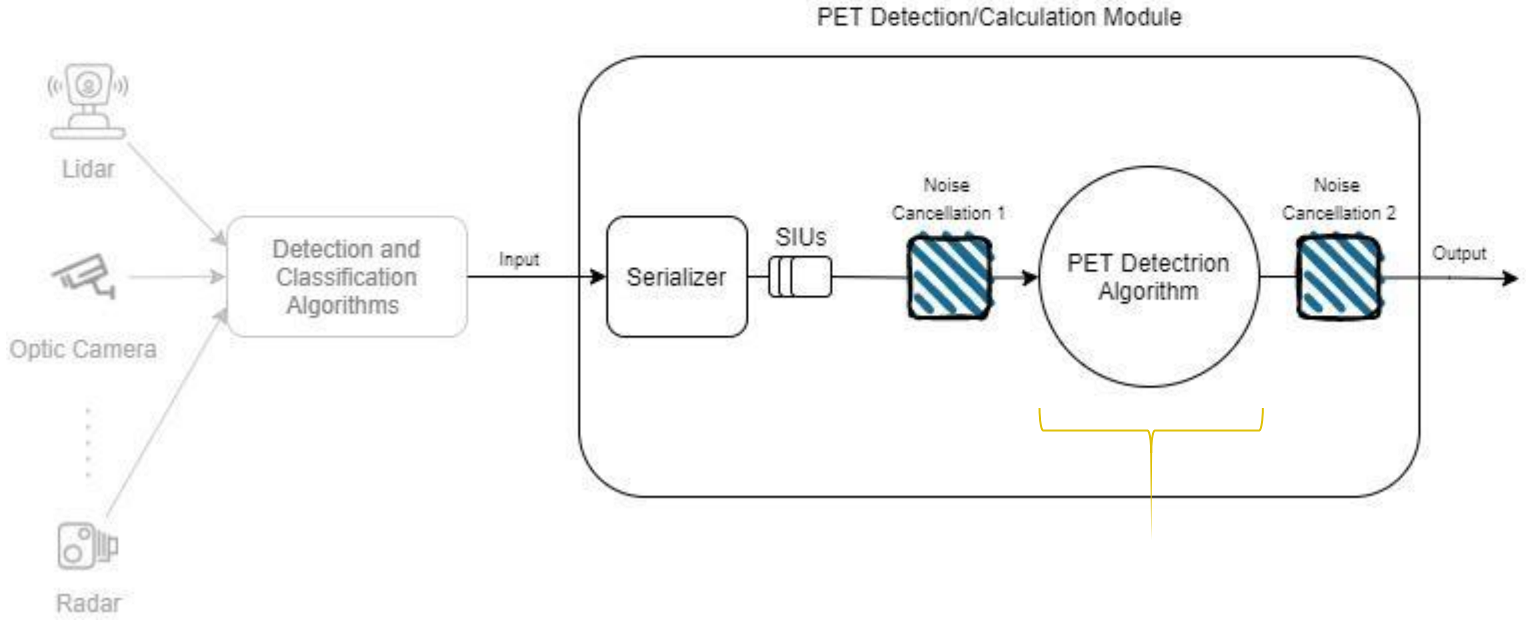
PET: Serializer

1. Decoupled
2. Realtime/Continuous
3. Precise
4. Generalized
5. Easy to use
6. Fault tolerant



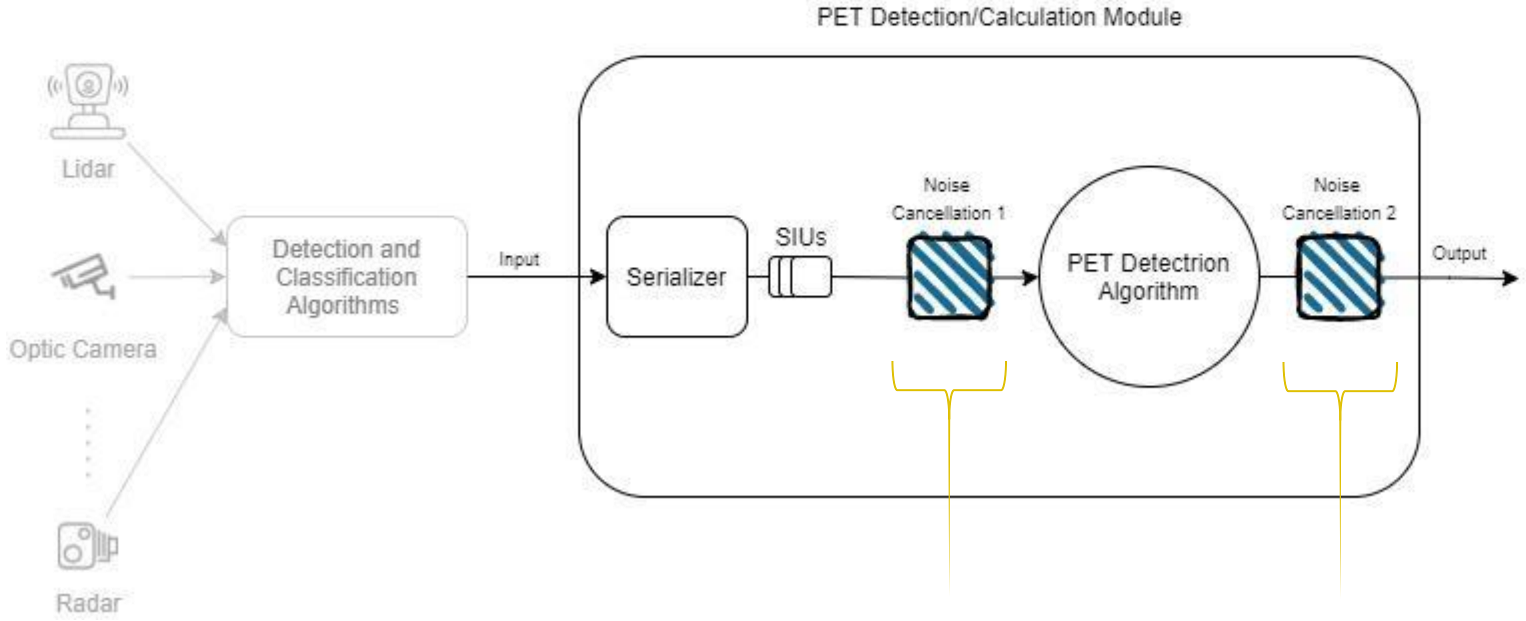
PET: Detection Module

1. Decoupled
2. Realtime/Continuous
3. Precise
4. Generalized
5. Easy to use
6. Fault tolerant



PET: Noise Cancellation

1. Decoupled
2. Realtime/Continuous
3. Precise
4. Generalized
5. Easy to use
6. Fault tolerant



PET: Serializer

1. Decoupled
2. Realtime/Continuous
3. Precise
4. Generalized
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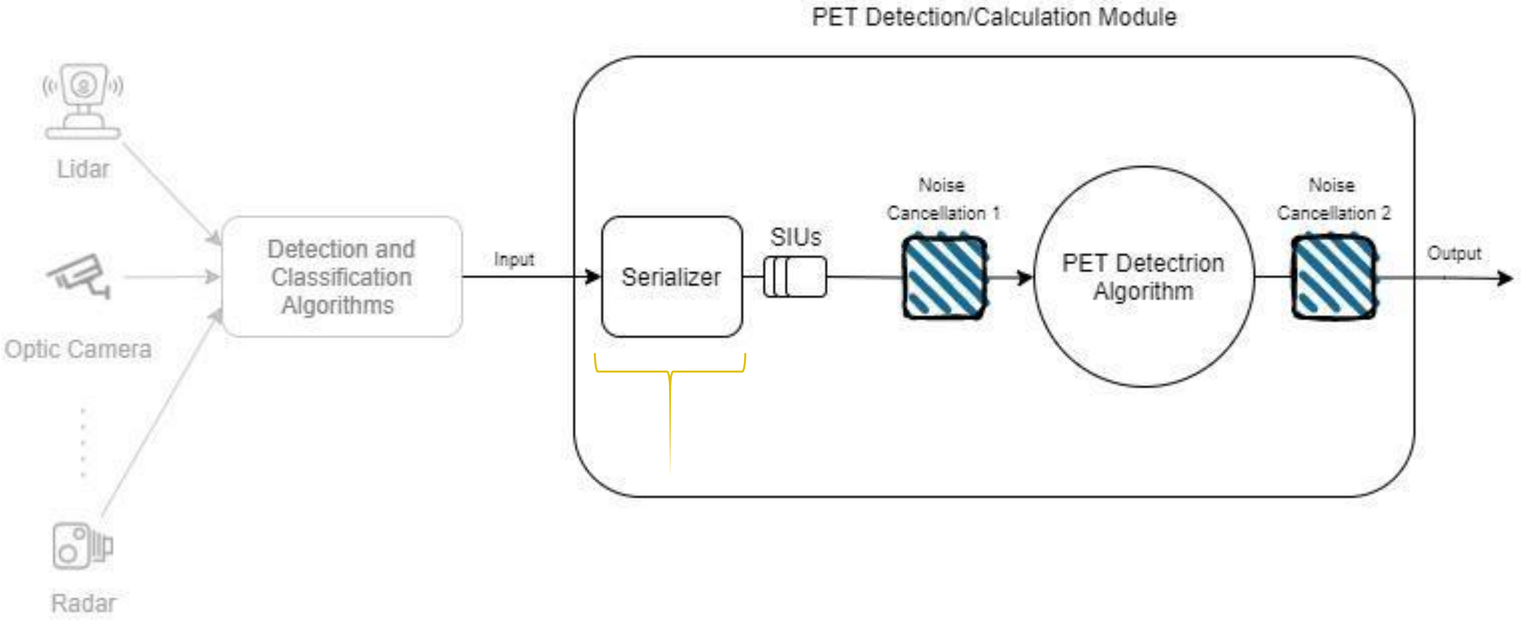
6. Fault tolerant



Inputs of Serializer

1. Object ID
2. X and Y position in frame
3. Width and length of bounding box
4. Rotation of the bounding box in frame
5. ClassType of the object

Output:

Standard Input Unit (SIU)

timestamp,objectId_1,centerX_1,century_1,width_1,length_1, angle_1,classType_1,objectId_2,centerX_2,century_2,width_2, length_2,angle_2,classType_2,<End of the SIU Token>

PET: Detection Module

1. Decoupled
2. Realtime/Continuous
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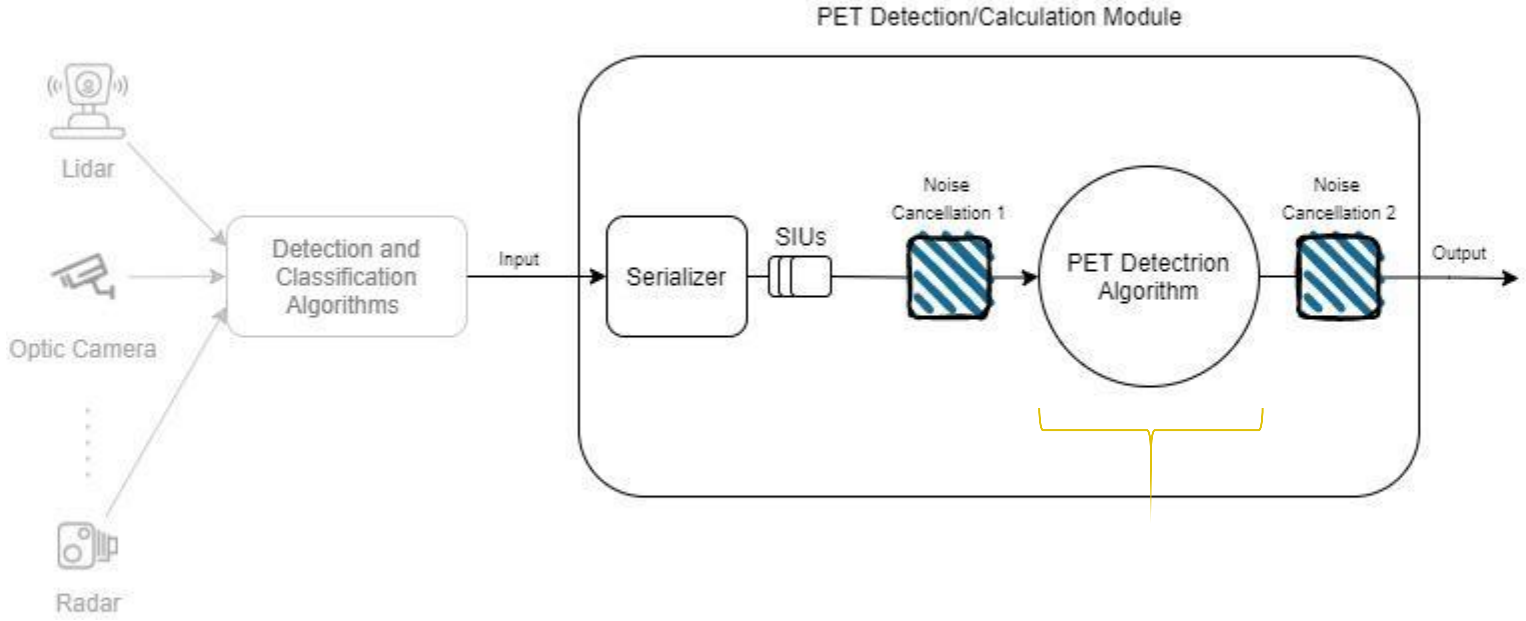
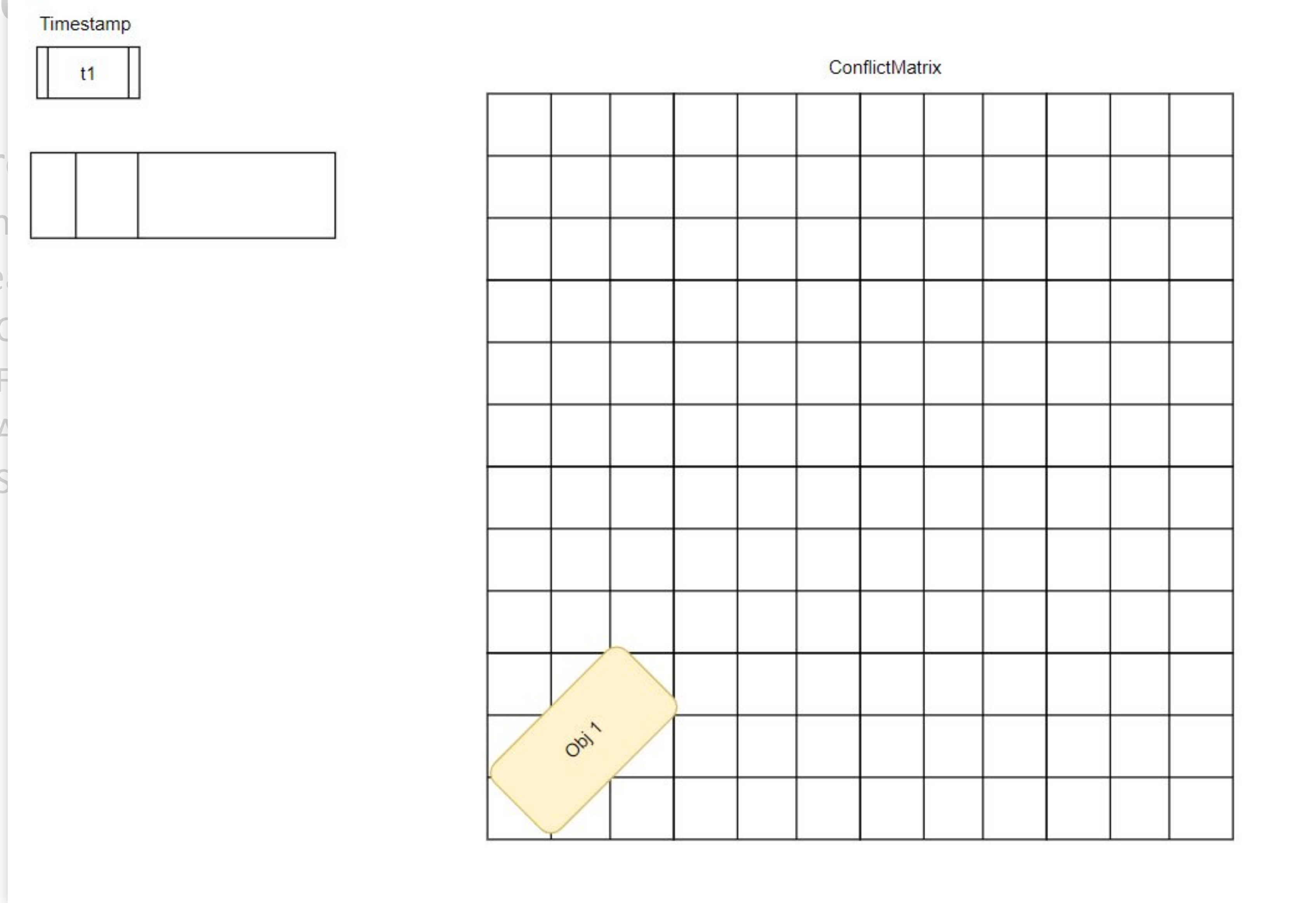


PET: Detection and Calculation

- Overall process consists of following steps:
  1. Fetching a SIU
  2. For each object:
     1. Calculate area pixels
     2. Fetch conflicts candidates
     3. Apply filters
     4. Submit objects in the conflict matrix

PET: Detection and Calculation

- Overall pr
  1. Fetch
  2. For e
     1. C
     2. F
     3. A
     4. S



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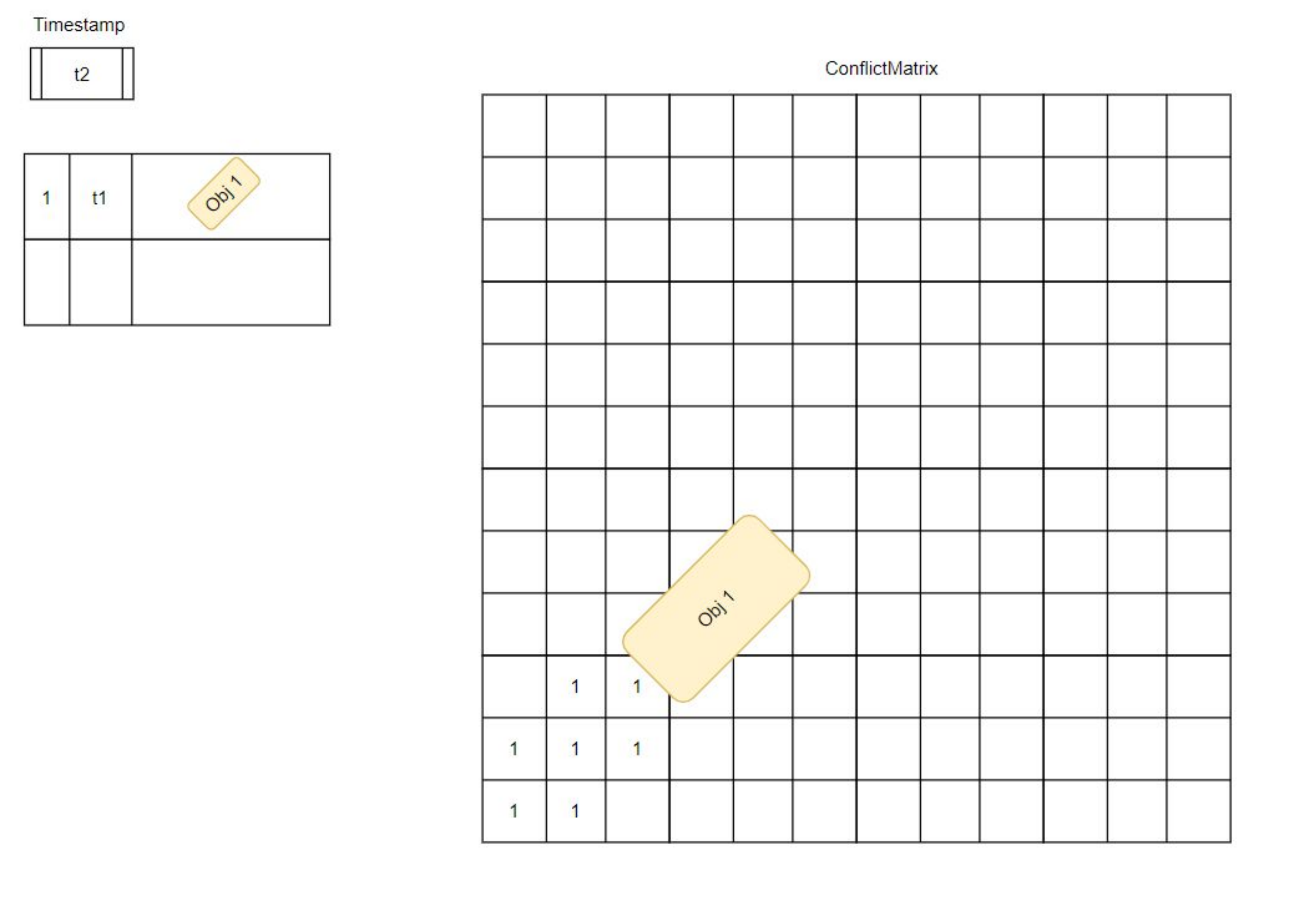

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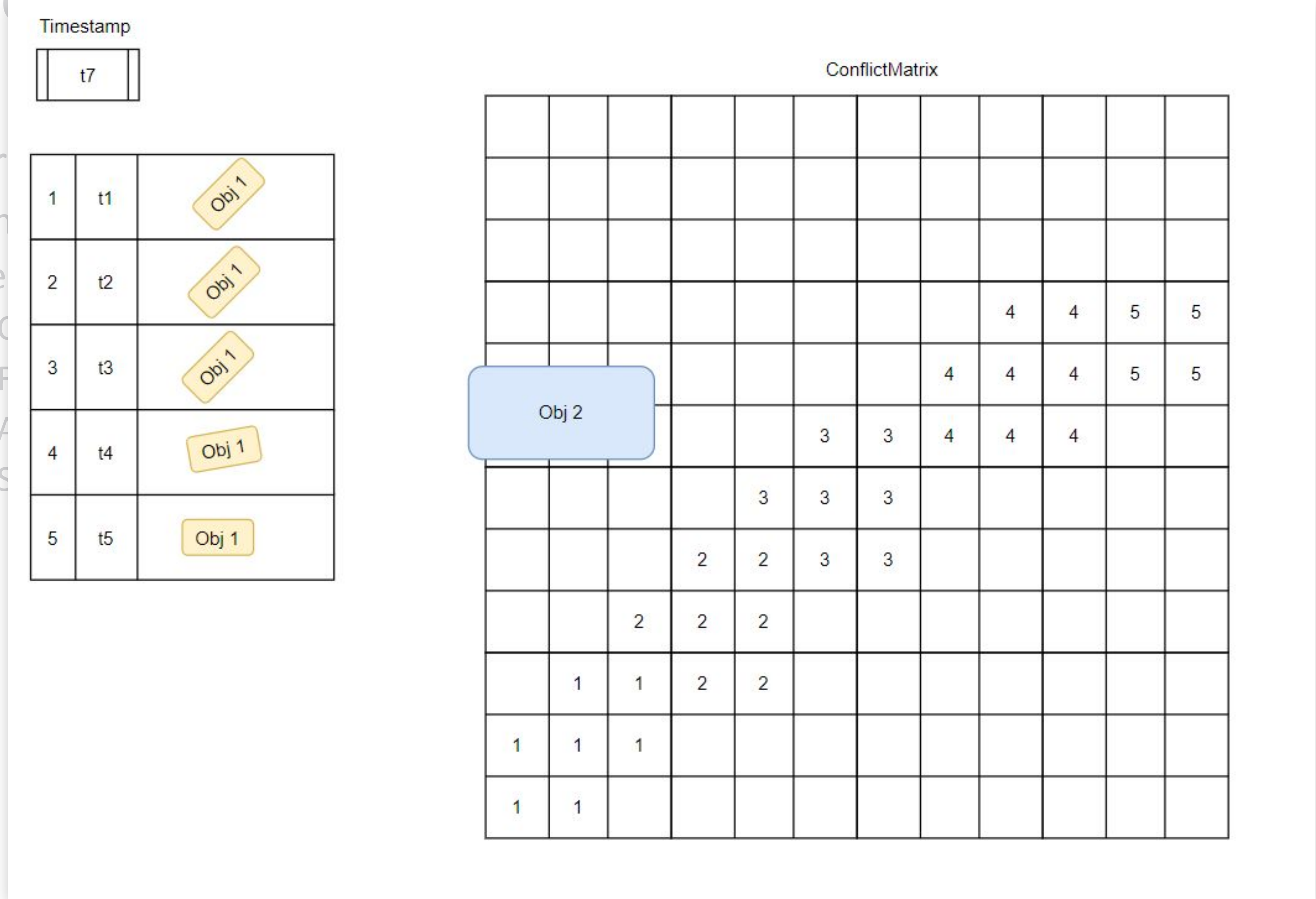

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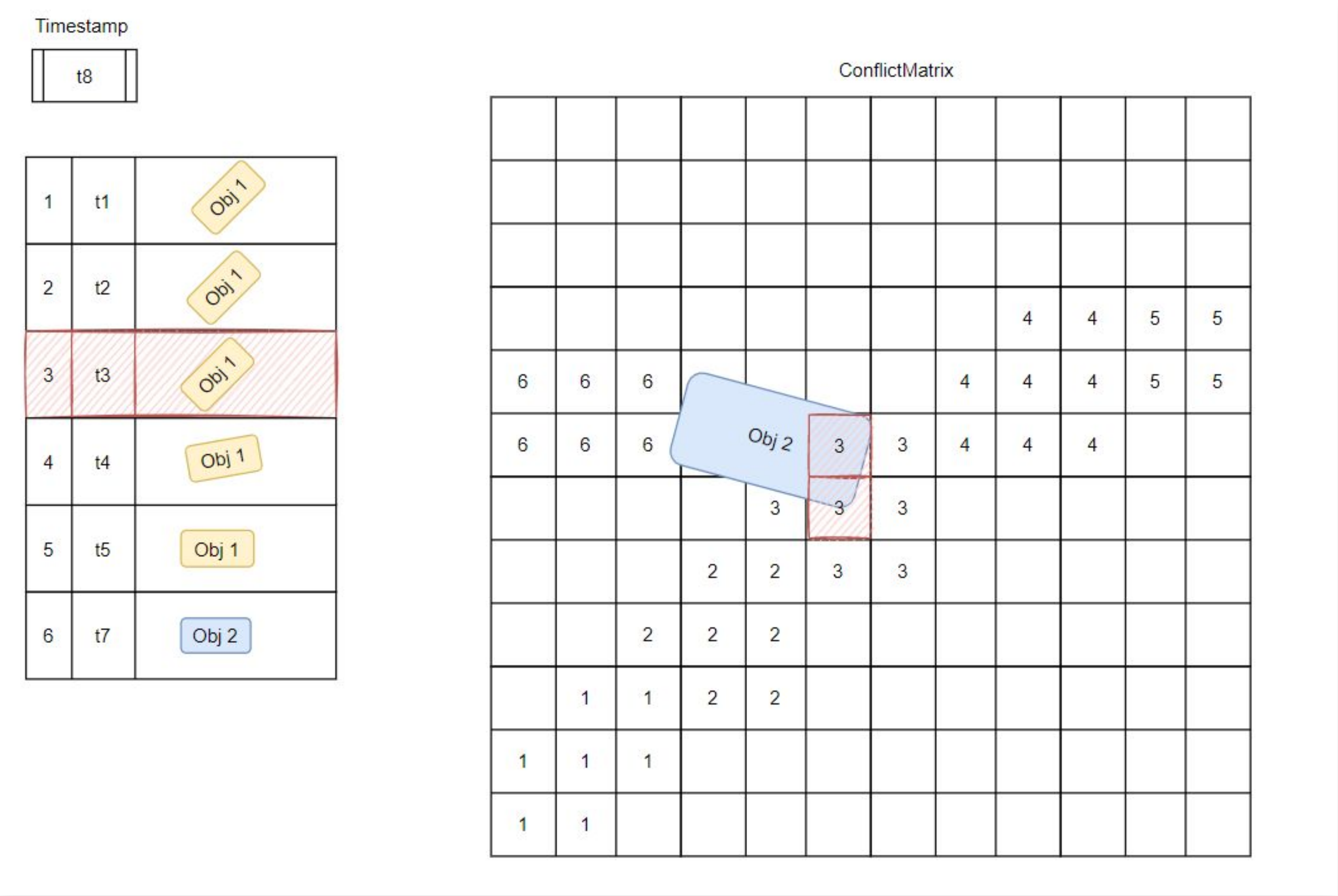

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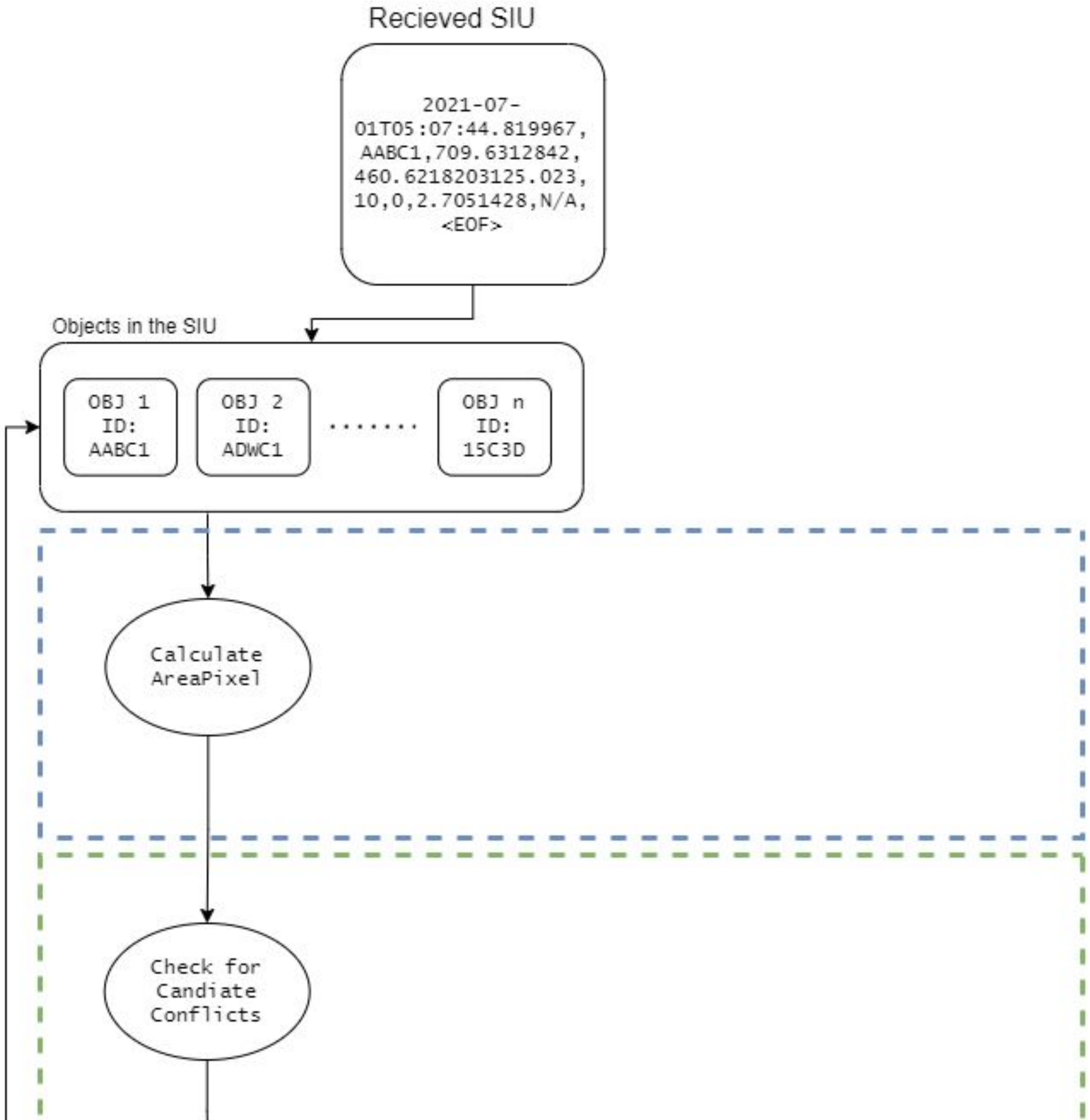

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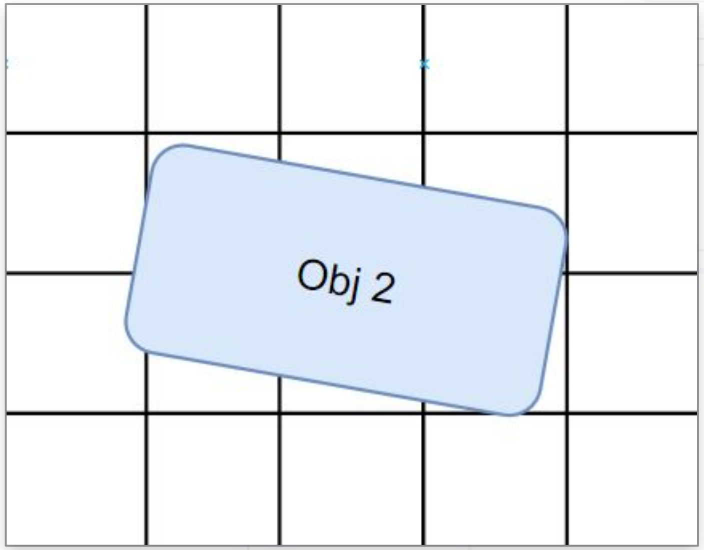

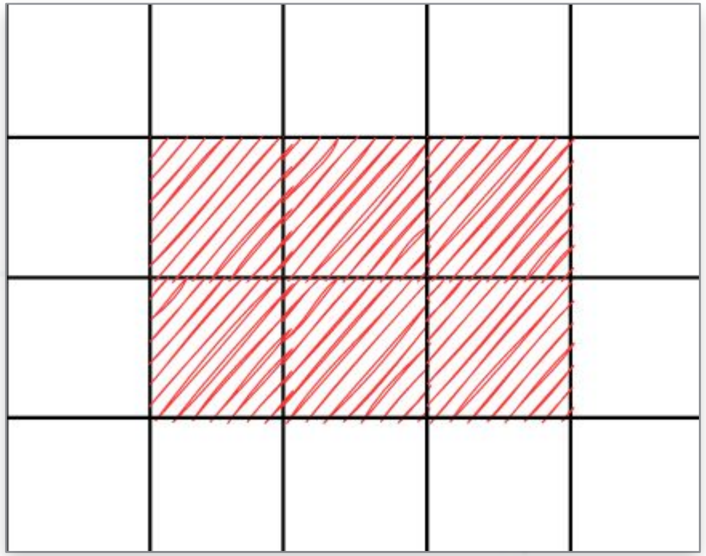

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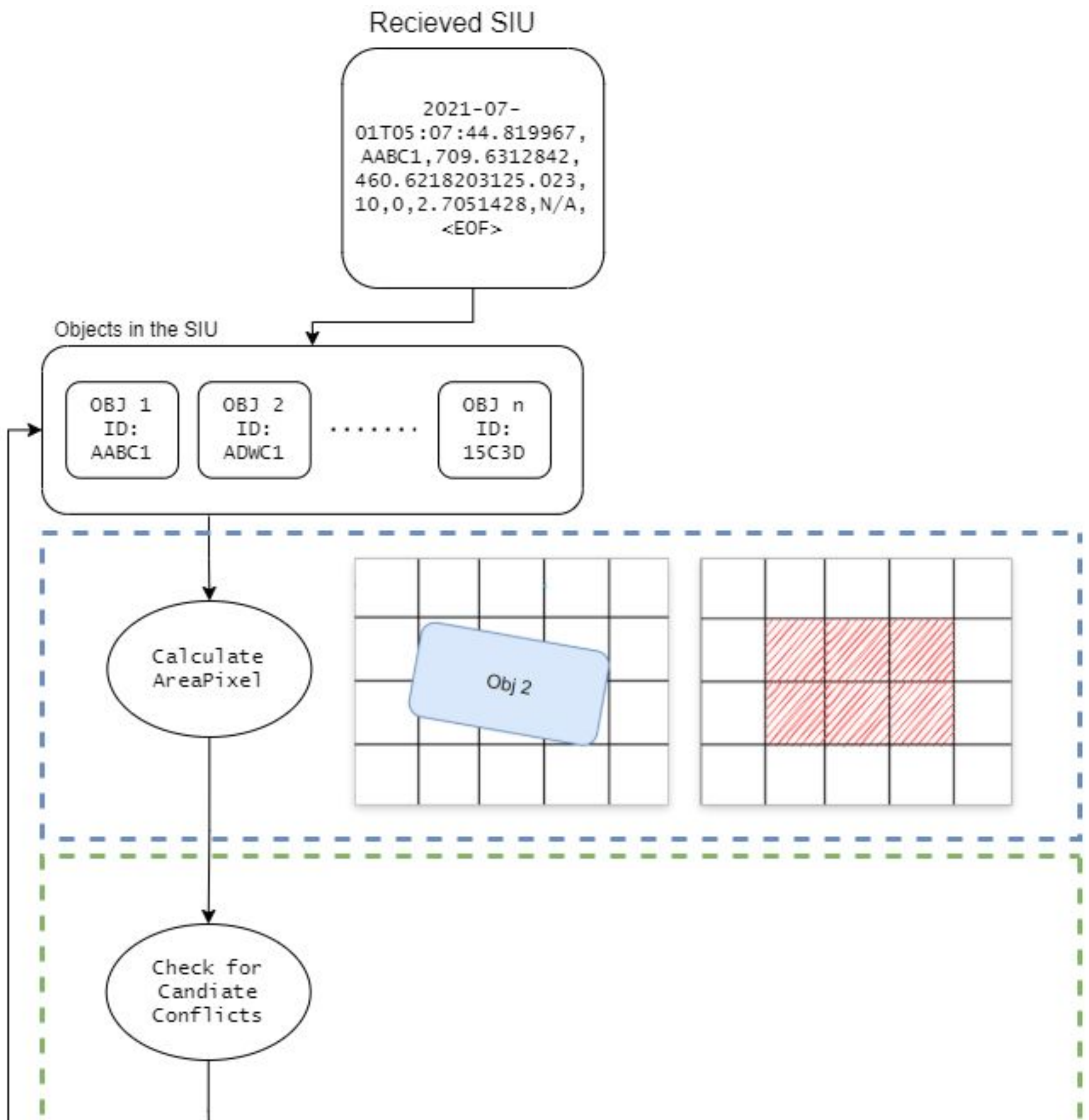
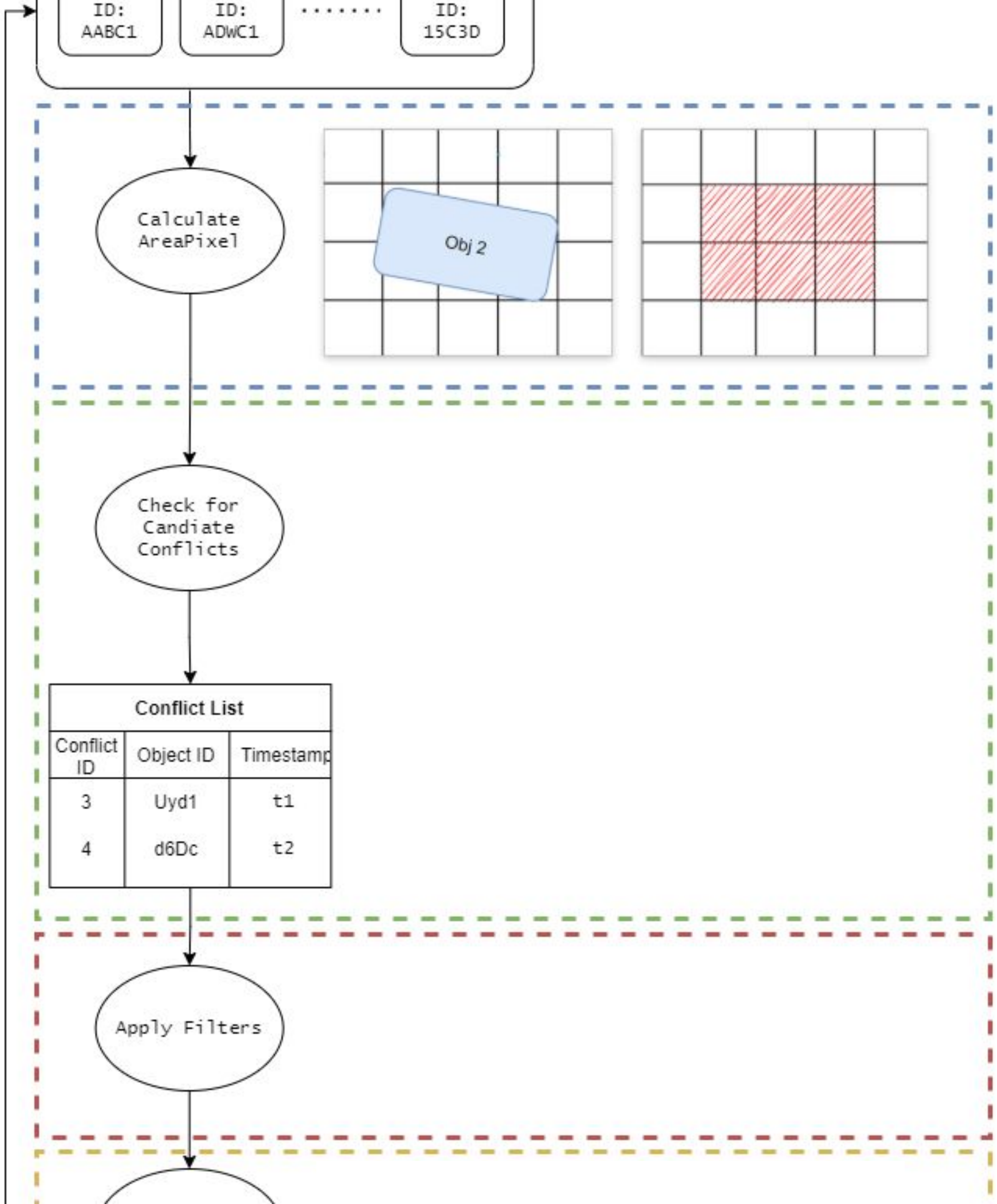
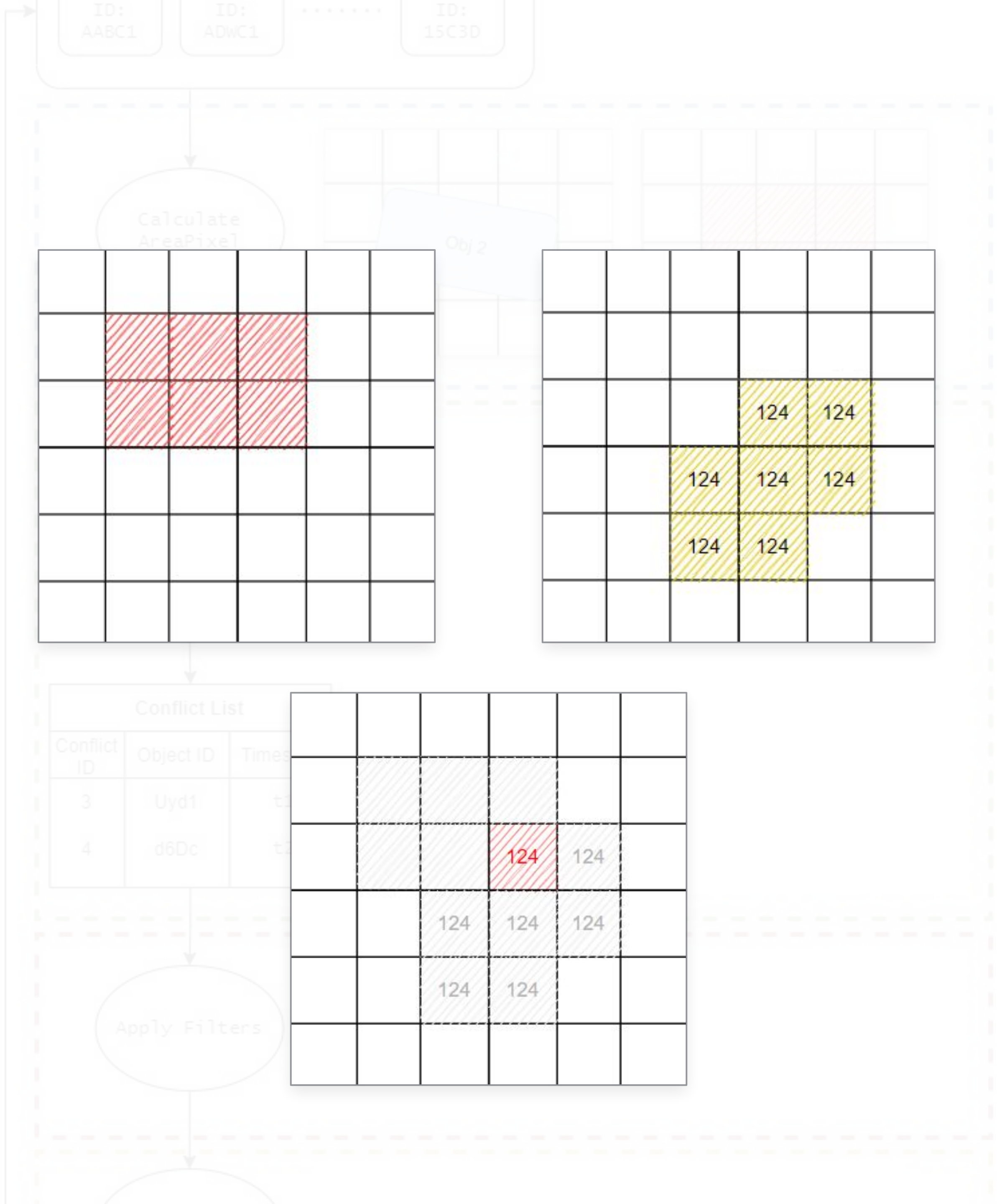
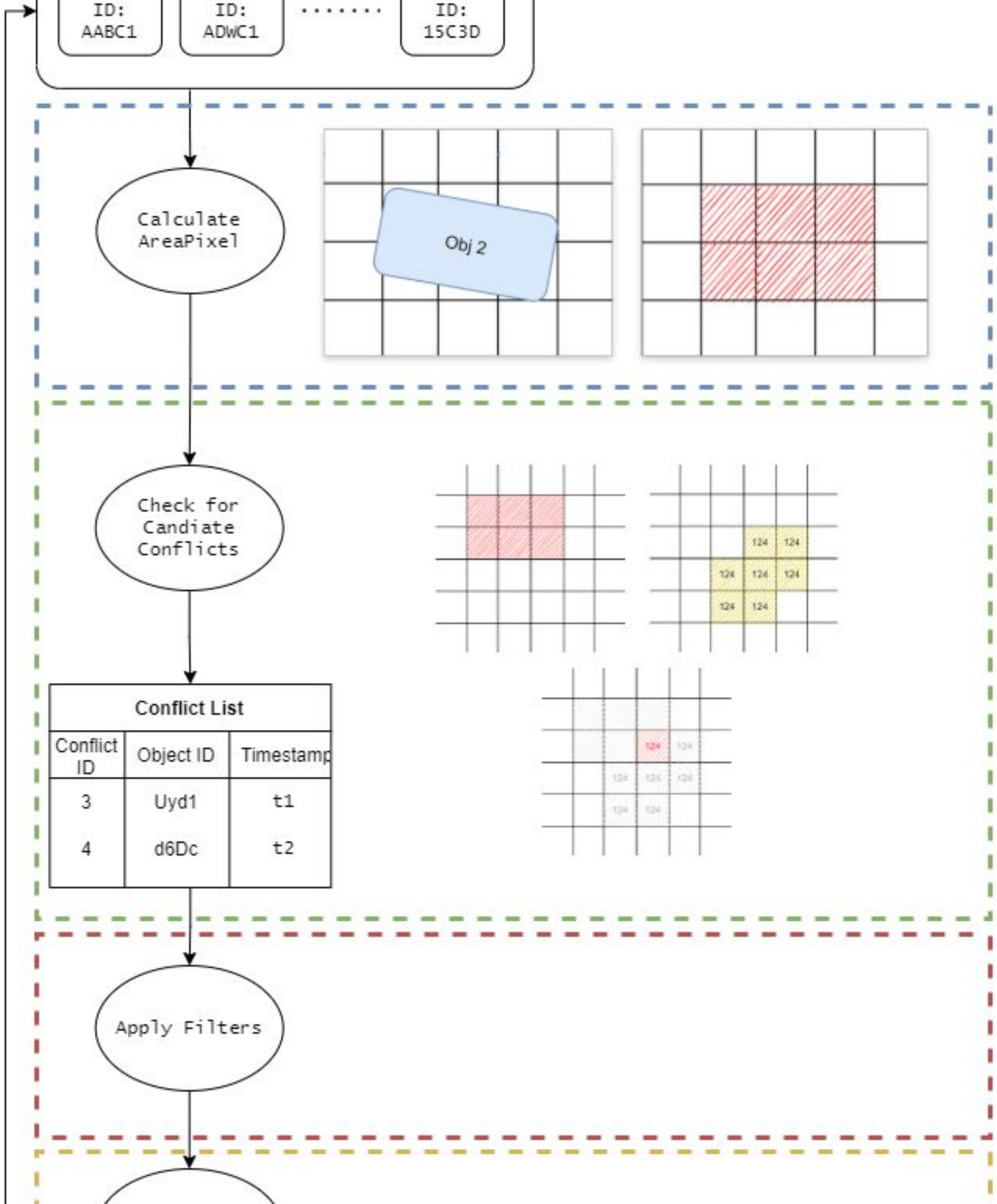



ID: AABC1
ID: ADWC1
....
ID: 15C3D
Calculate AreaPixel
Obj 2
Check for Candiate Conflicts
Conflict List
Conflict ID
Object ID
Timestamp
3
Uyd1
t1
4
d6Dc
t2
Apply Filters



ID: AABC1
ID: ADWC1
ID: 1SC3D
Calculate AreaPixel
Obj 2
124
124
124
124
124
124
124
Conflict List
Conflict ID
Object ID
3
Uyd1
4
d6Dc
124
124
124
124
124
124
124
Apply Filters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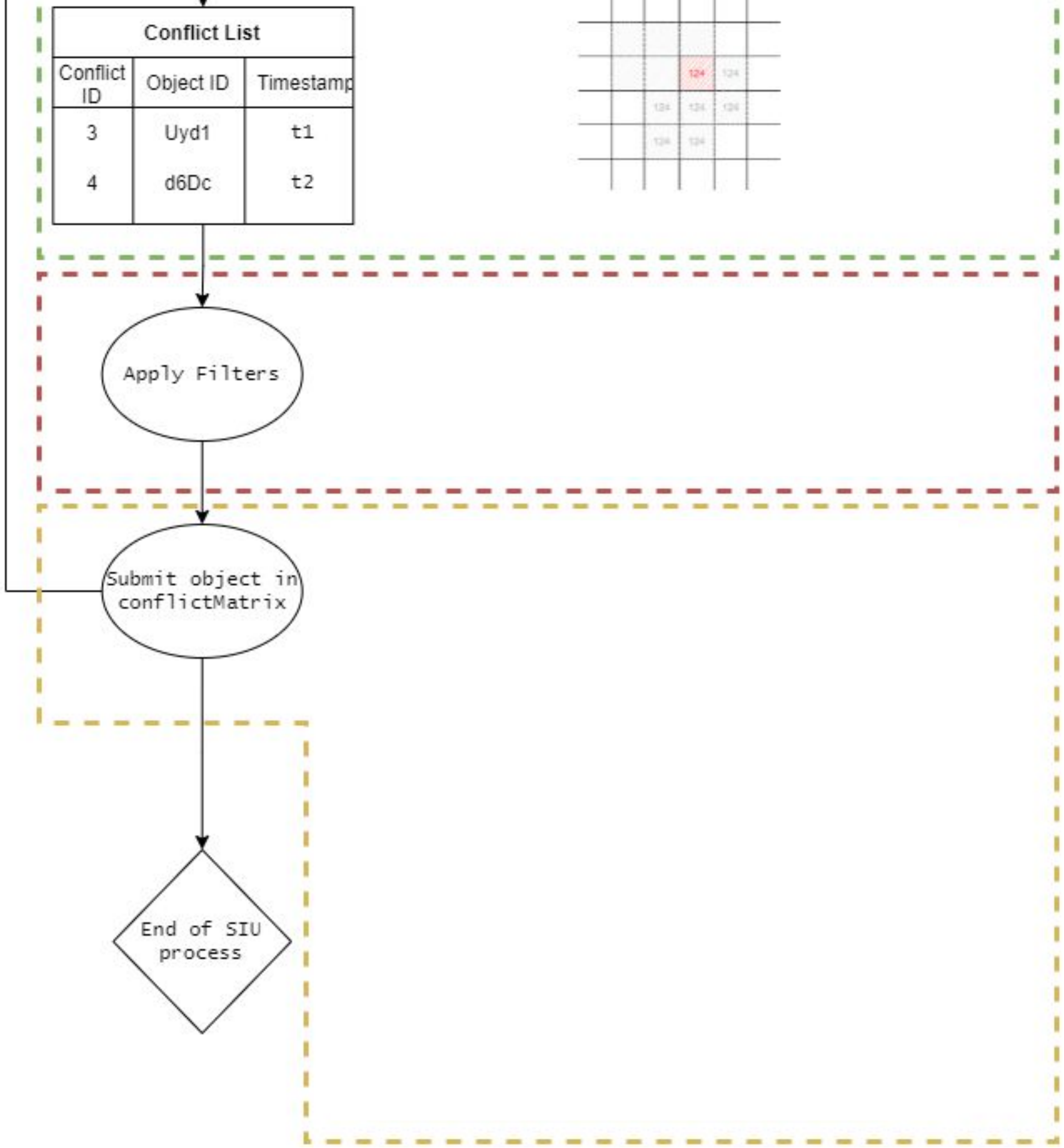
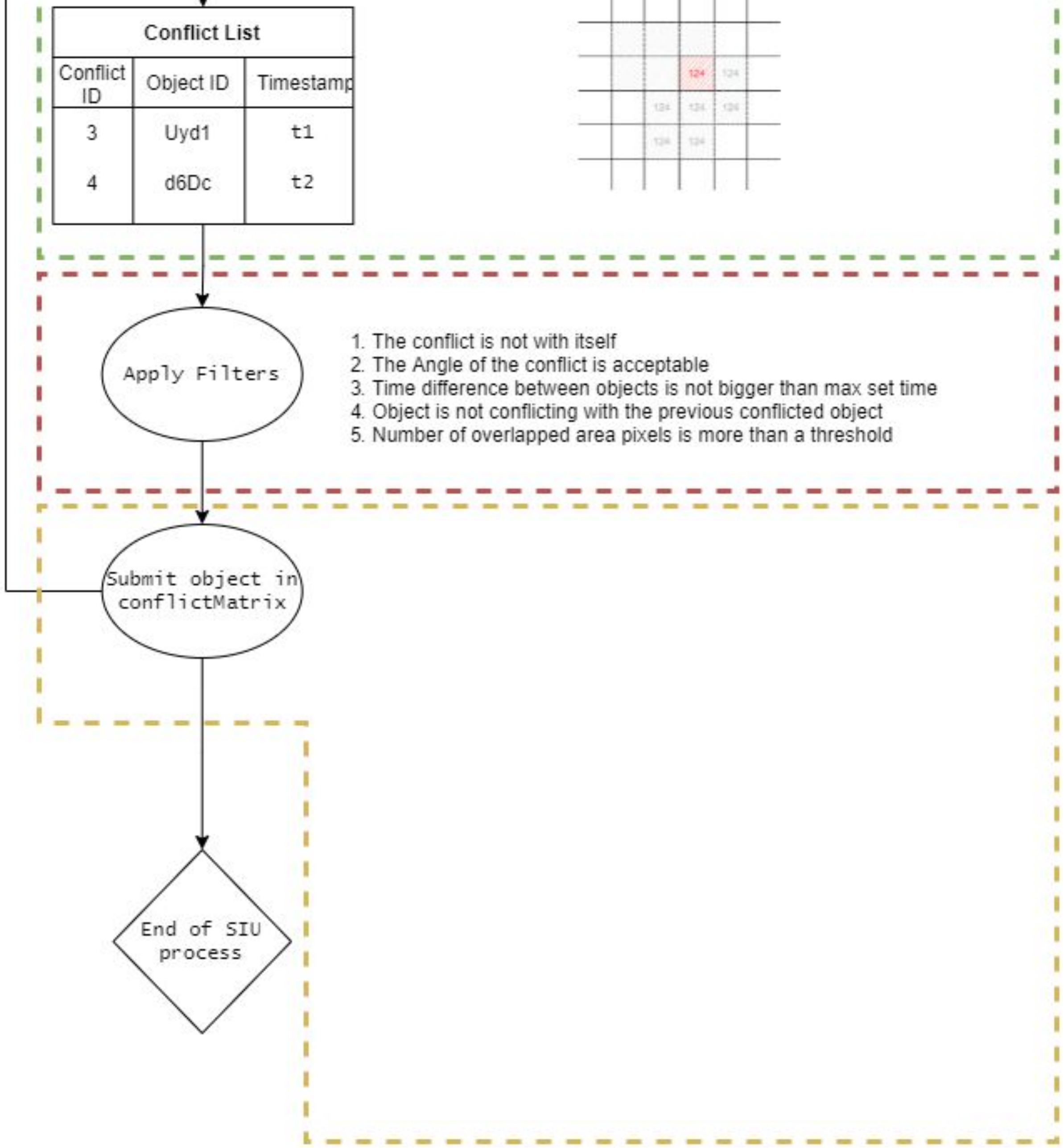
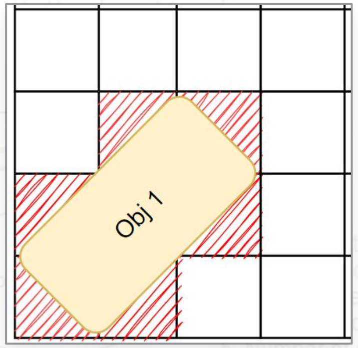
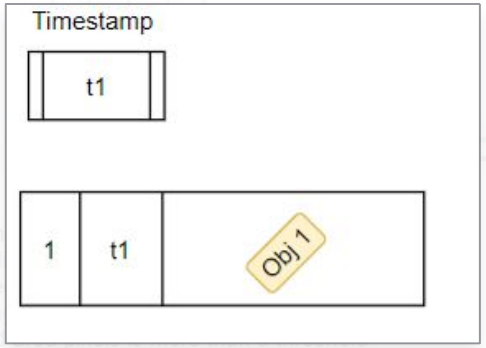

Conflict List
Conflict ID
Object ID
Timestamp
3
Uyd1
t1
4
d6Dc
t2
Apply Filters
Submit object in conflictMatrix
End of SIU process

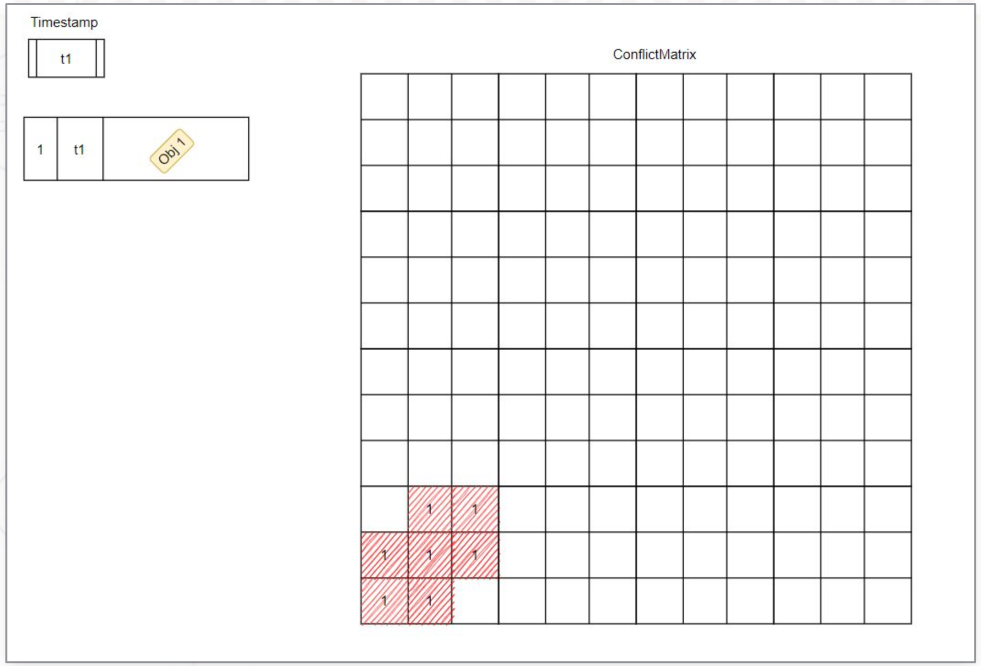


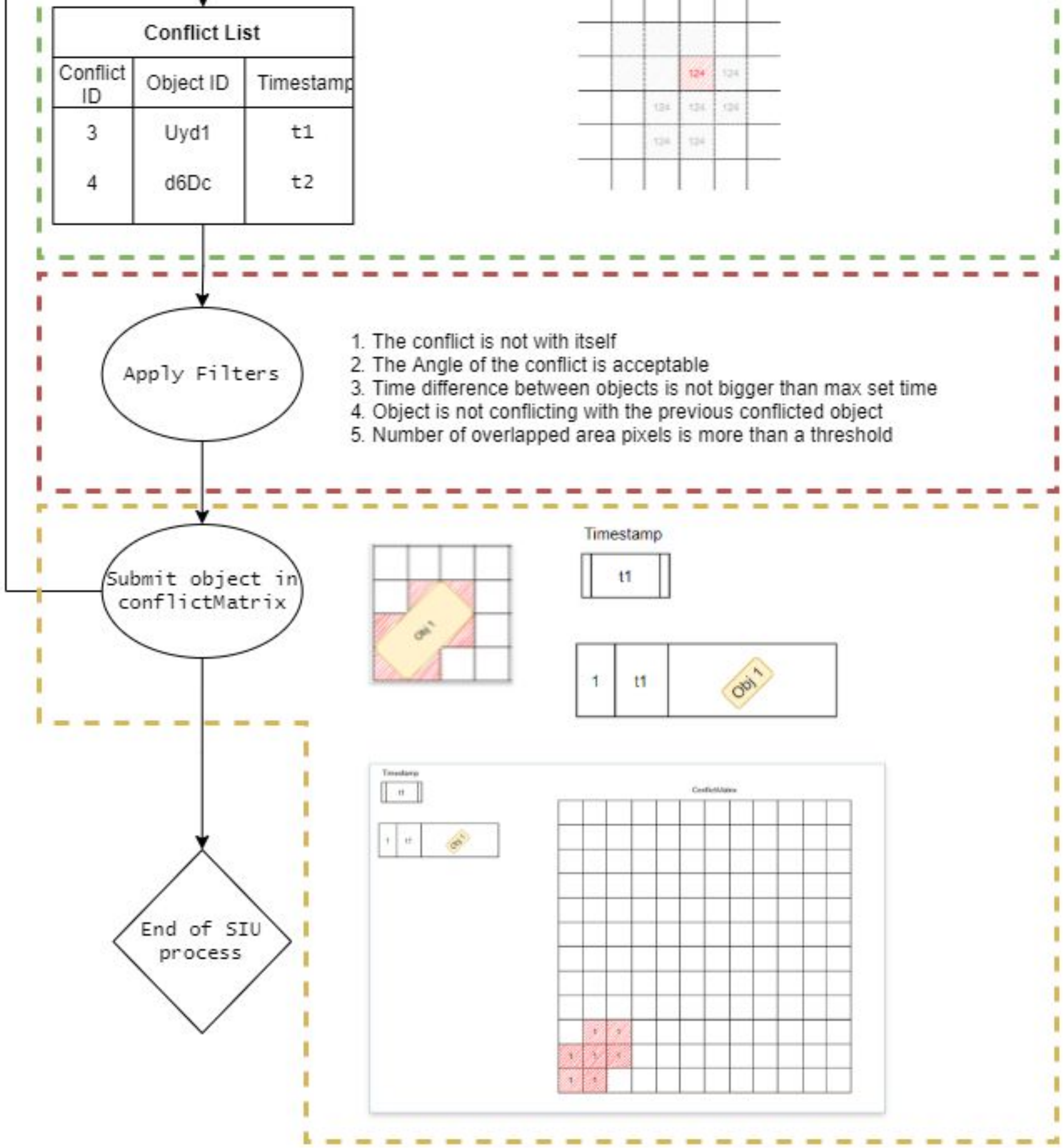
Conflict List

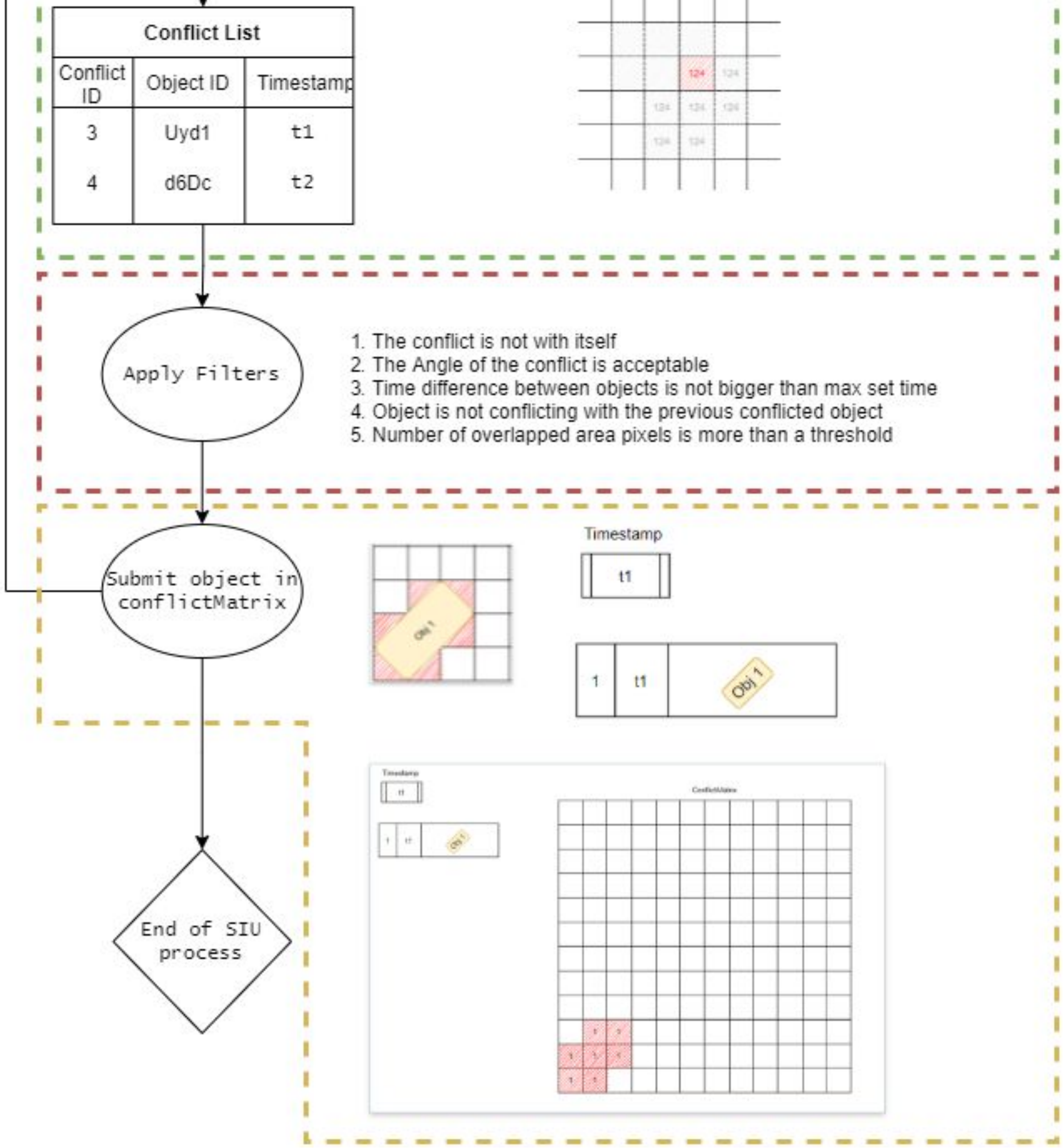
Conflict ID	Object ID	Timestamp
3	Uyd1	t1
4	d6Dc	t2


Obj 1


Timestamp
t1
1
t1
Obj 1


Timestamp
t1
1
t1
Obj 1
ConflictMatrix
1


Conflict List
Conflict ID
Object ID
Timestamp
3
Uyd1
t1
4
d6Dc
t2
Apply Filters
1. The conflict is not with itself
2. The Angle of the conflict is acceptable
3. Time difference between objects is not bigger than max set time
4. Object is not conflicting with the previous conflicted object
5. Number of overlapped area pixels is more than a threshold
Submit object in conflictMatrix
Timestamp
t1
1
t1
Obj 1
End of SIU process


Conflict List
Conflict ID
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Uyd1
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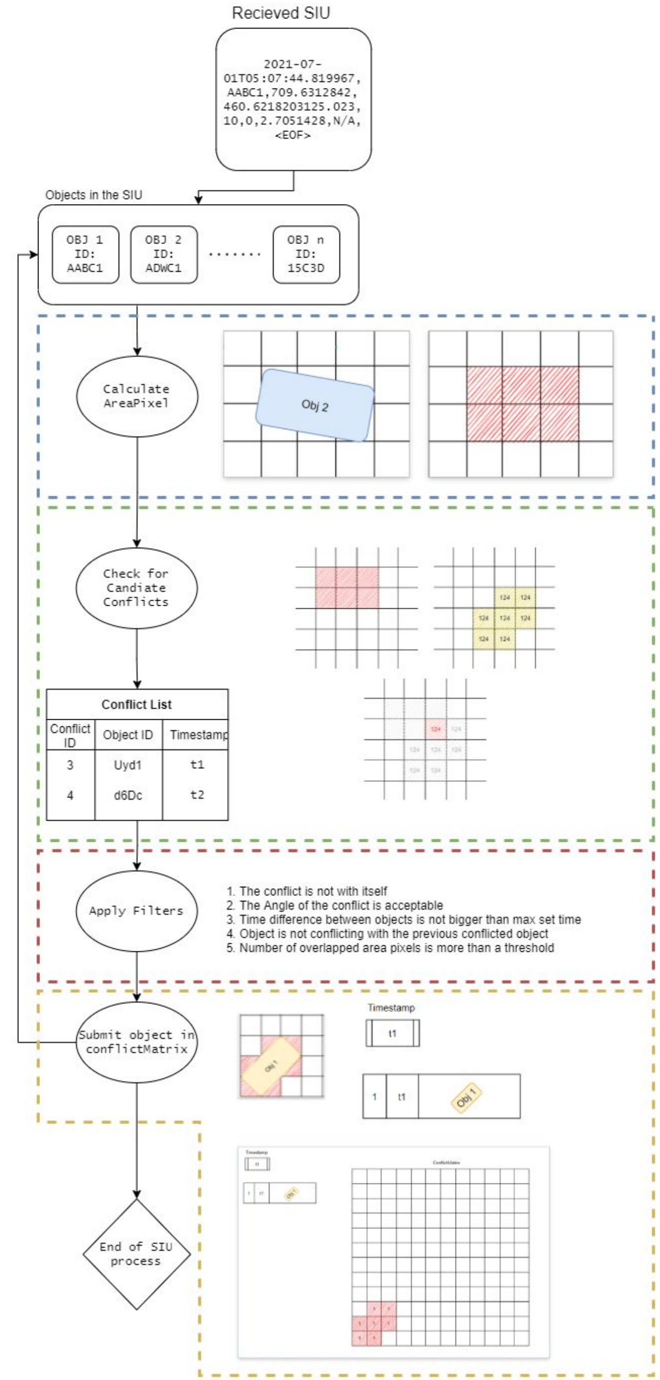
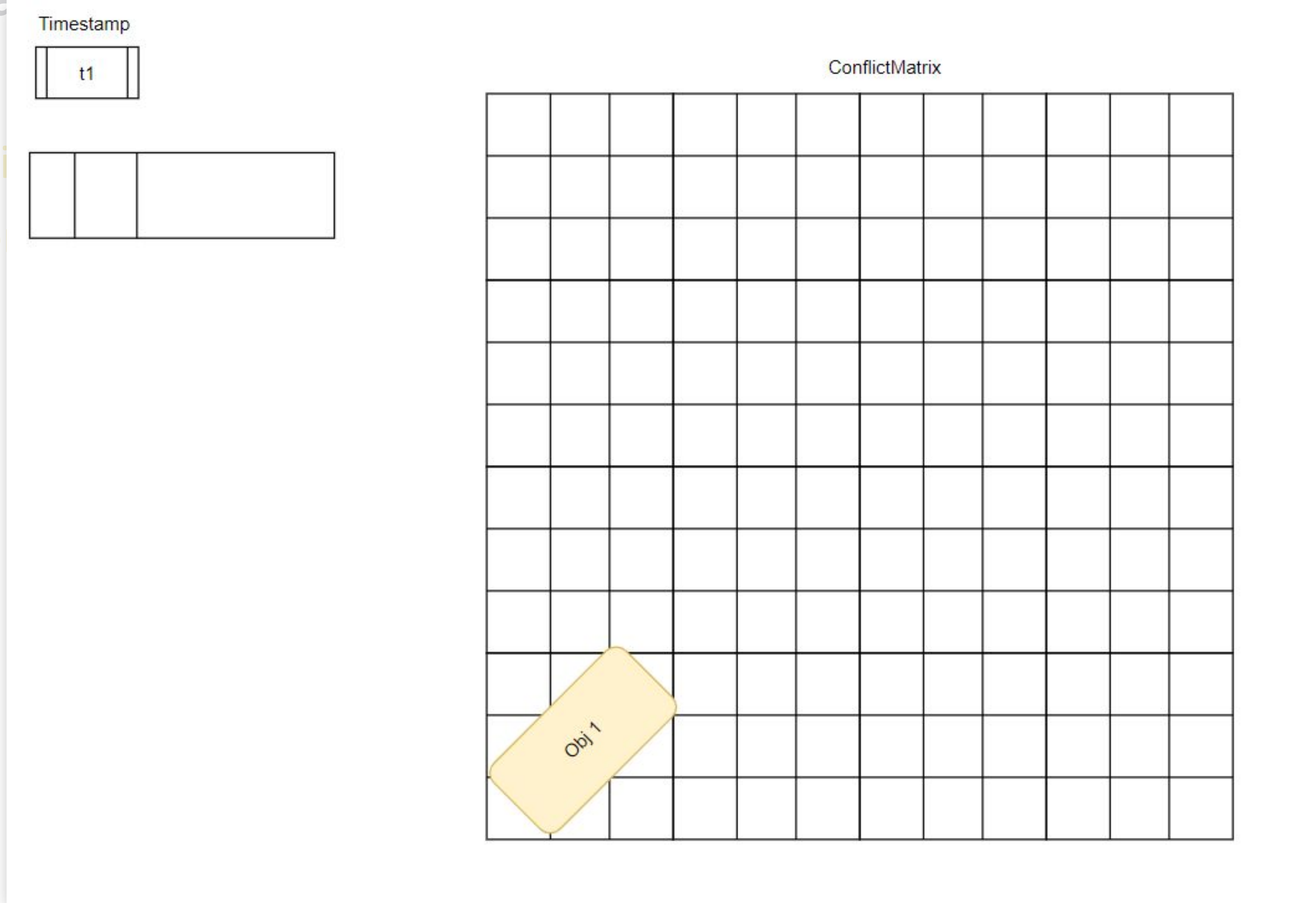
Submit object in conflictMatrix
Obj 1
Timestamp
t1
1
t1
Obj 1
End of SIU process

PET: Detection and Calculation



Detection and Calculation: Calculate PET for each objects in the frame

- Use Confli
- Store info



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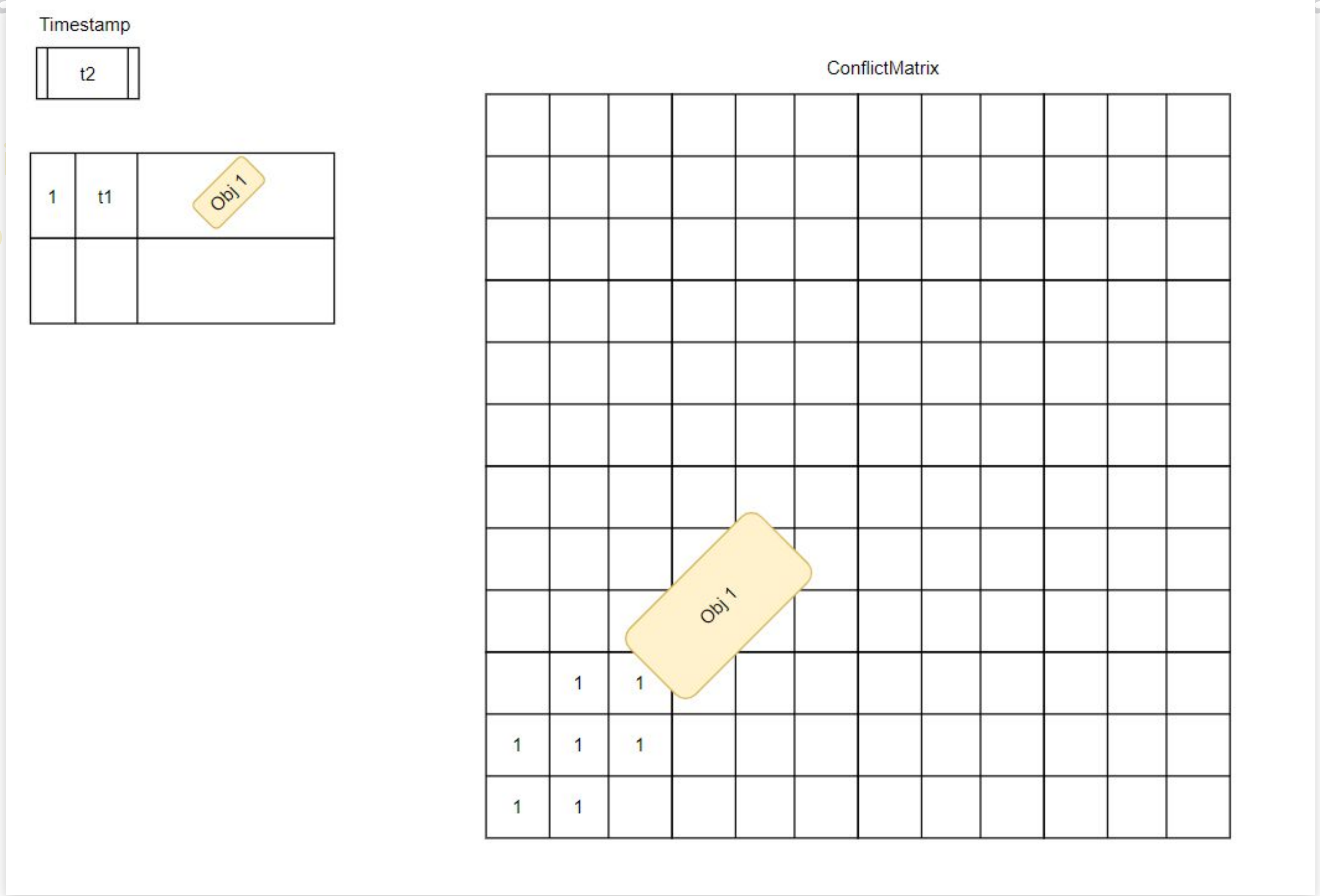

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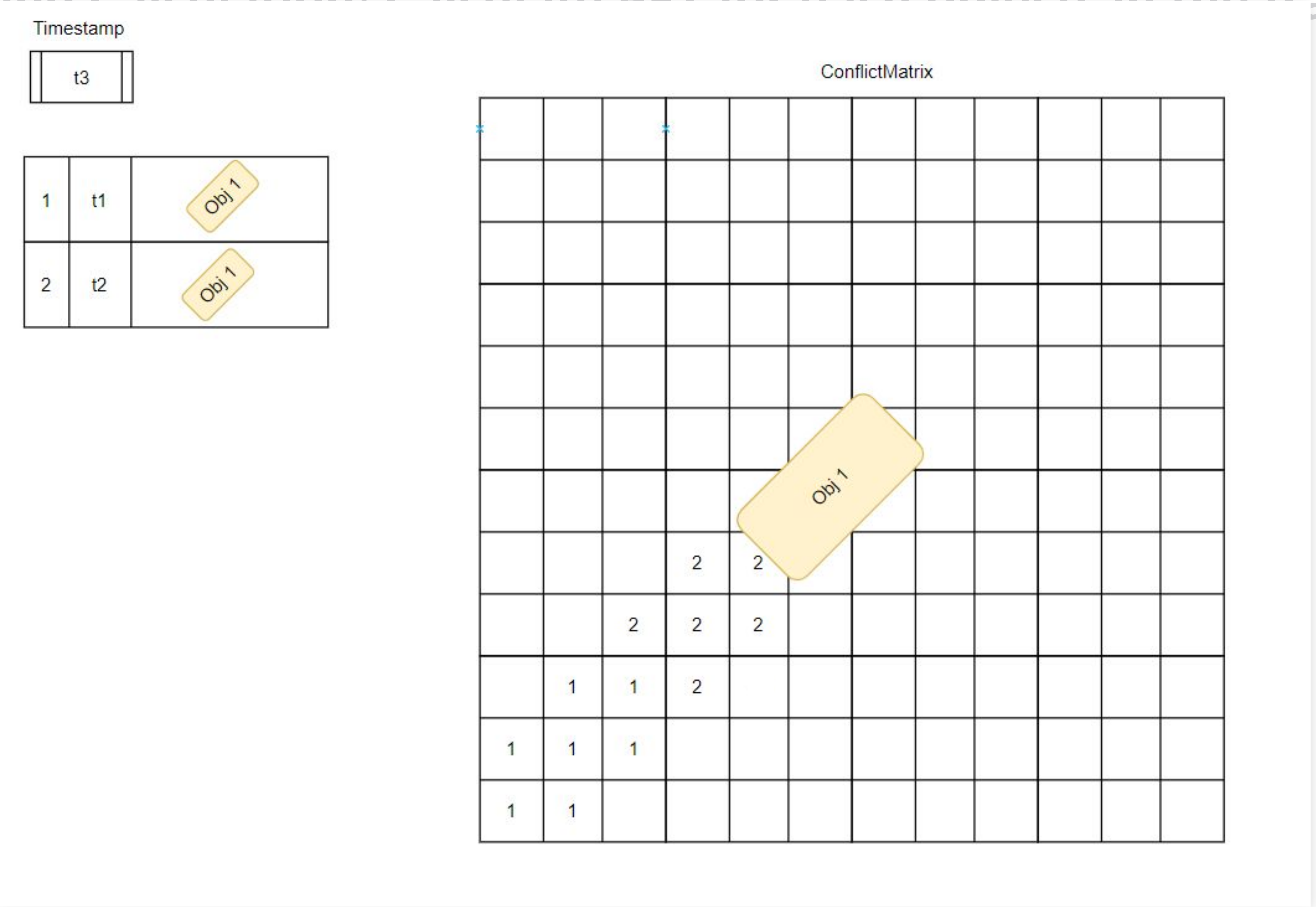

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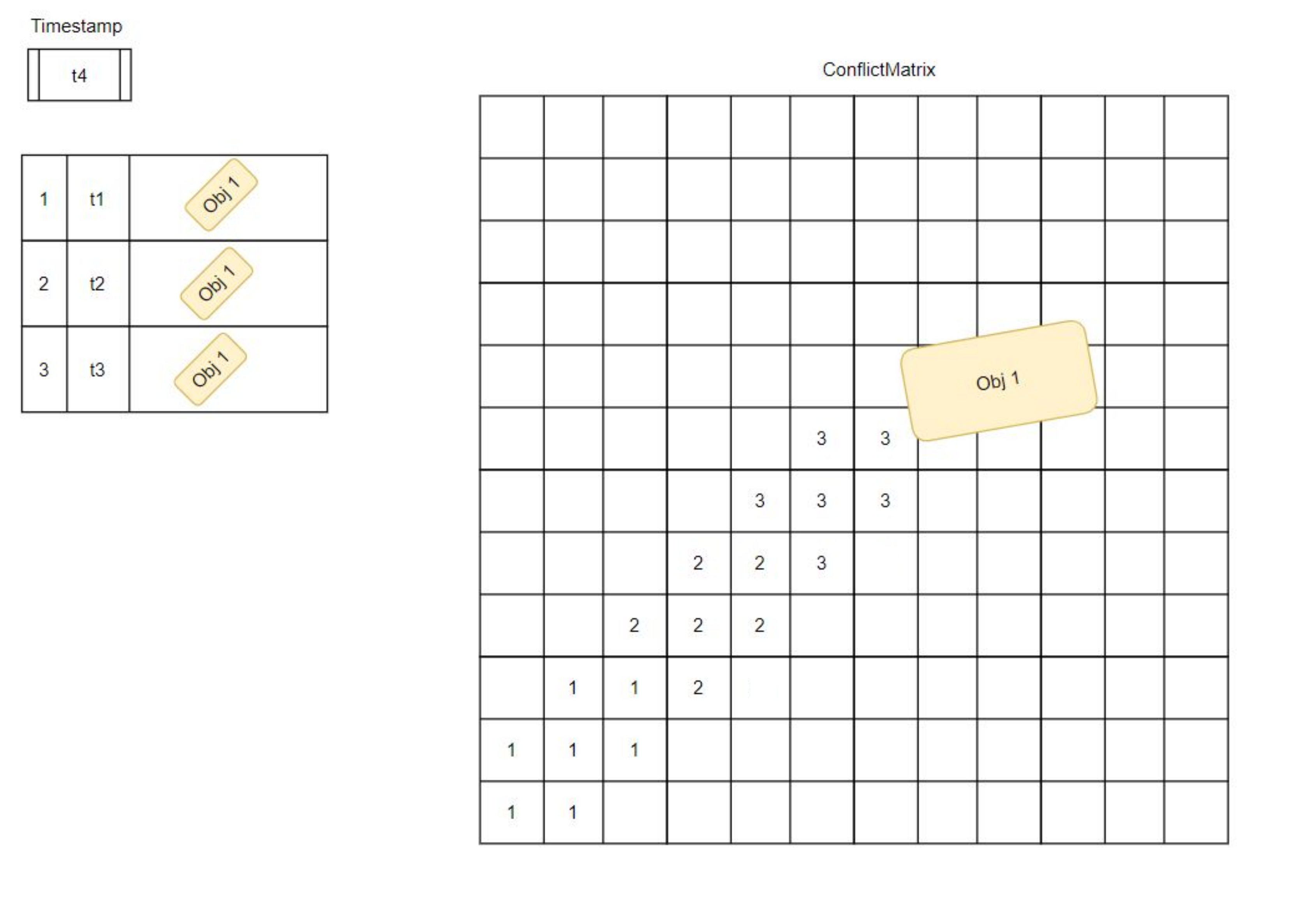

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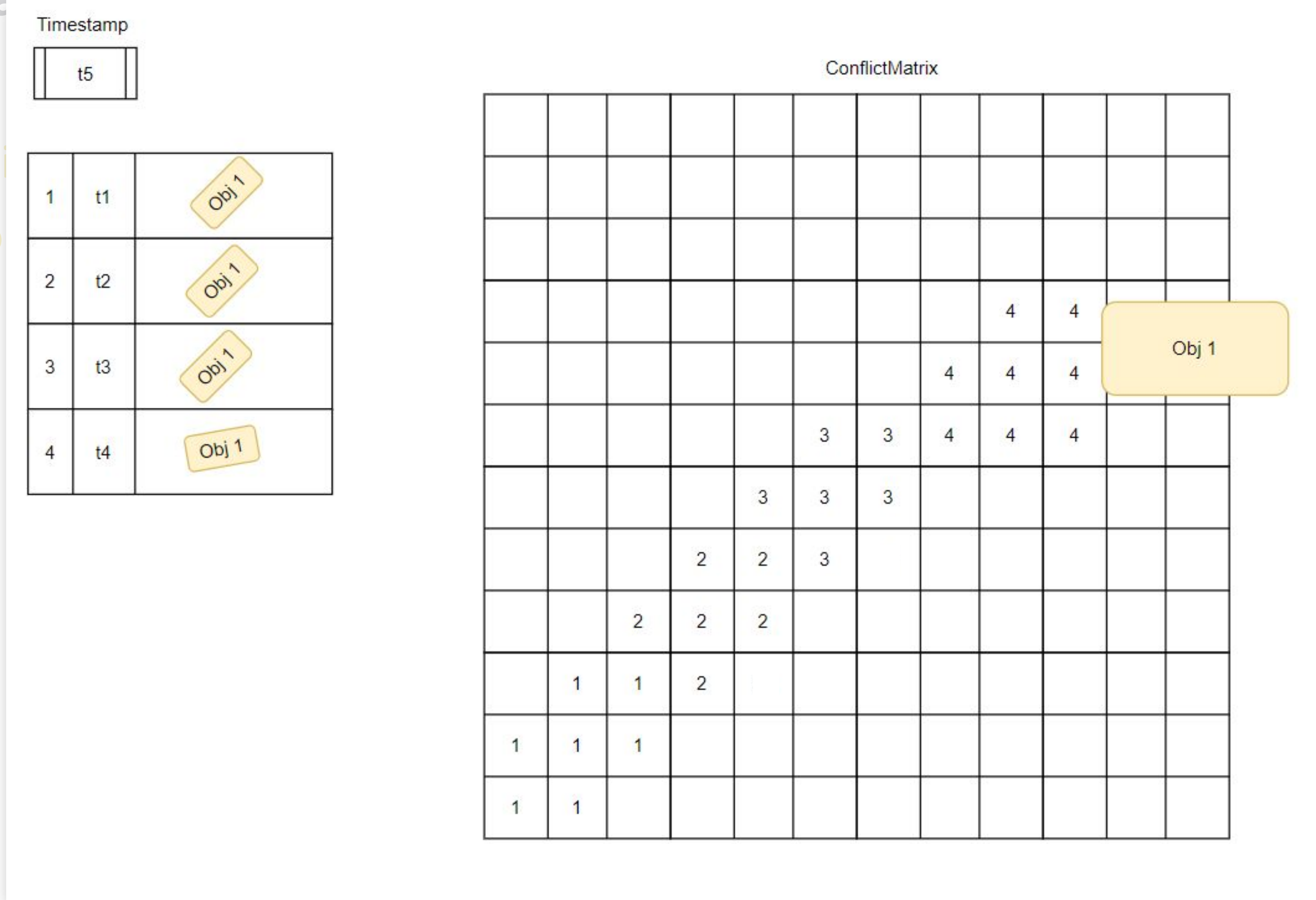

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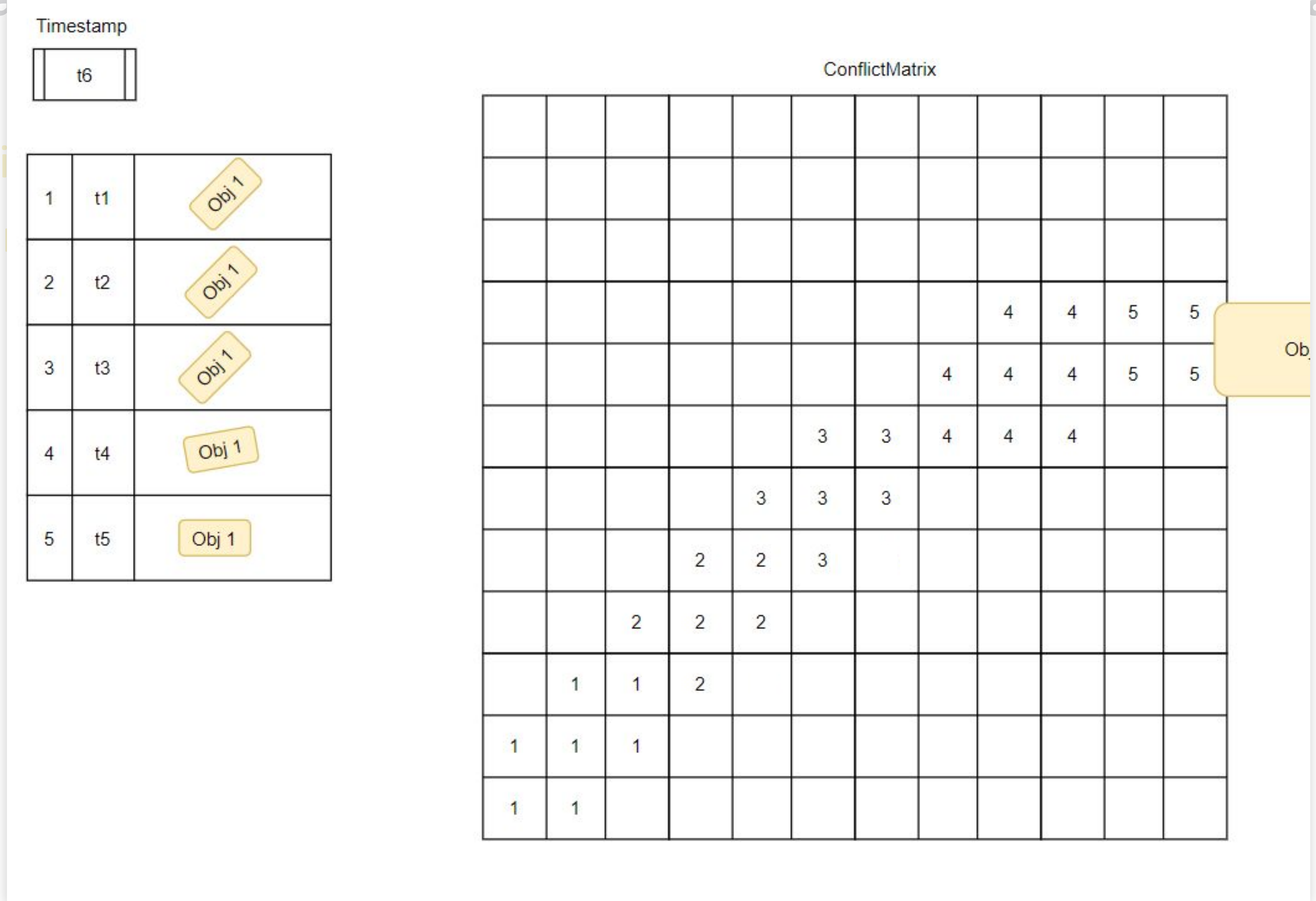

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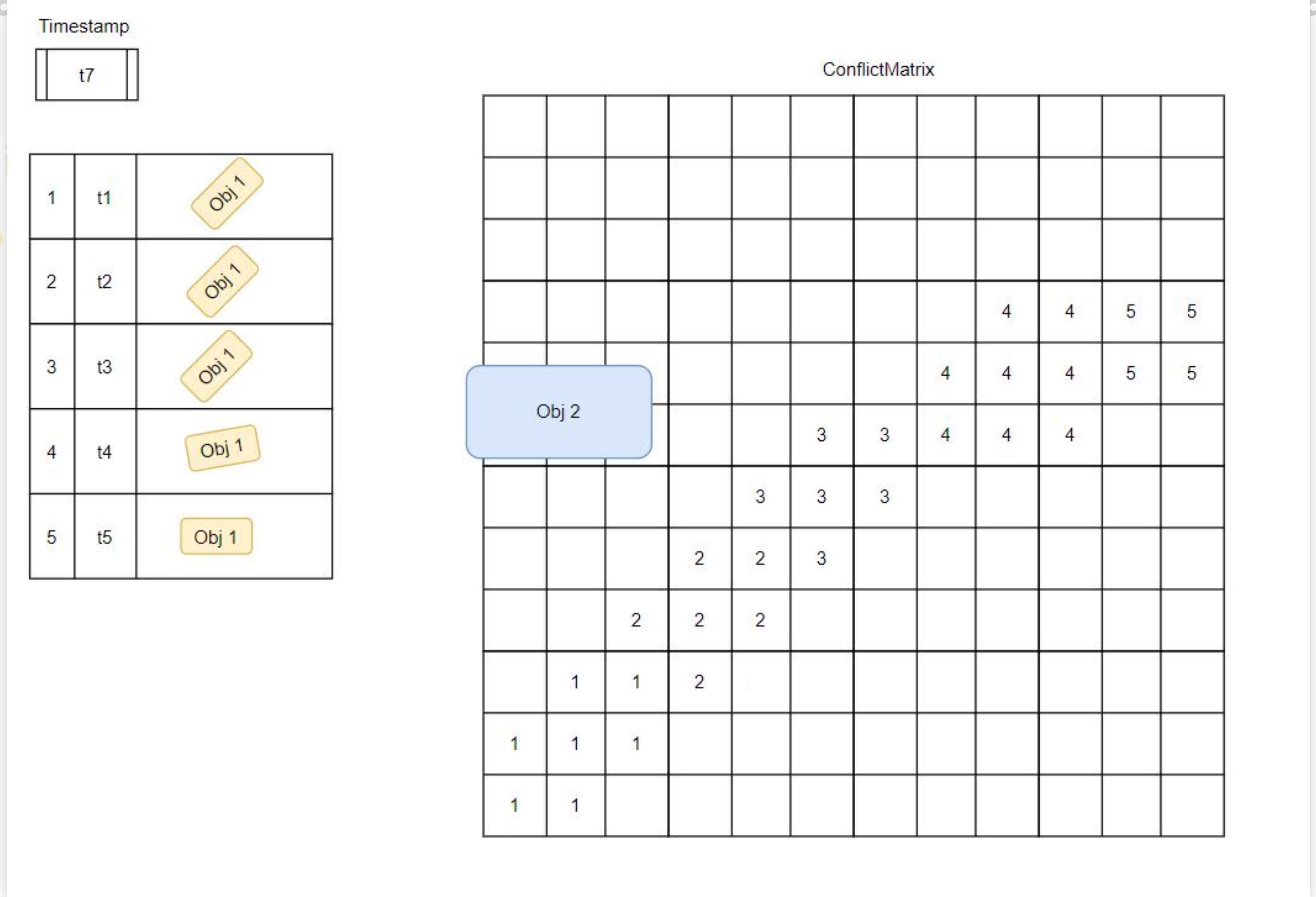

Detection and Calculation: Calculate PET for each objects in the frame

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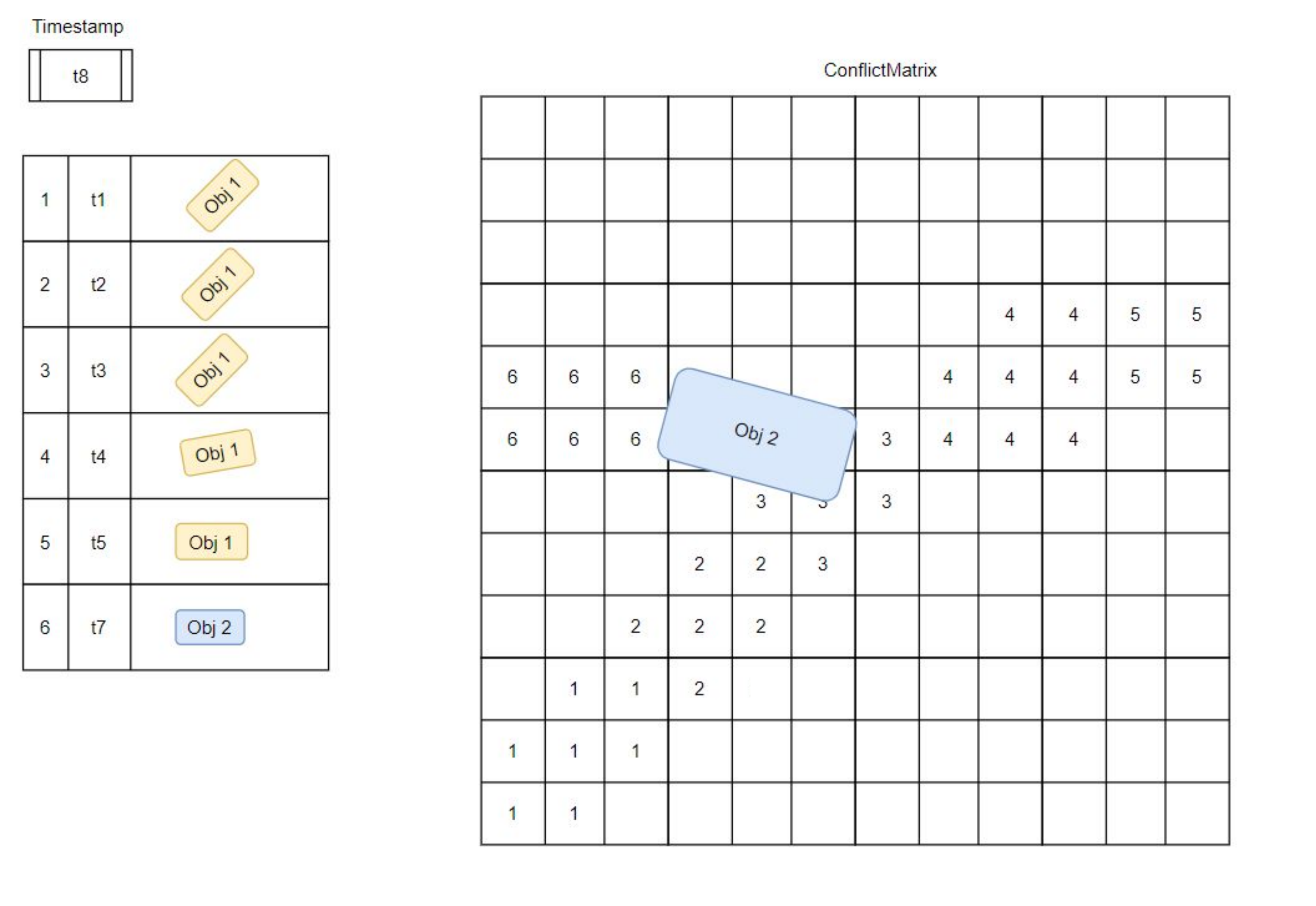

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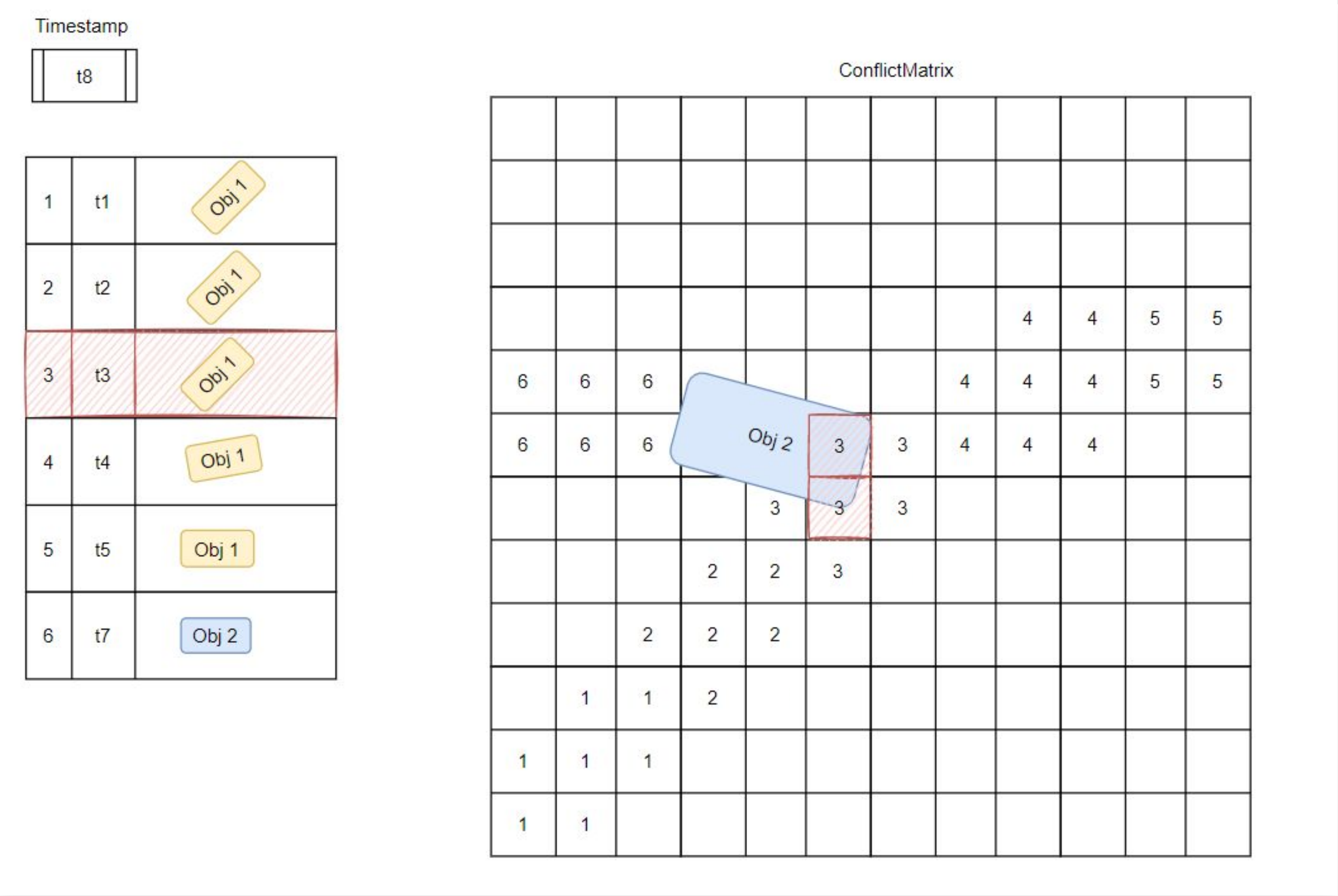

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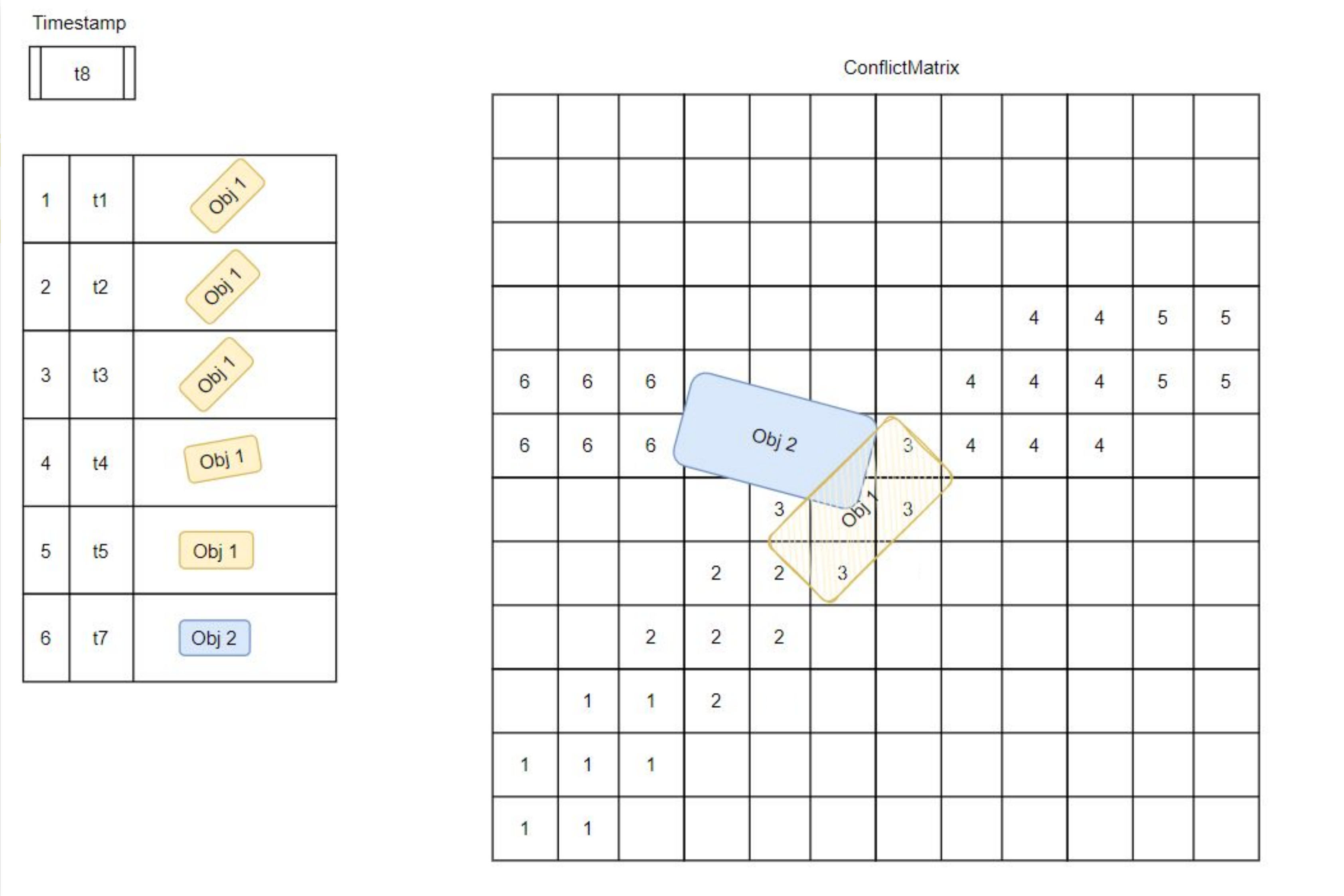

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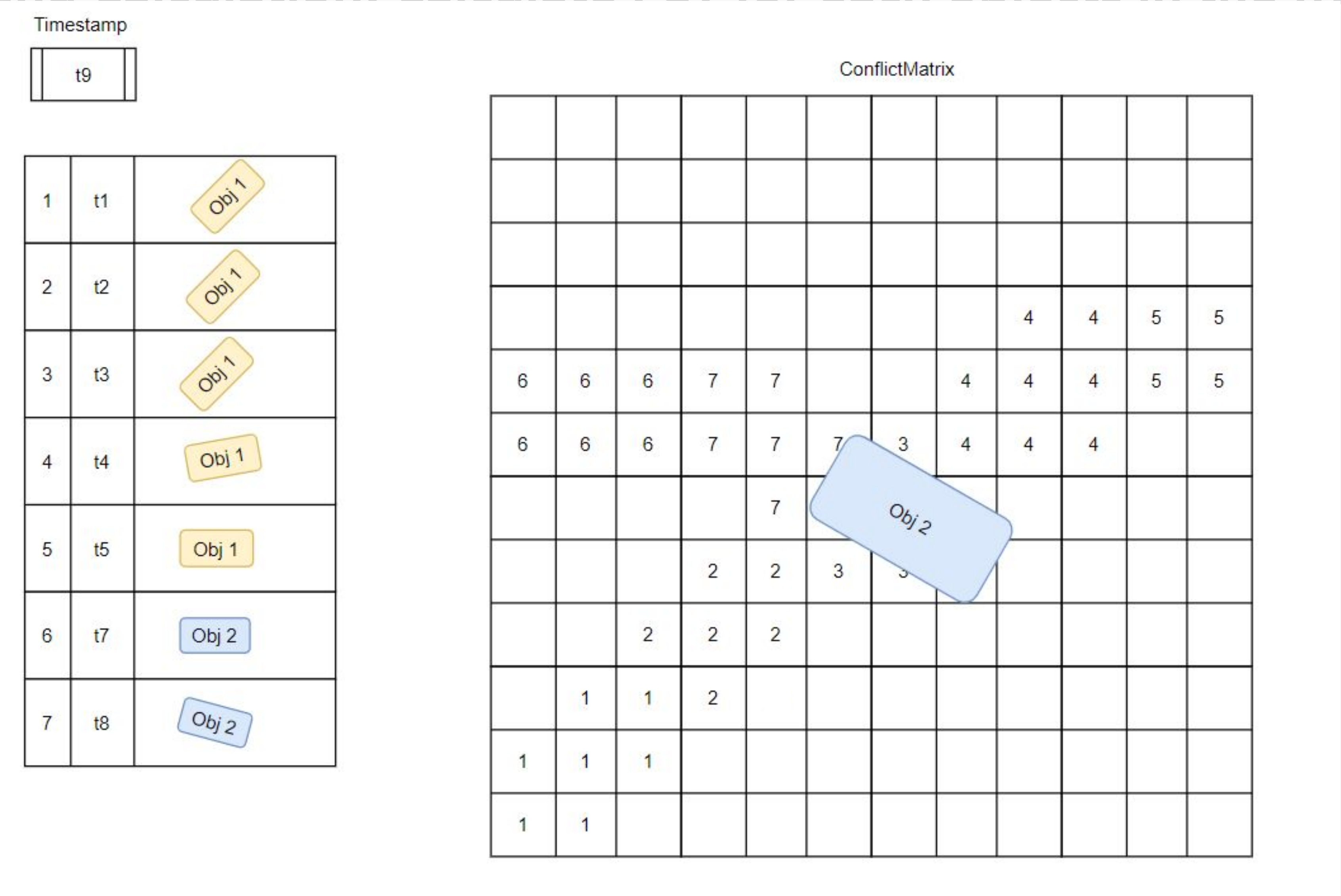

Detection and Calculation: Calculate PET for Each Objects in Frame

- Conflict candidates need to be validated by some filters:

Detection and Calculation: Calculate PET for Each Objects in Frame

- Conflict candidates need to be validated by some filters:
    1. The conflict is not with itself

Detection and Calculation: Calculate PET for Each Objects in Frame

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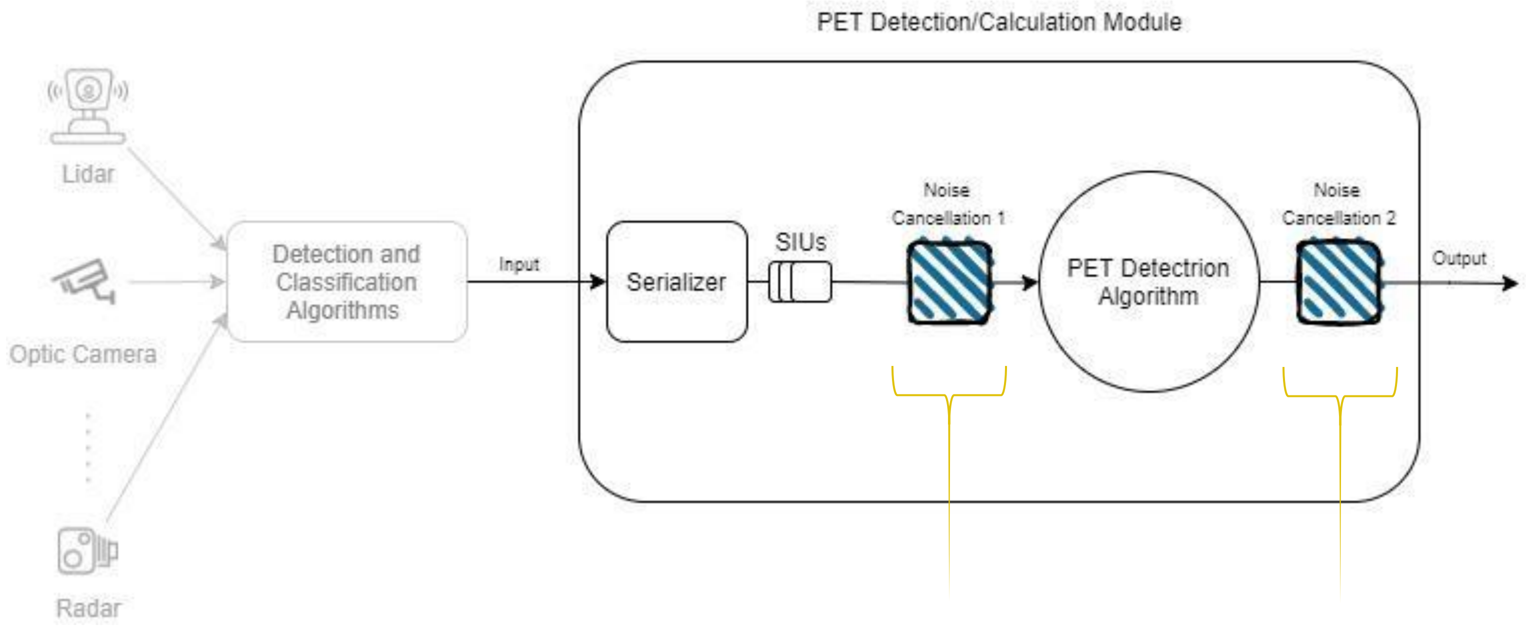
  3. Time difference between objects is not bigger than max set time
  4. Object is not conflicting with the previous conflicted object
  5. Number of overlapped area pixels is more than a threshold (will be discussed later)

PET: Noise Cancellation

1. Decoupled
2. Realtime/Continuous
3. Precise
4. Generalized
5. Easy to use
6. Fault tolerant



PET: Fault Tolerance

1. False positive detection of objects

PET: Fault Tolerance

1. Fa
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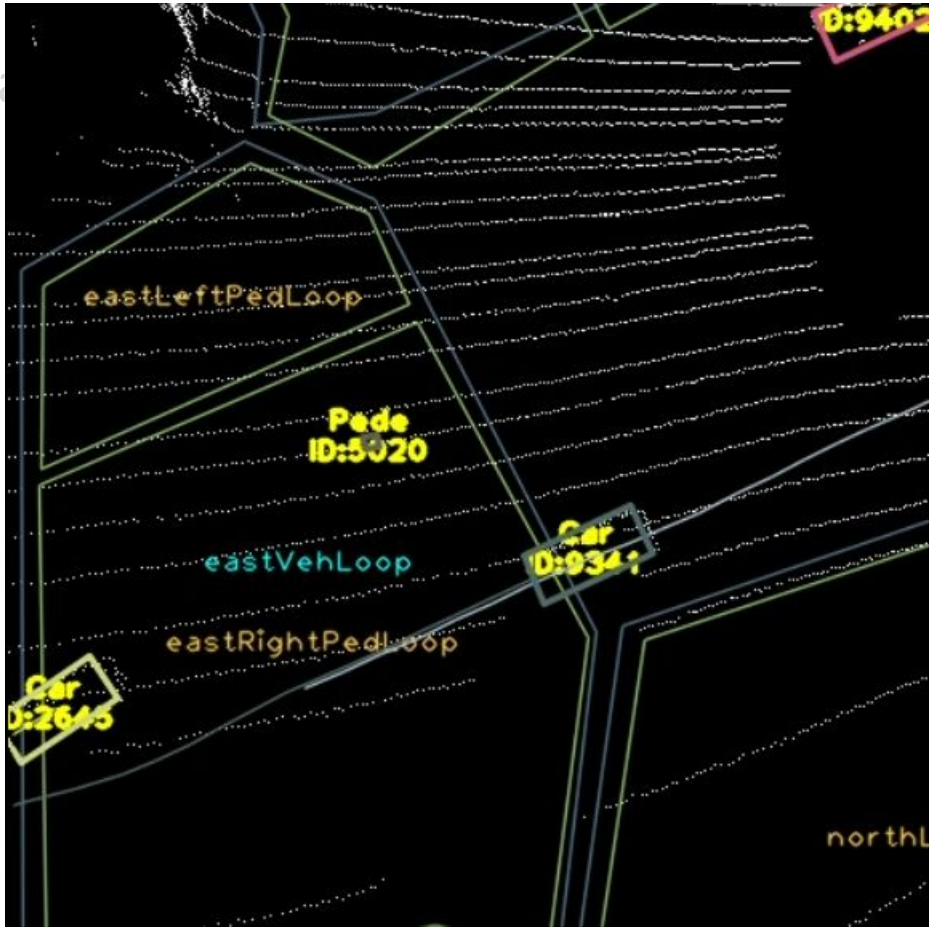

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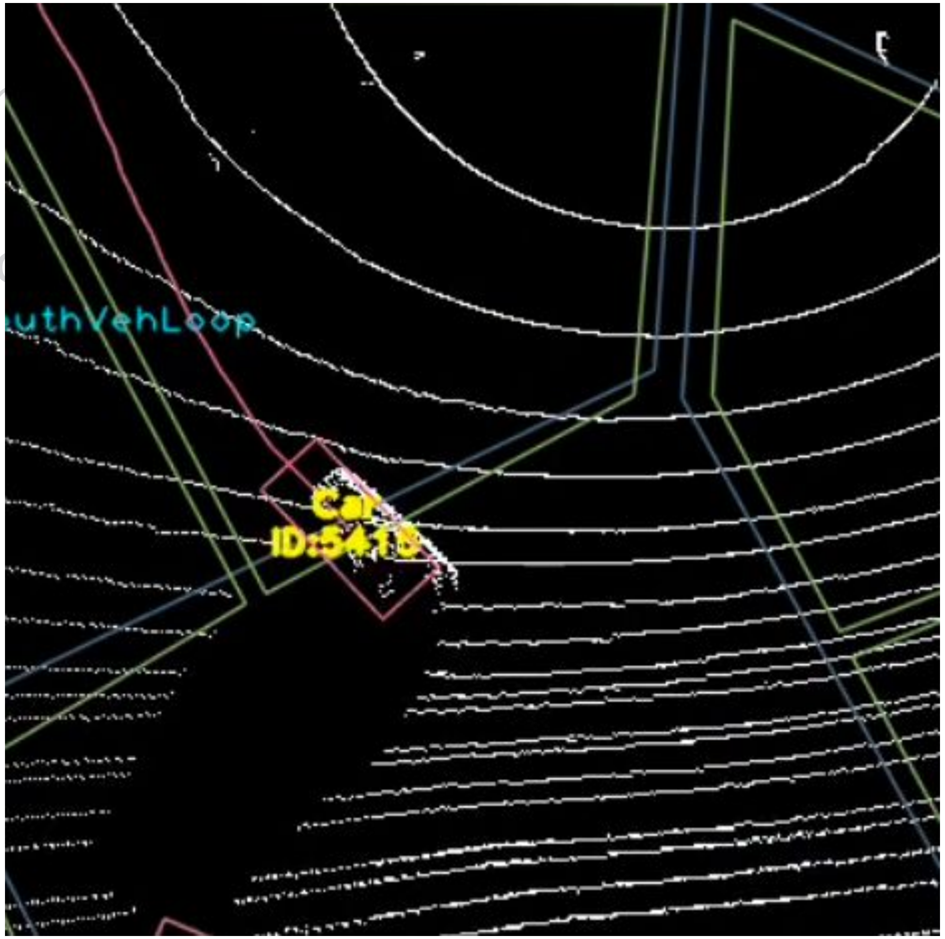

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Delayed SIUs

Validating Turning Movements

False positive detection of objects: Delayed SIUs

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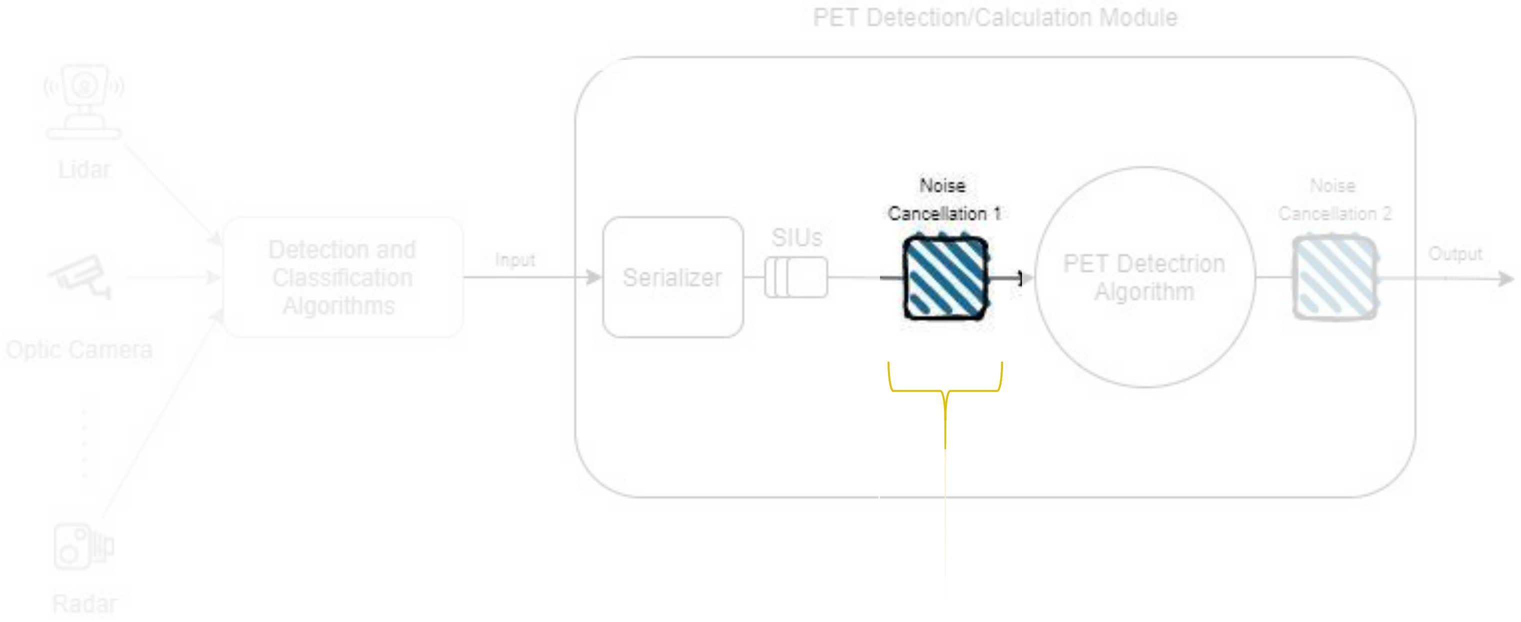

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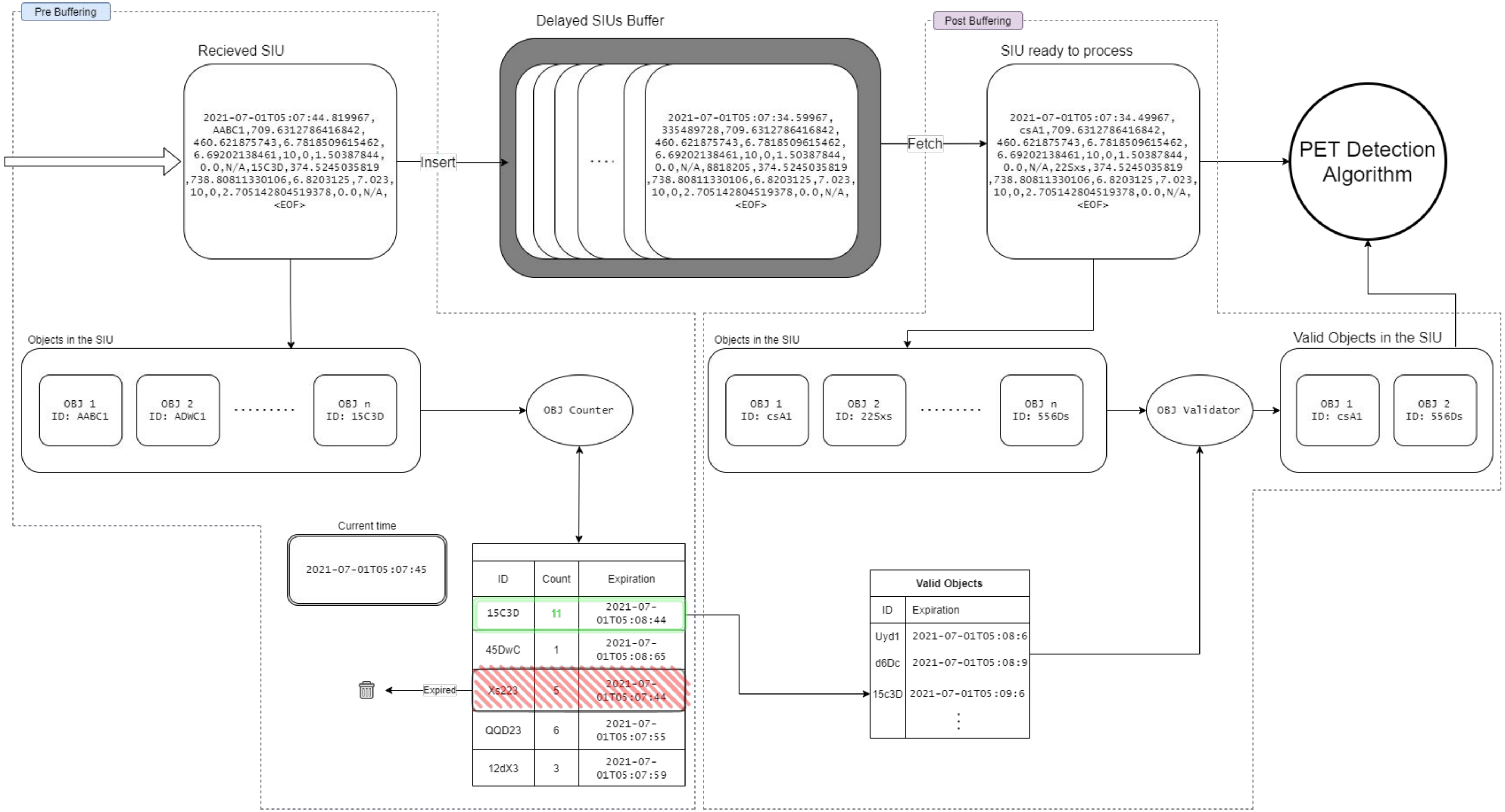

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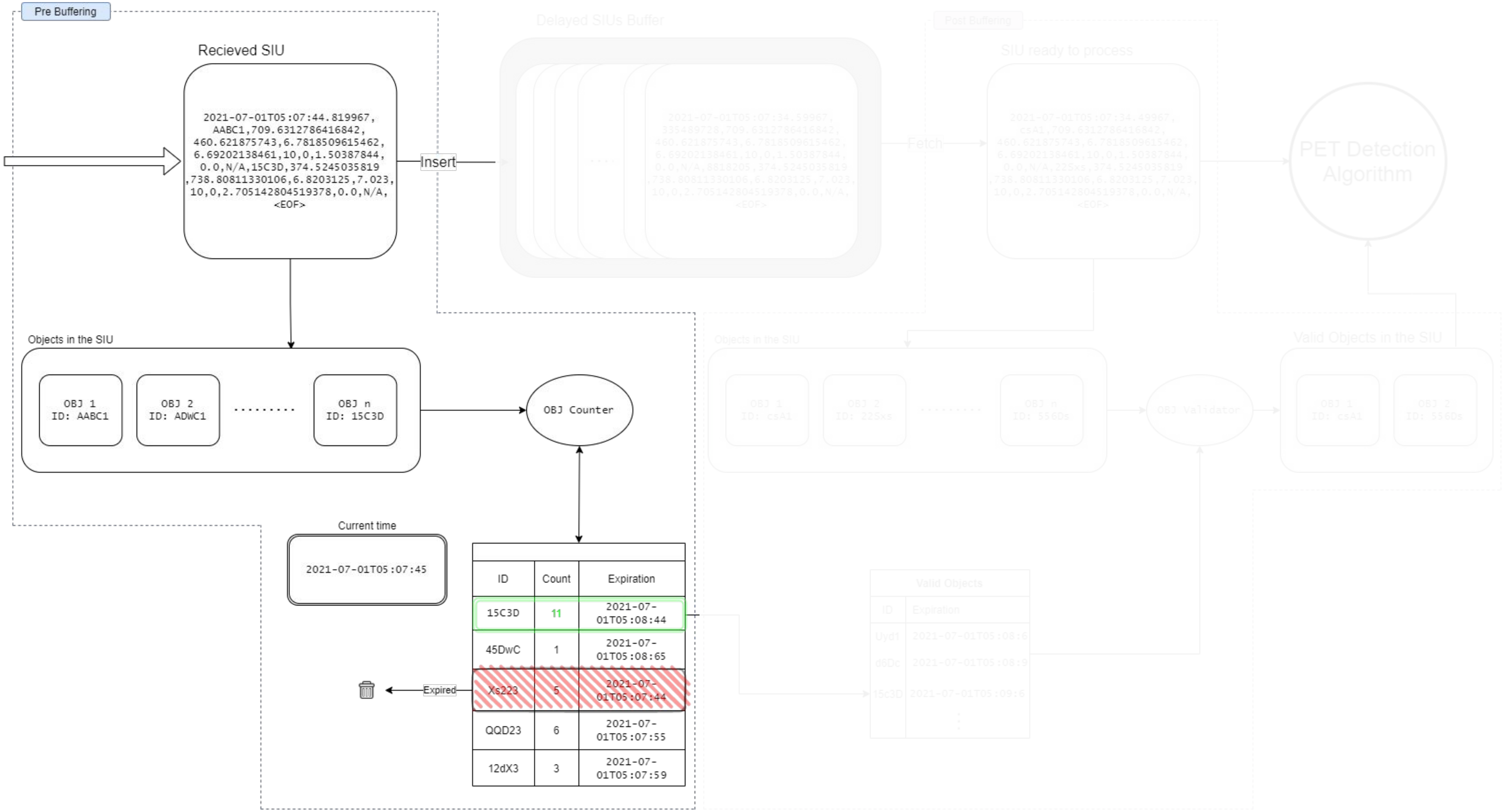

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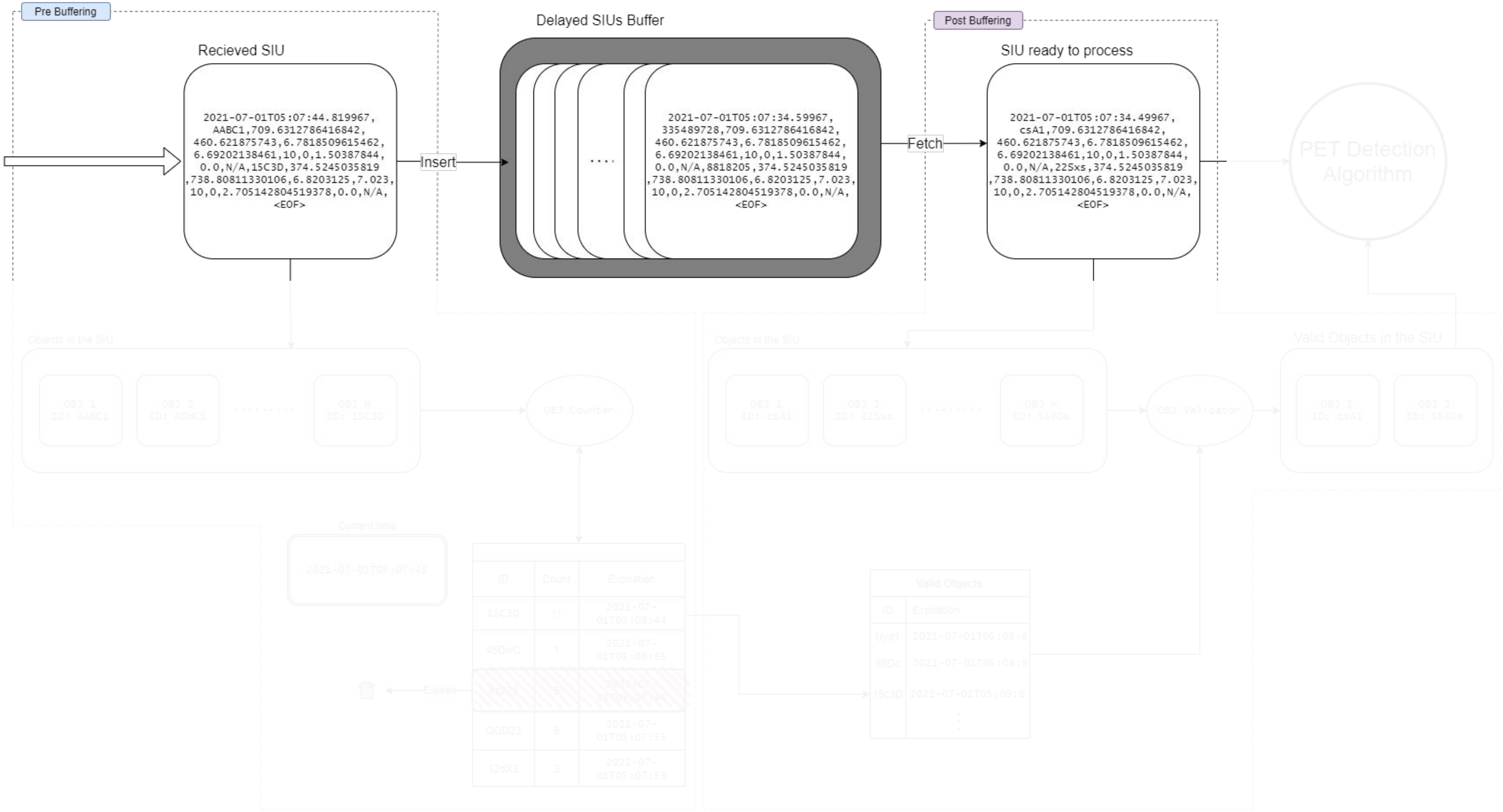

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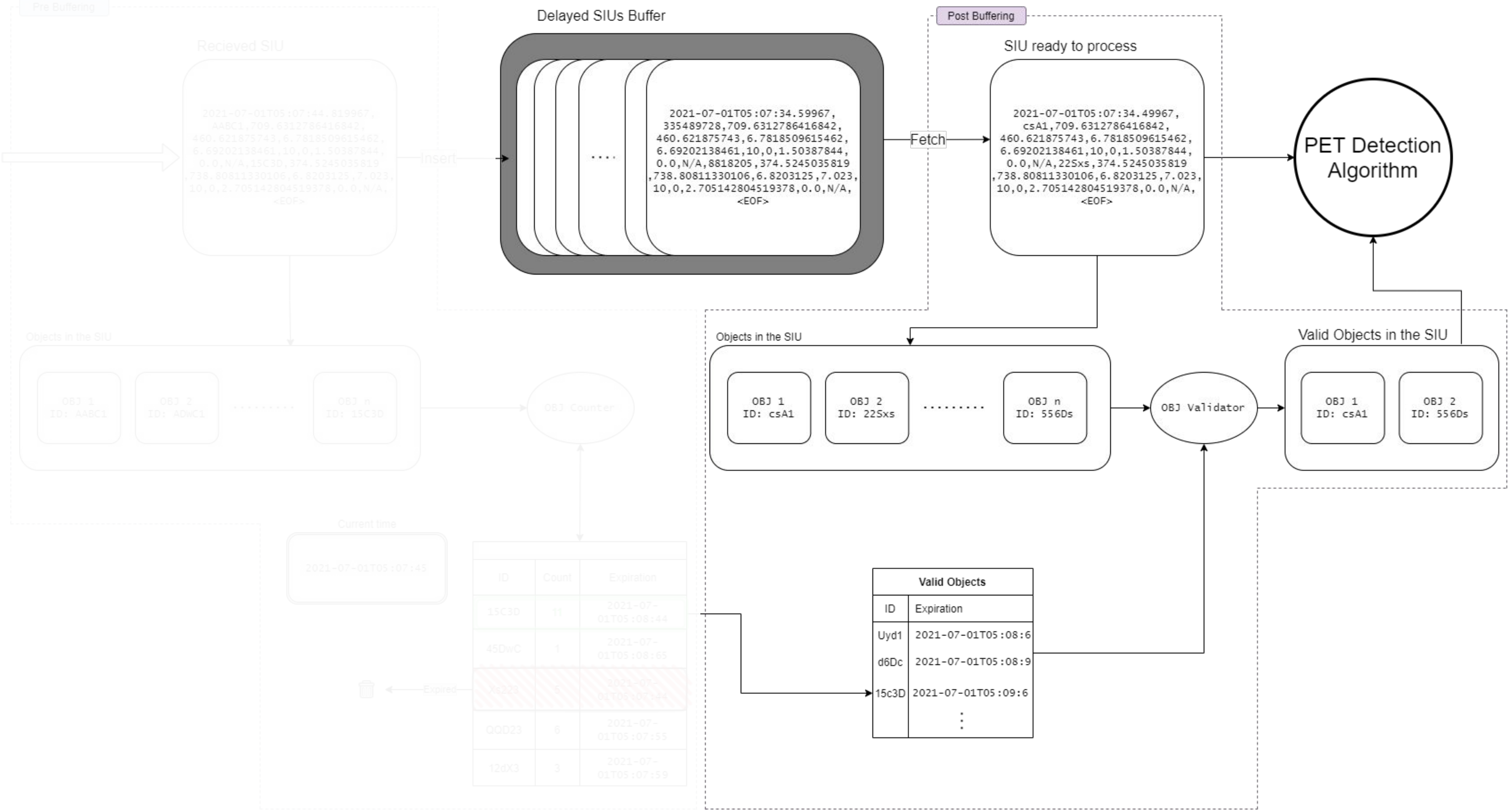

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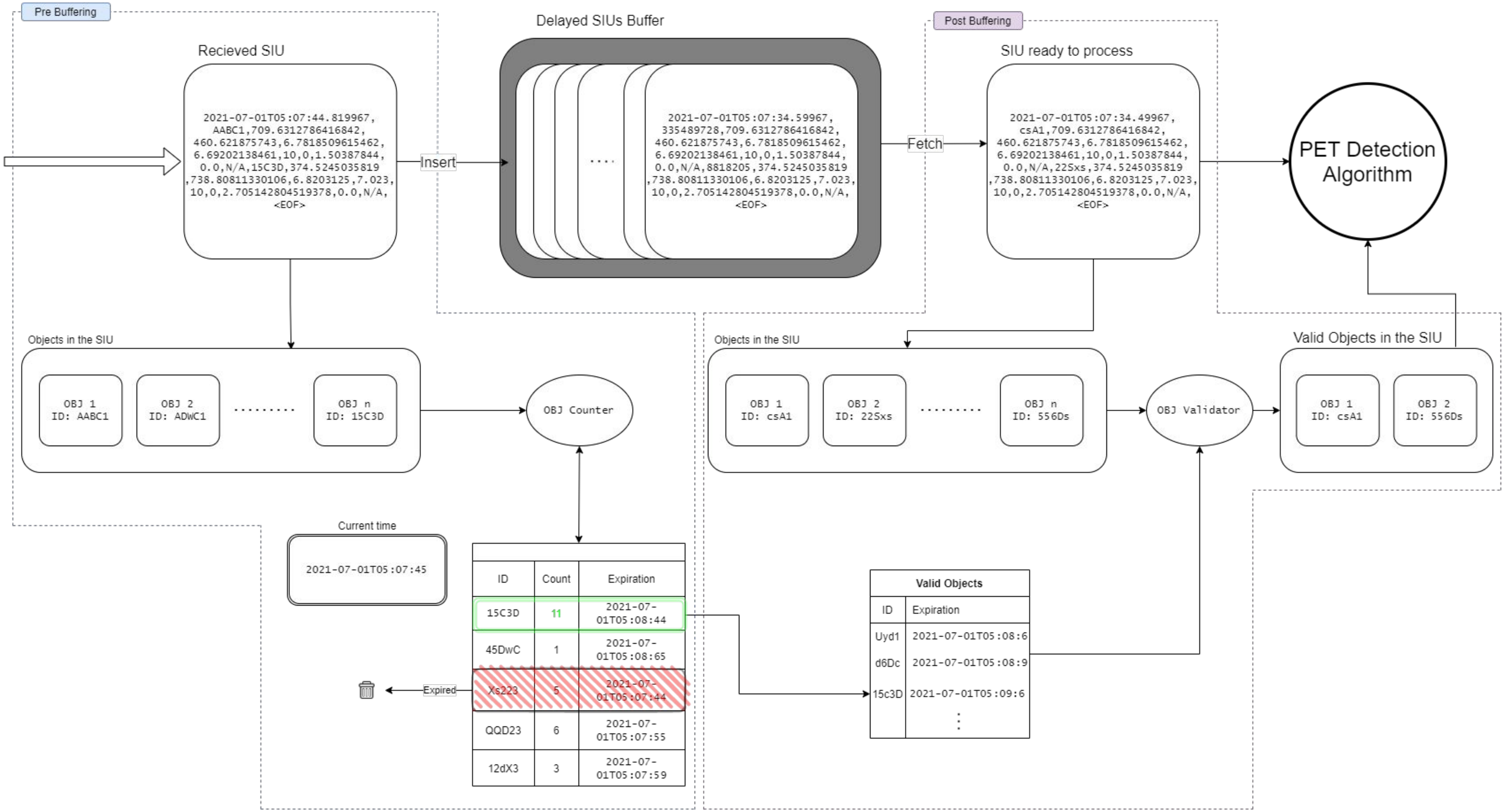


False positive detection of objects: Validating Turning Movements

1. False positive detection of objects
2. Inaccurate bounding boxes
3. Inaccurate object class type
4. False negative detection of objects

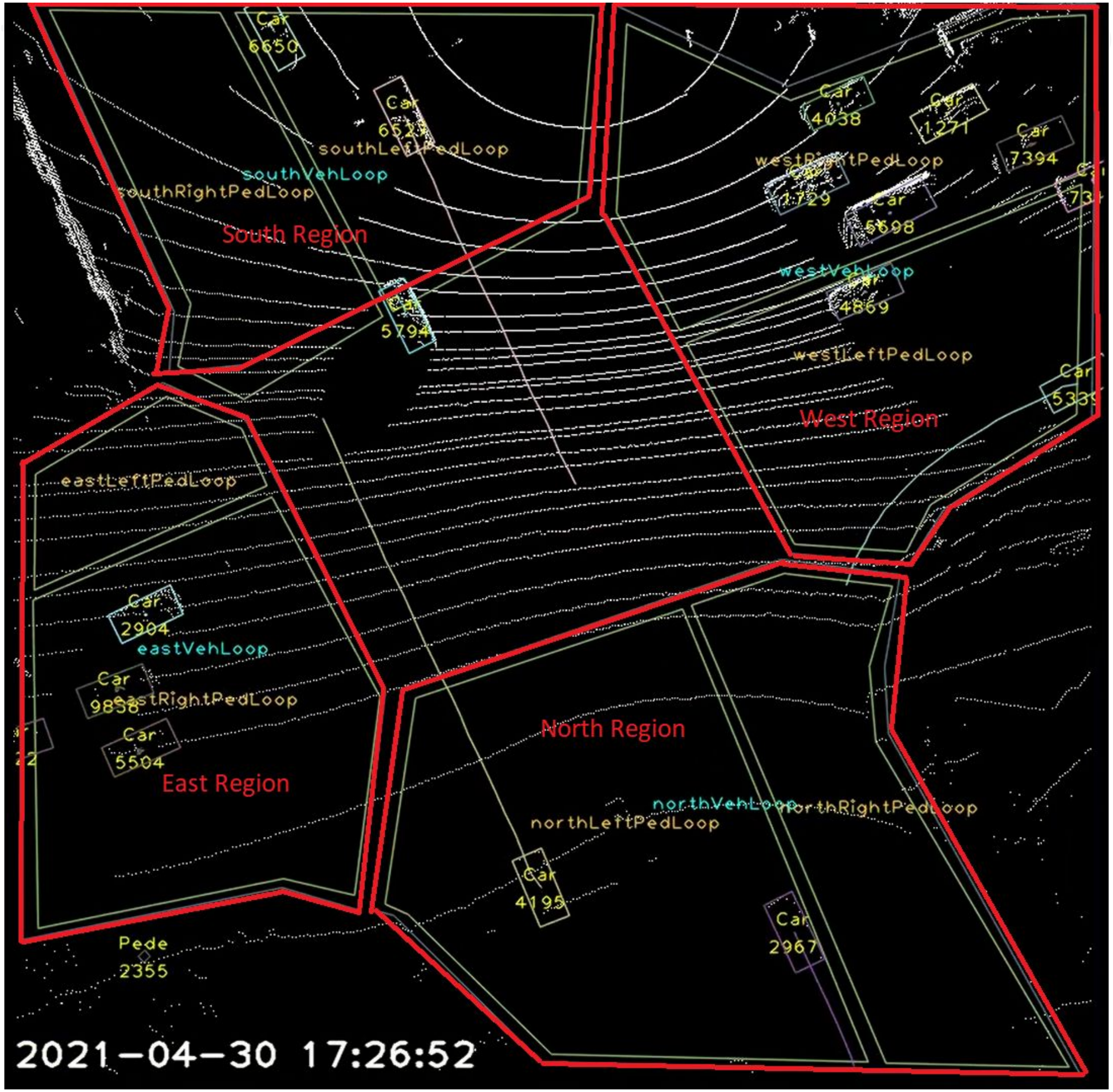
Delayed SIUs

Validating Turning Movements

False positive detection of objects: Validating Turning Movements

- Different approach and sits after the PET detection module
- Filters out the invalid turning movements
- It effects the Realtime process, however, does not change the continuity of the module
- Needs to define each region on the calibration stage of the sensors

False positive de vements



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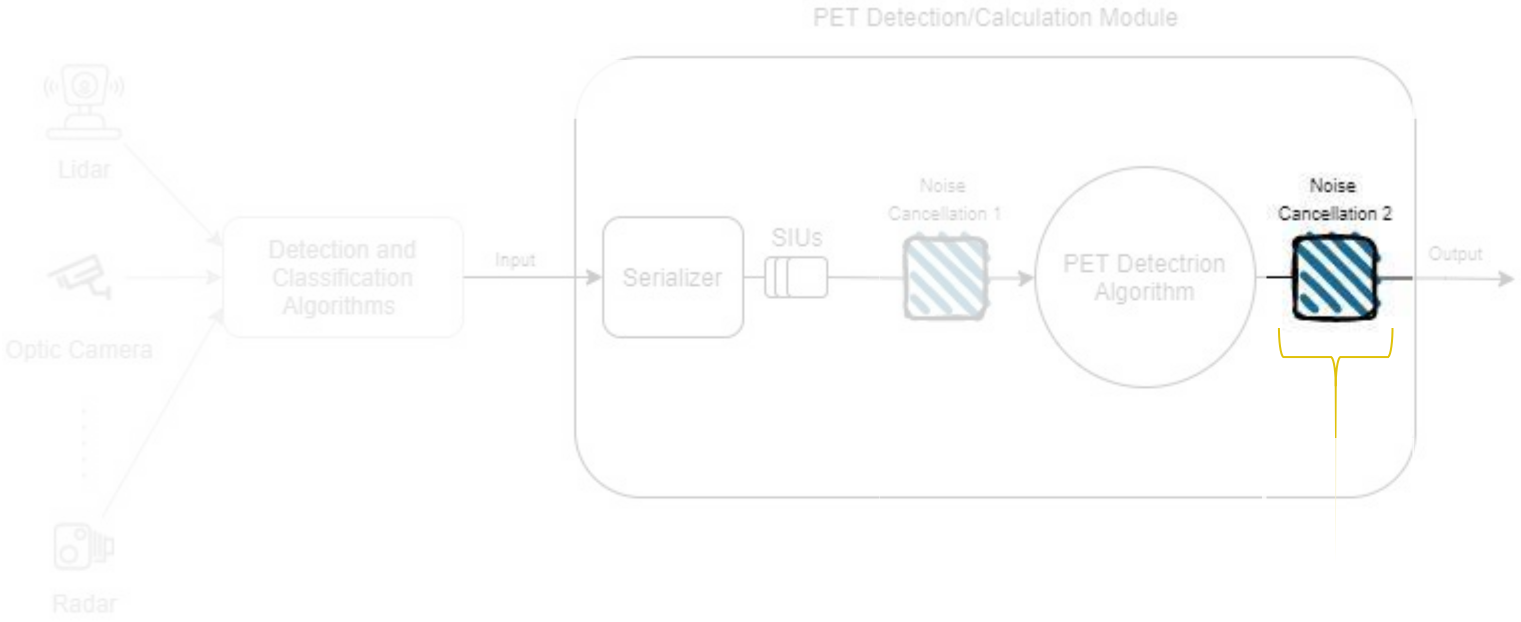

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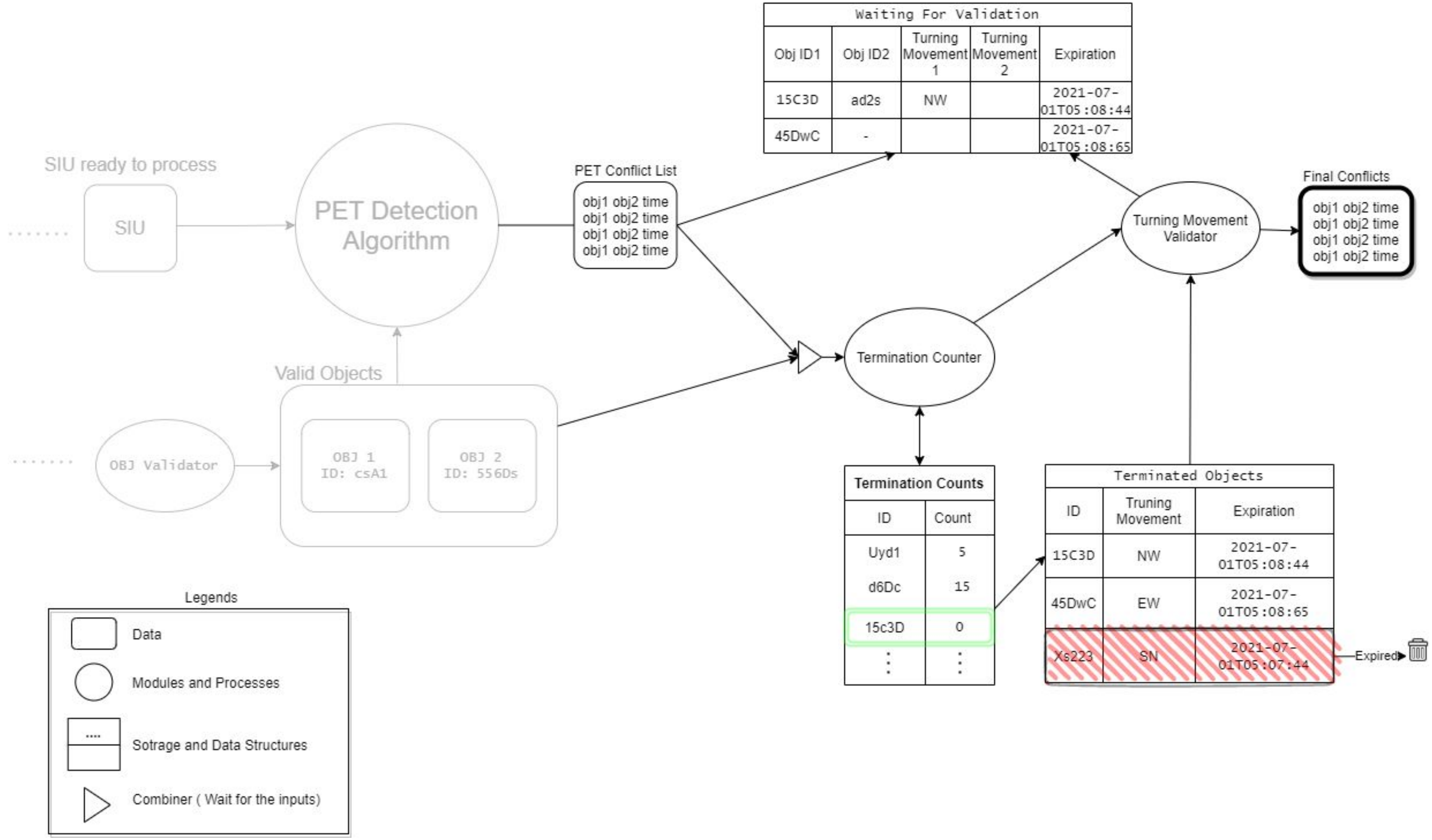

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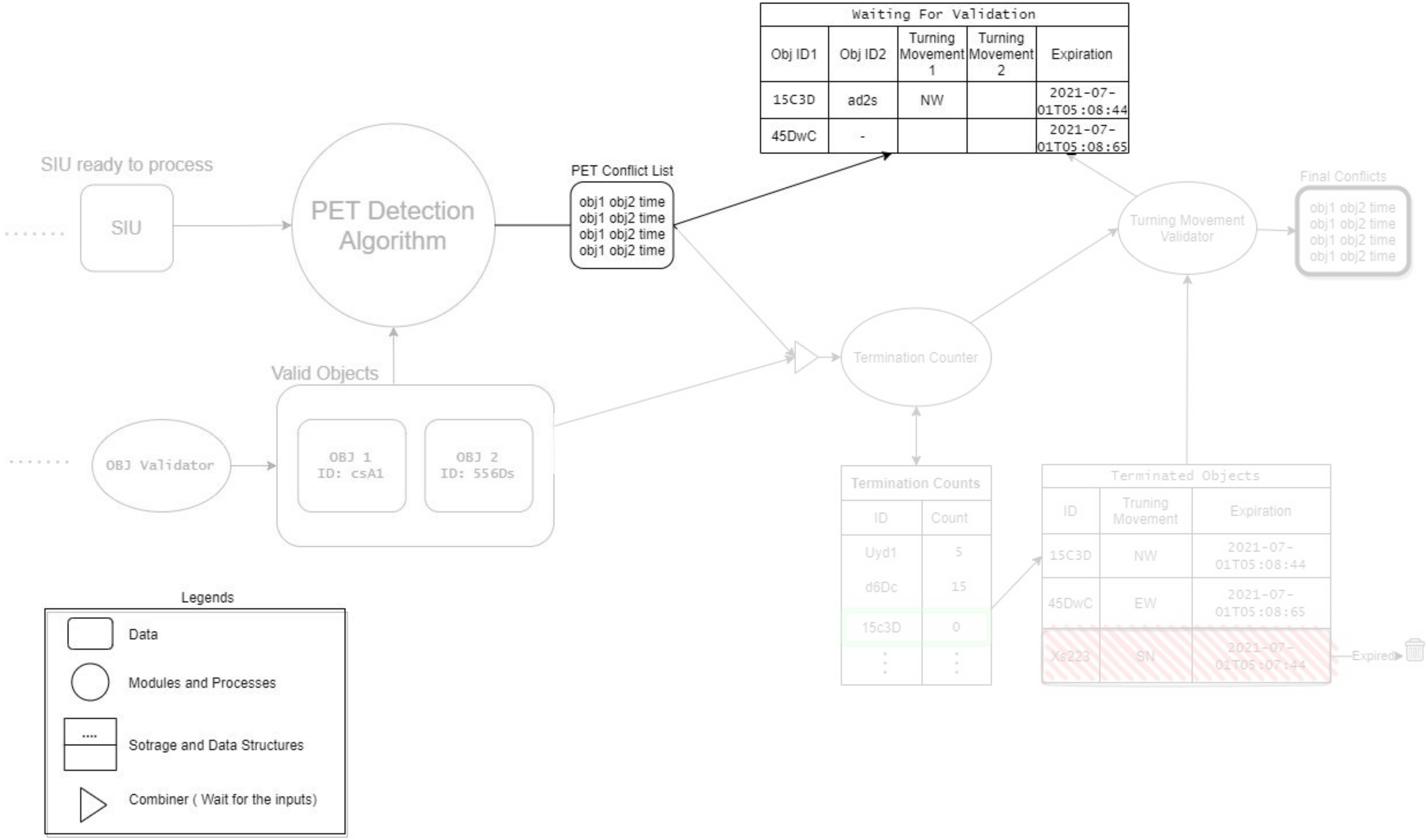

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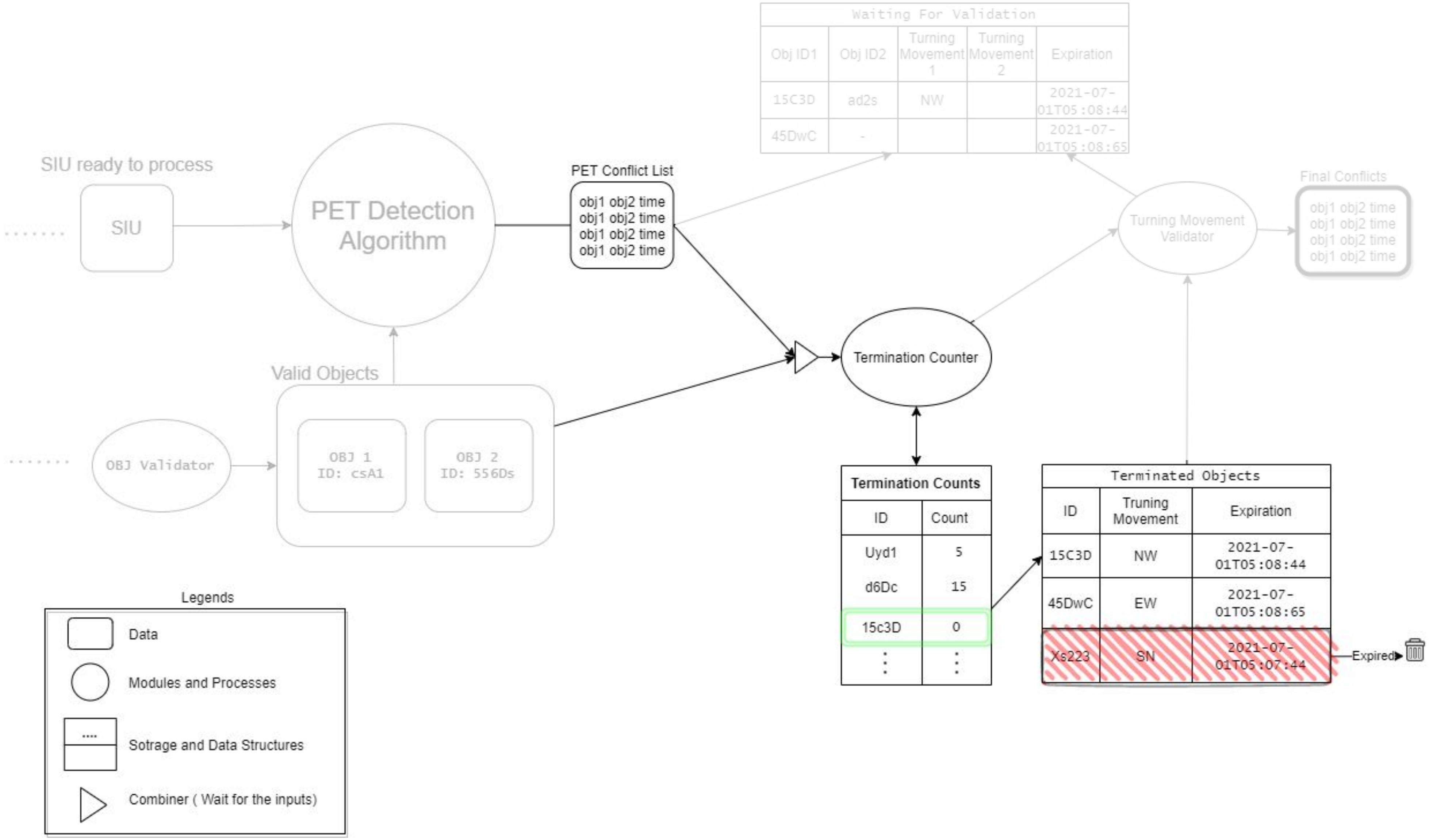

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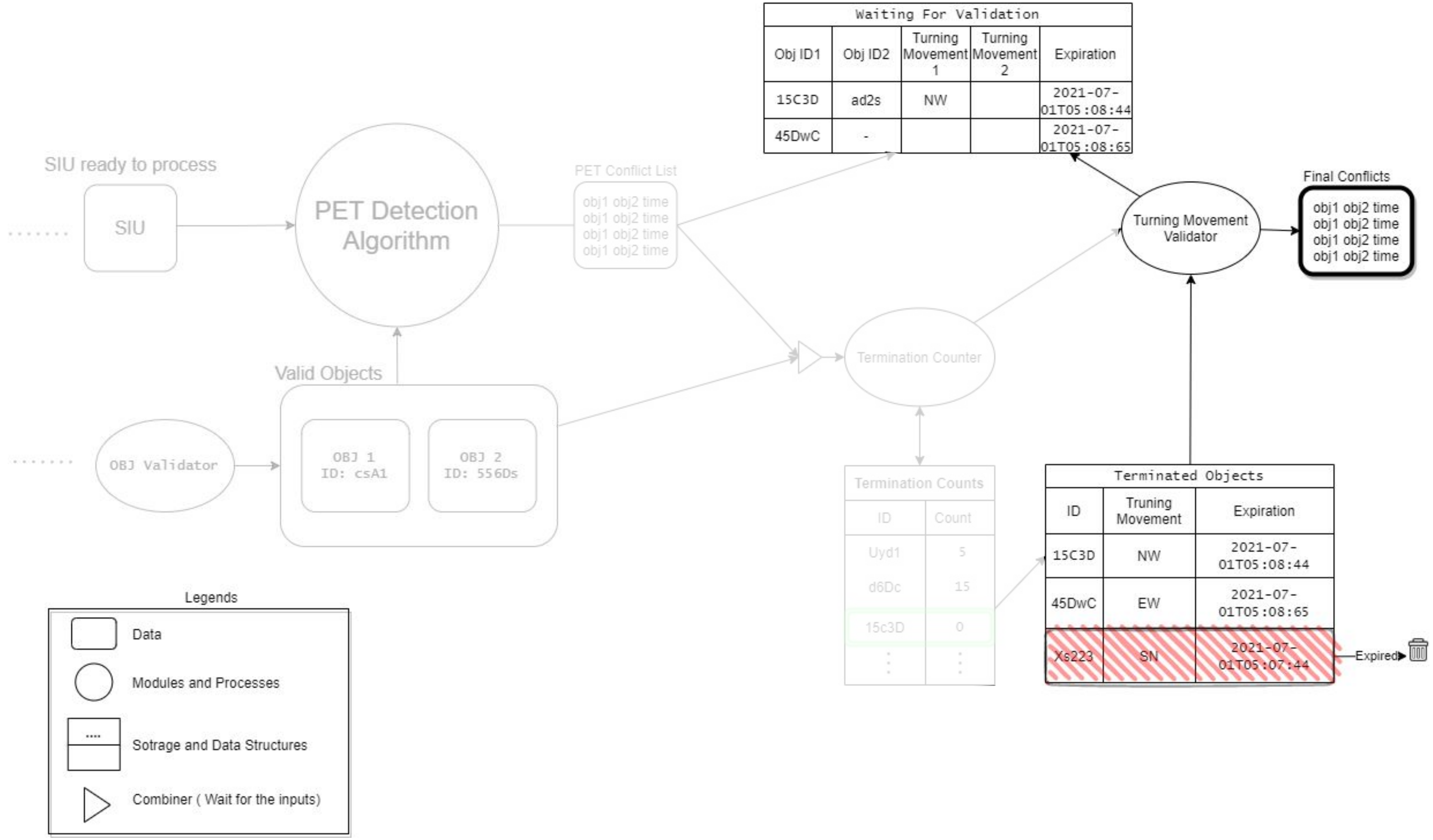

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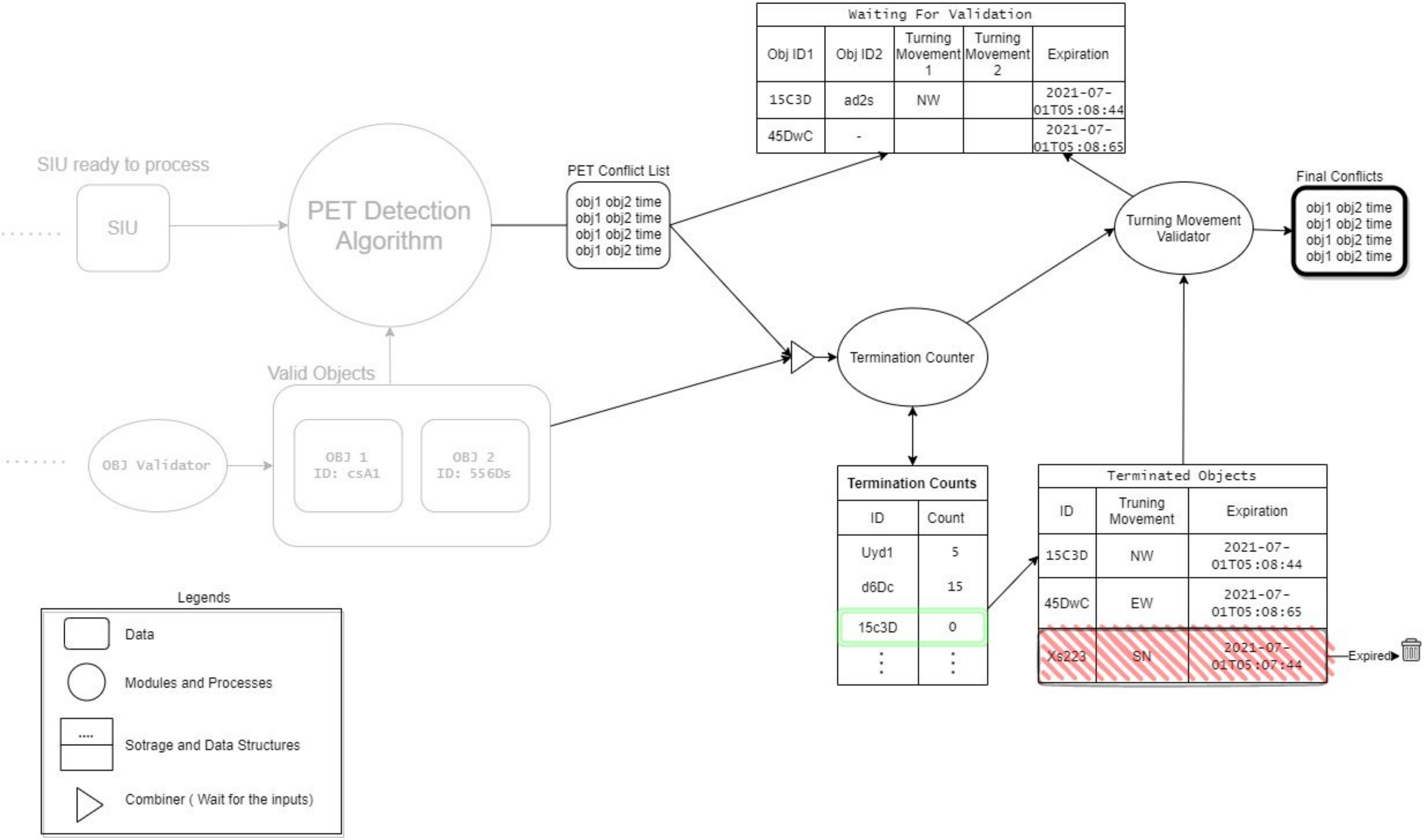


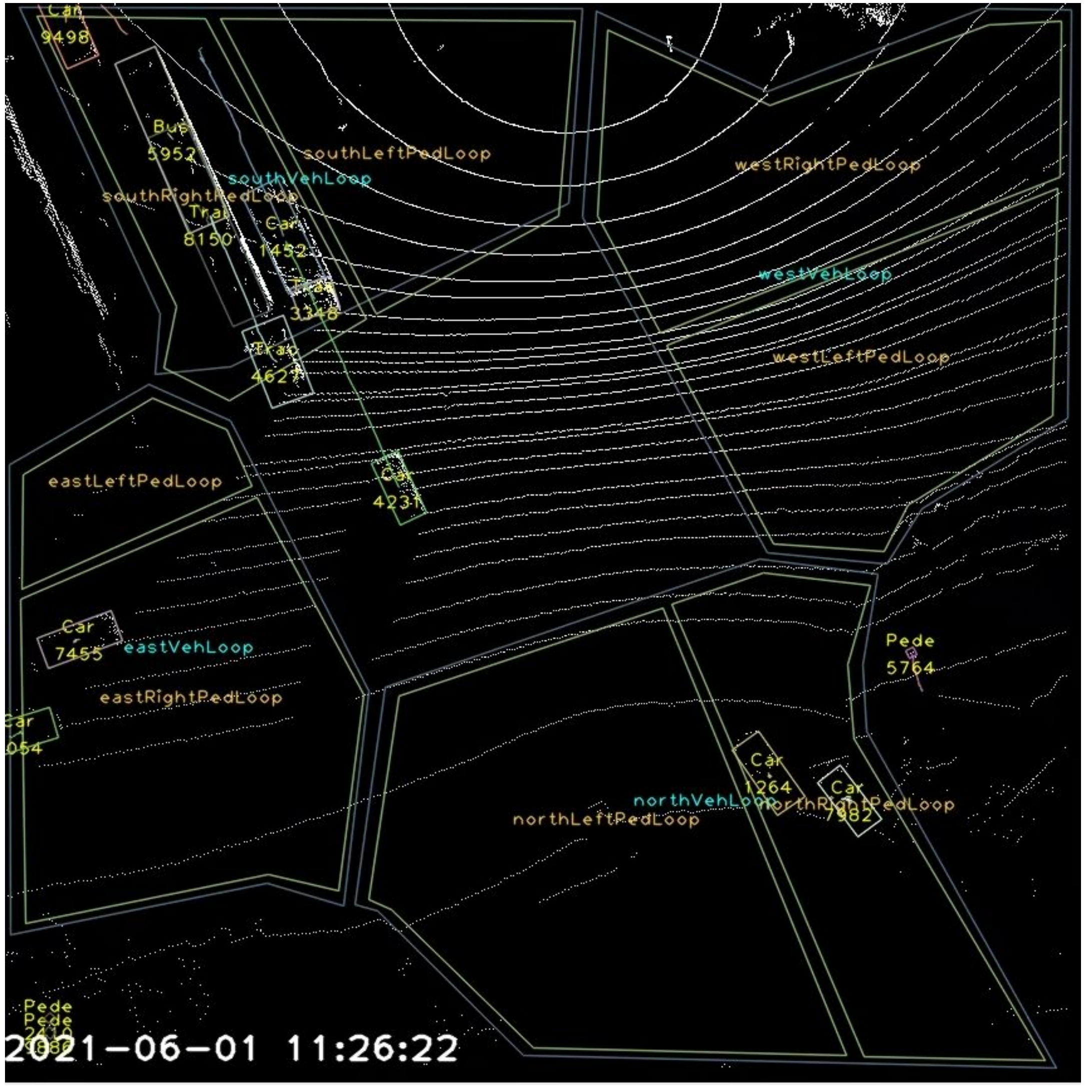
Fault tolerance: Inaccurate bounding boxes

1. False positive detection of objects
2. Inaccurate bounding boxes
3. Inaccurate object class type
4. False negative detection of objects

Fault tolerance: Inaccurate bounding boxes

- False conflicts should be avoided
- It reduces the precision of the module, but benefits are more than shortcomings

Fault tolerance: Inaccurate bounding boxes



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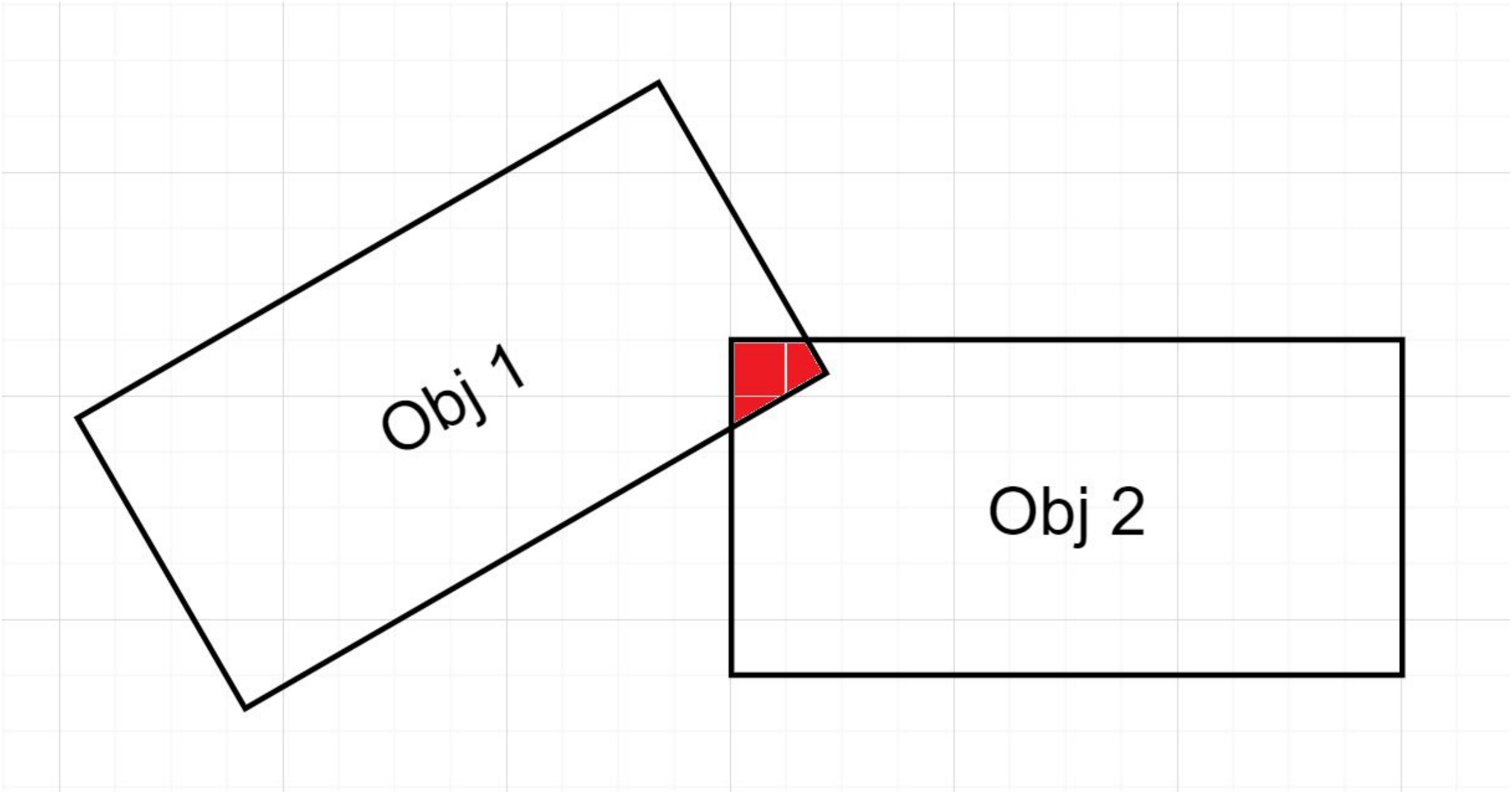

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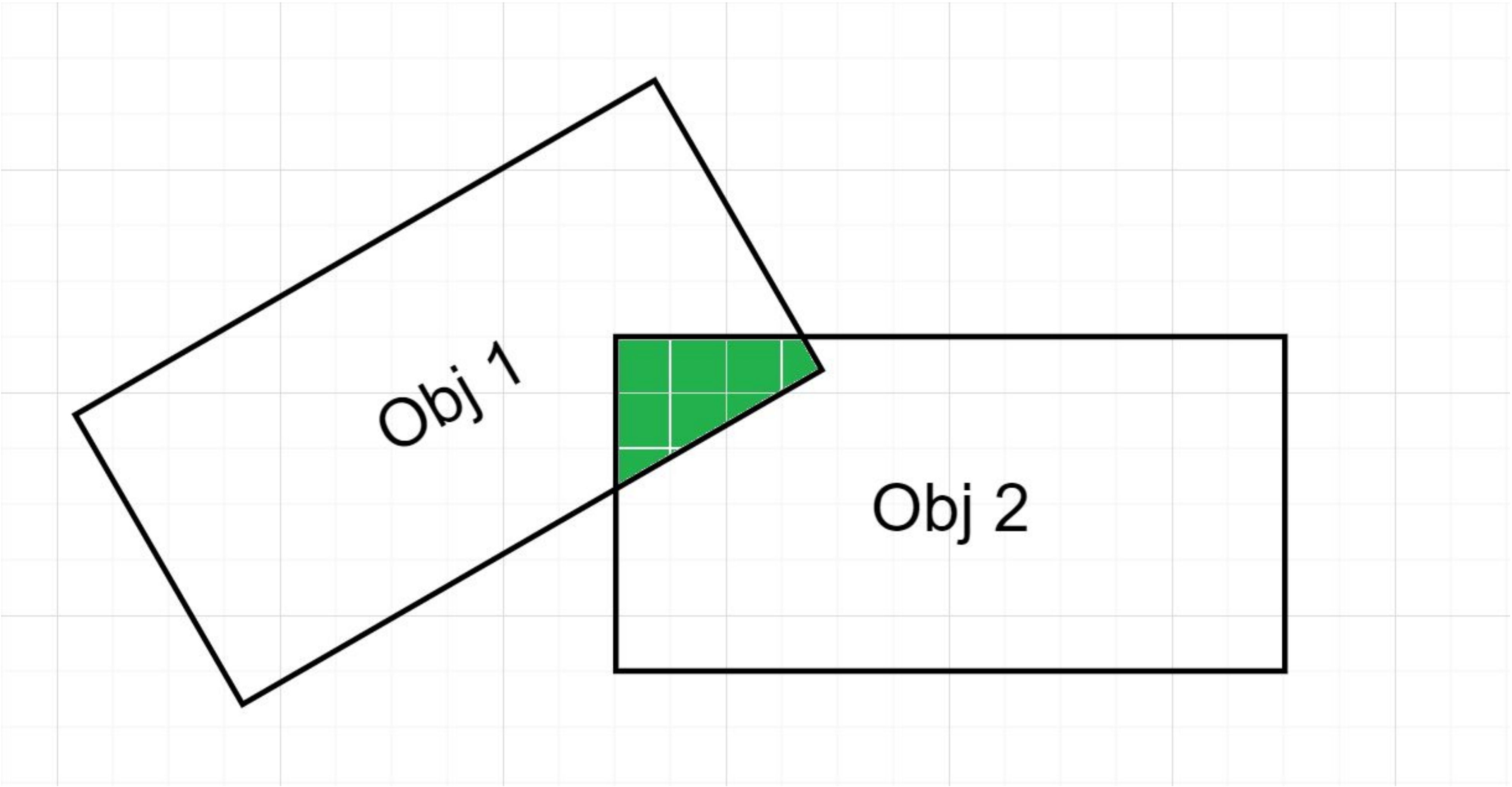

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PET

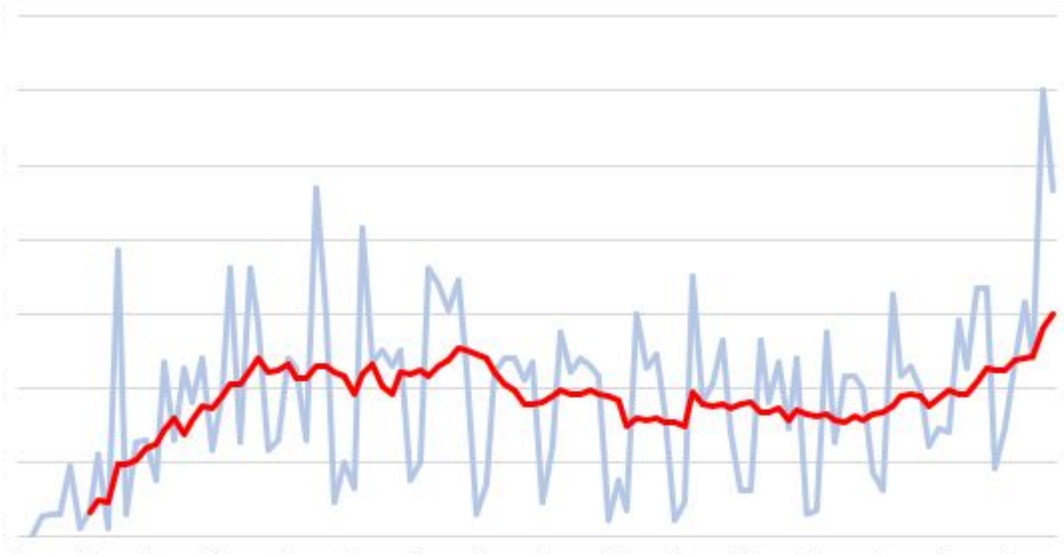
Serializer, PET Module, Noise Cancelation Modules

Speed

Momentary Speed Module, Average Speed Module

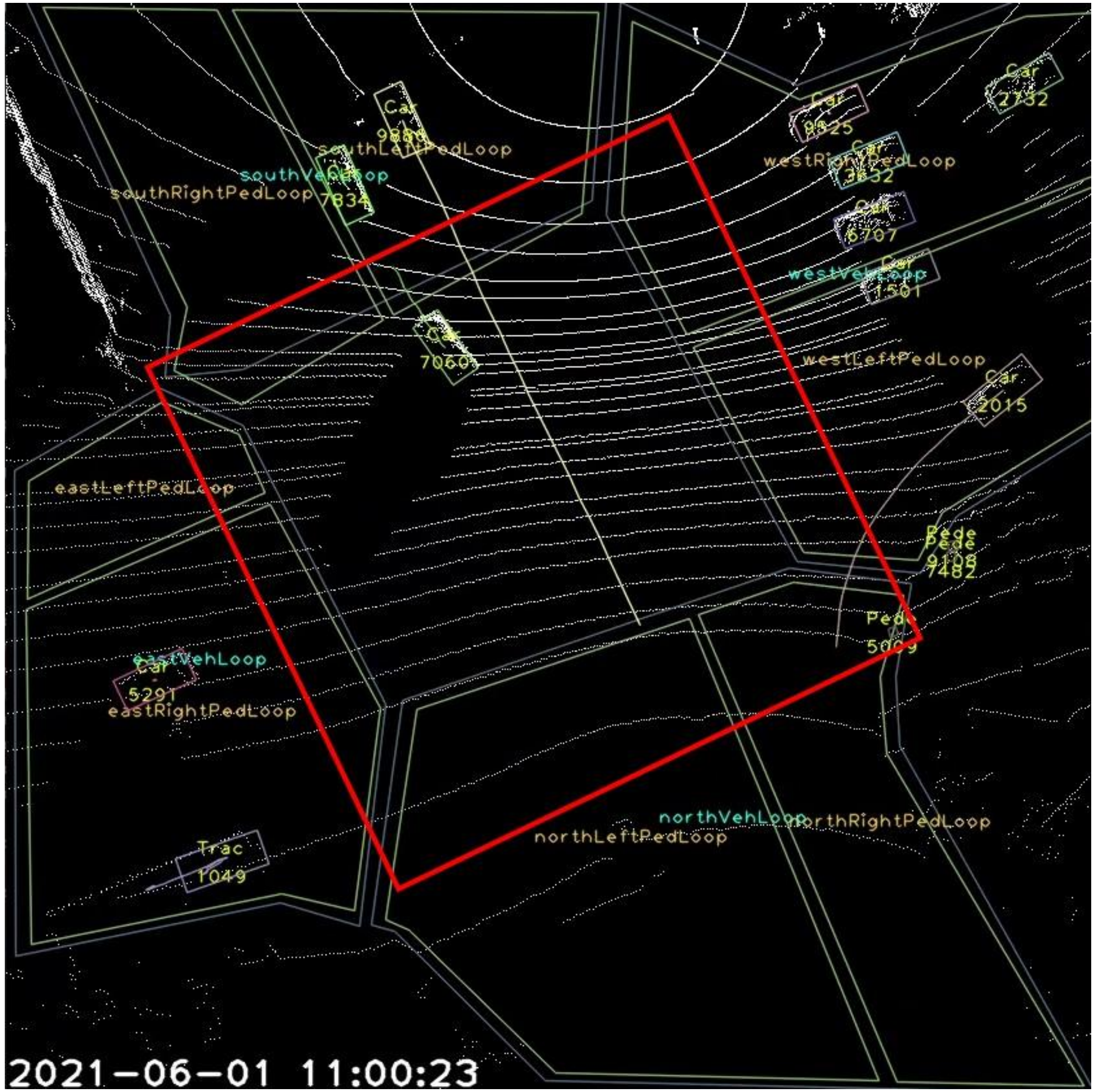
Speed: Momentary

- Need to have pixel to meter unit
- For overcome the inaccuracy caused by detection we used moving average technique
- Based on the position of an object in its four previous frames, we calculate speed of the object



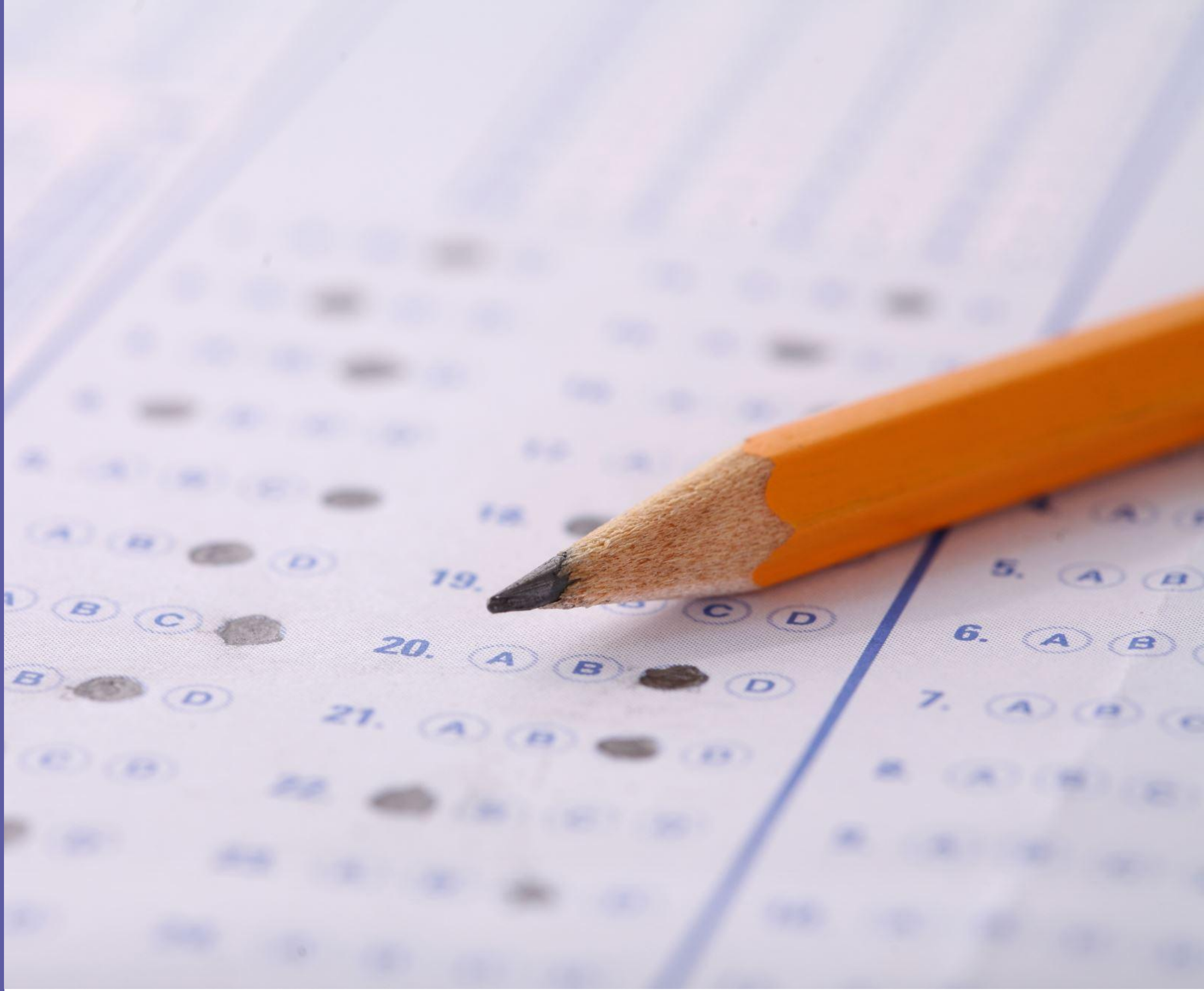
Speed: Average Speed

- Need to define a region that represents the intersection
- Take the average of the momentary speed of an object inside of the region
- This analysis only considers the magnitude of the speed



Validation

Setup, PET annotation software, PET Experiments, Speed Experiments



Setup

- Our solution is installed on many BlueCity sensors in different cities
- For our experiments we used 45 minutes data of Edmonton sensor
- Raw data and annotated video clip of that 45 minutes were collected and analyzed
- Frame rate of the sensor is 11 fps

PET: Ground Truth

- Hard task to do and needed special software for annotation

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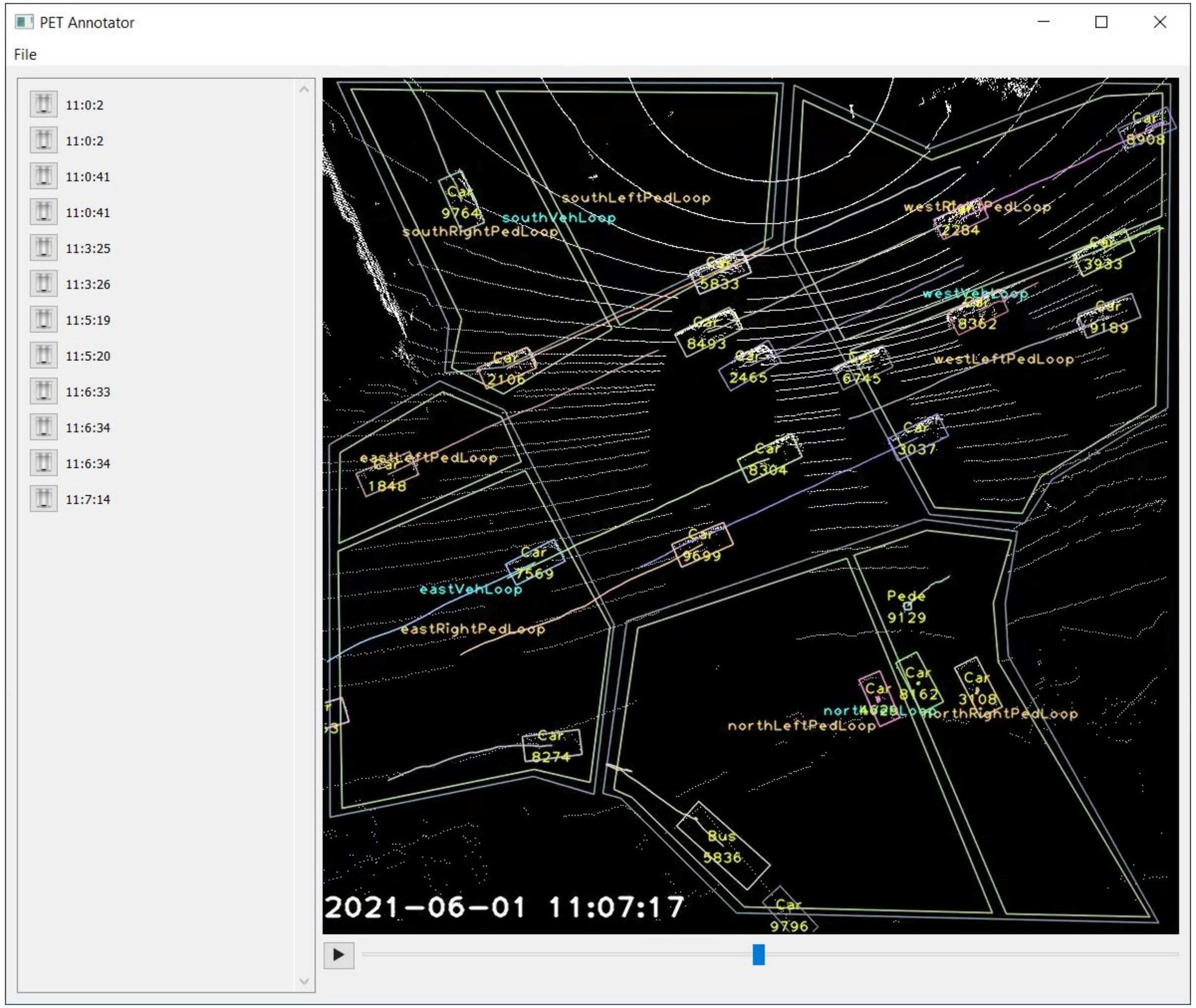
PET: Ground Truth

- Hard task to do and needed special software for annotation
- Tests only PET conflict detection and only for PET less than 3 seconds
- Added 3 seconds tail to each road users on the clip for helping the annotators
- Used 3 annotators for annotation

PET: Annotation Software

PET: Annotation Software

- Video clip player with shortcuts for changing the frame rates, skipping and …. Of clips



PET: Annotation Software

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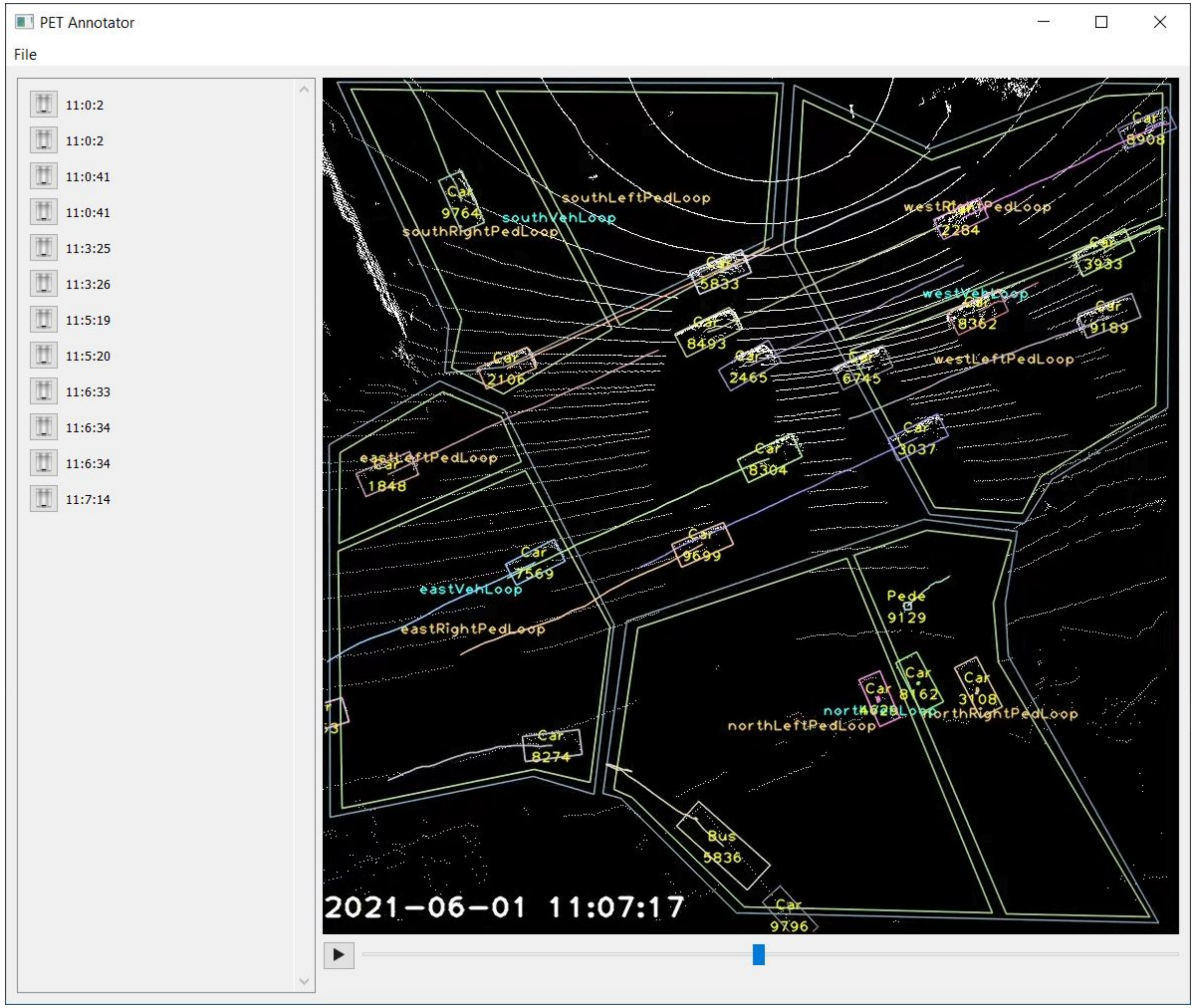
- Records the clicked position



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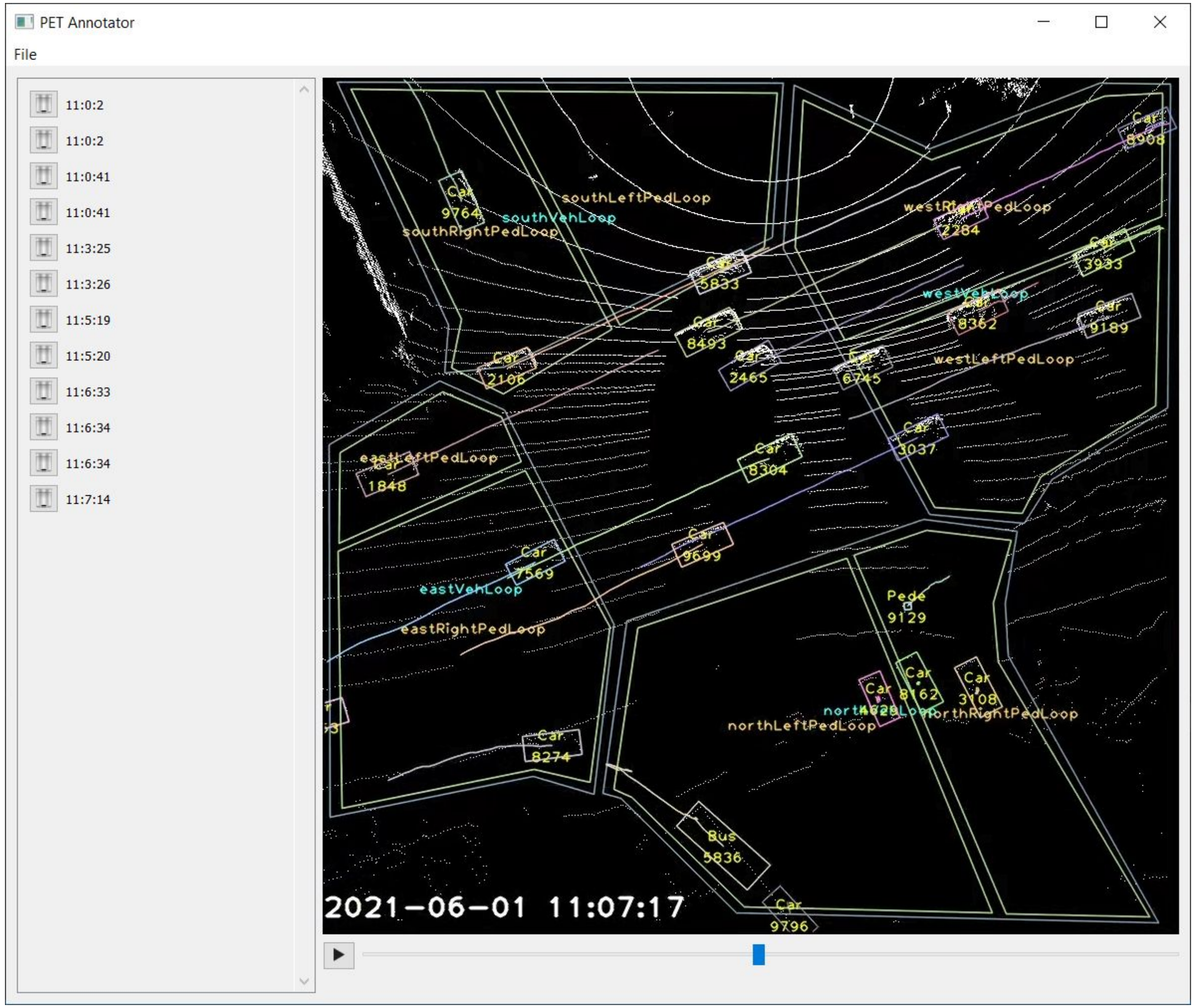

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- Captures the timestamp of the click
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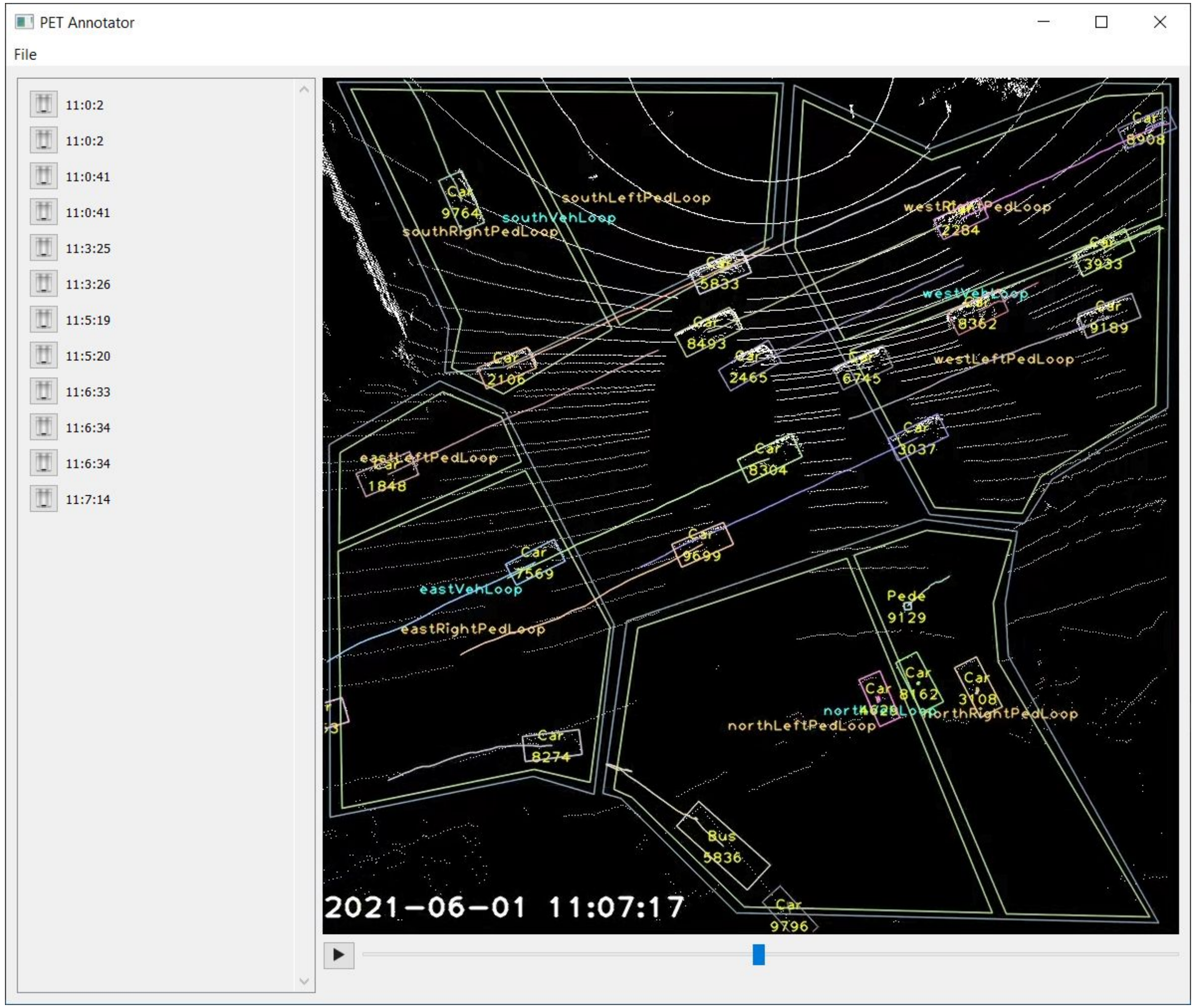
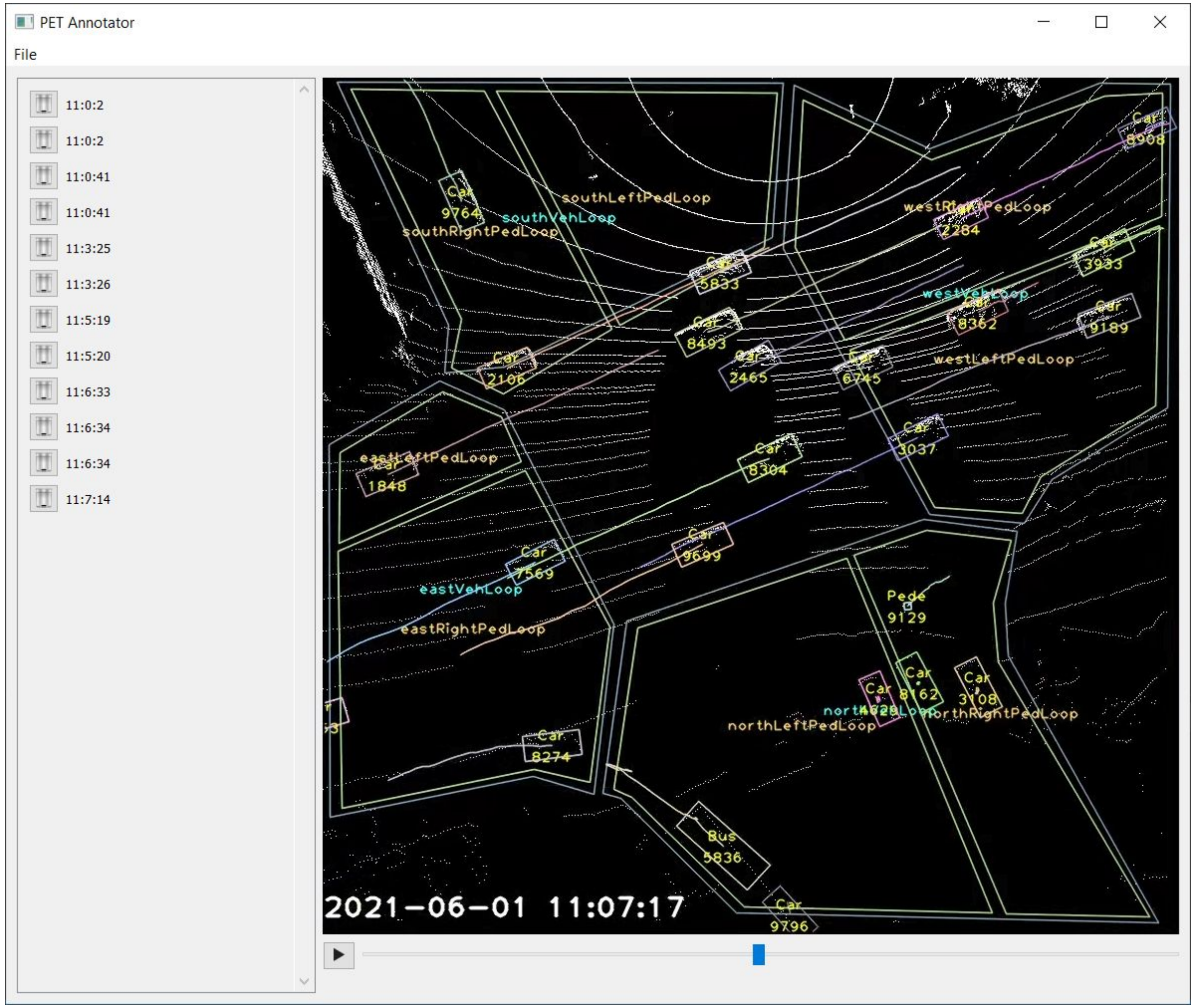


PET: Annotation Software

- Video clip player with shortcuts for changing the frame rates, skipping and …. Of clips
- Records the clicked position
- Captures the timestamp of the click
- Ability to delete the unintentional clicks
- Exports the clicked position and timestamp of each click



PET: Experiments

Exp 1: PET Performance

Check the performance of PET detection module with and without Noise removal modules

Exp 2: Delayed SIUs Setting

Checks the performance of the PET module with different setting of Delayed SIUs

Exp 3: Processing Speed

Checks the effect of different noise cancelation module on processing speed of the PET detection module

Exp 1: PET Performance

- Tested in 4 different modes:
  1. Without any noise cancelation module
  2. With delayed SIUs module active
  3. With validating turning movements
  4. With both delayed SIUs and turning movement validator modules

Exp 1: PET Performance

- Tested in 4 different modes:
  1. Without any noise cancelation
  2.
  3.
  4.

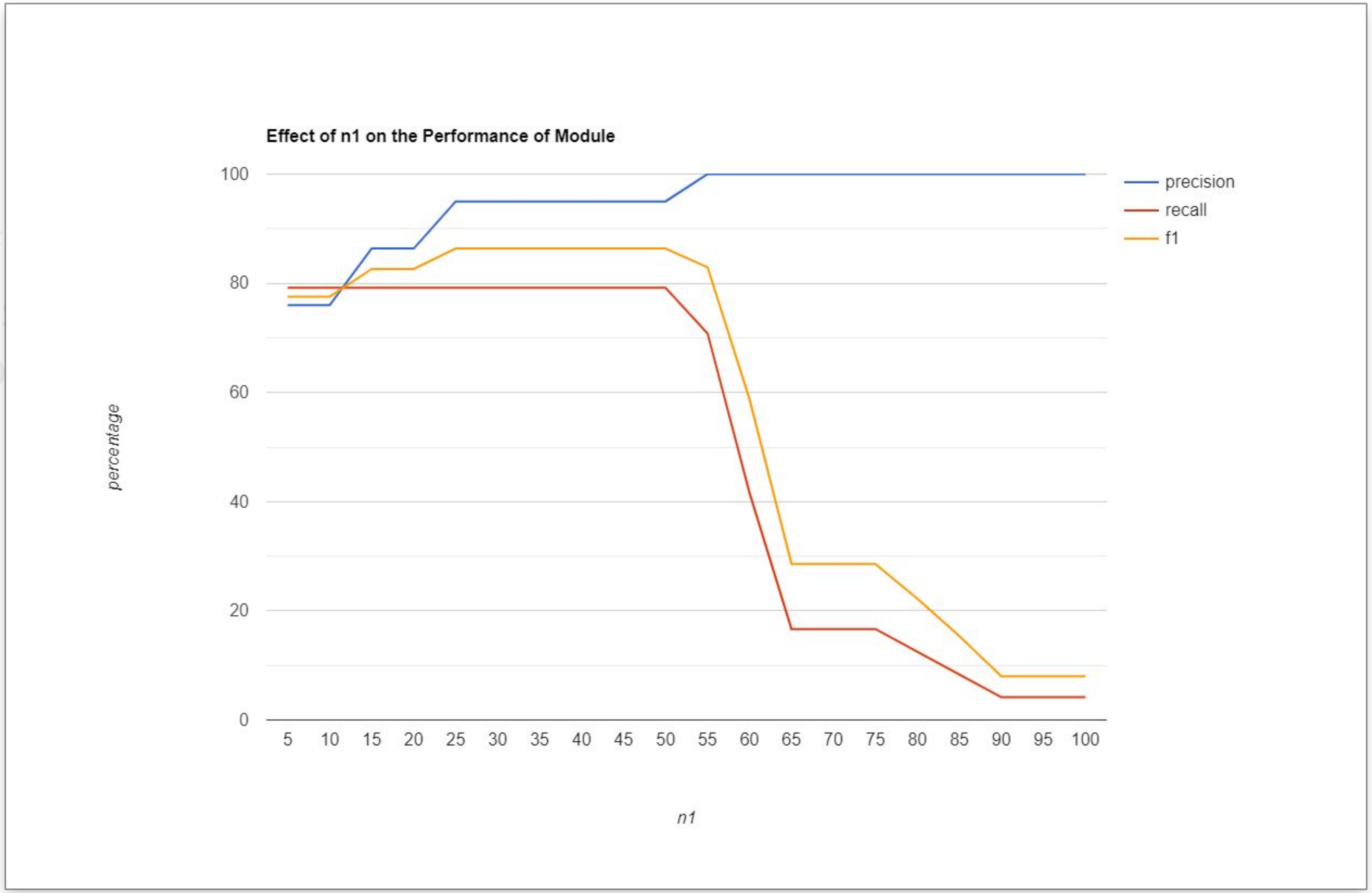
	No Filter	Delayed Frame	Turning Movement	All Filters	Ground truth
Detected PET	731	213	122	68	79
Matched	75	66	66	64	-
False PET	656	147	56	4	-
Missed PET	4	13	13	15	-
Precision	10.25 %	30.98%	54.09%	**94.11%**	-
Recall	**94.93 %**	83.53 %	83.54 %	81.01 %	-
F1-score	18.50%	45.11%	65,66%	**86.29%**	-

Exp 2: Delayed SIUs Setting

- Effects of delayed SIUs on the performance is significant
- Length of a noise appearance is not a constant and depends on the sensor and the environment

Exp 2: Delayed SIUs Setting

- Effects of
performa
- Length of
not a con
the senso



Exp 2: Delayed Frame Setting

- Effects of de… performance…
- Length of a … not a consta… the sensor a…

n_1	No. Detected PET	No. Matched PET	Precision	Recall	F1
5	25	19	76%	79.16%	77.55%
10	25	19	76%	79.16%	77.55%
15	22	19	86.36%	79.16%	82.60%
20	22	19	86.36%	79.16%	82.60%
25	20	19	95%	79.16%	**86.36%**
30	20	19	95%	79.16%	**86.36%**
35	20	19	95%	79.16%	**86.36%**
40	20	19	95%	79.16%	**86.36%**
45	20	19	95%	79.16%	**86.36%**
50	20	19	95%	79.16%	**86.36%**
55	17	17	100%	70.83%	82.92%
60	10	10	100%	41.66%	58.82%
65	4	4	100%	16.66%	28.57%
70	4	4	100%	16.66%	28.57%
75	4	4	100%	16.66%	28.57%
80	3	3	100%	12.5%	22.22%
85	2	2	100%	8.33%	15.38%
90	1	1	100%	4.16%	8%
95	1	1	100%	4.16%	8%
100	1	1	100%	4.16%	8%
Ground truth	24	-	-	-	-

Exp 3: processing speed

- Goal is to evaluate the effects of different noise removal modules on the processing time of the data
- Split the 45 minutes of data to 3 bins to account for the nuances in performance of testing machine
- Tested on a computer with 4 GB of Ram and a Core i5 Intel CPU.

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Time	All Filters(s)	Delayed Frame(s)	Turning Movement(s)	No Filter(s)
15:00 - 15:15 pm	537.61	537.70	635.90	643.00
15:15 - 15:30 pm	485.93	483.63	575.95	567.75
15:30 - 15:45 pm	490.78	490.49	581.68	576.40
Total Seconds	1514.33	1511.82	1793.55	1787.15

Speed: Validating Average Speed

- Only through movements were possible to validate
- Needed to define a region to calculate average speed in that region

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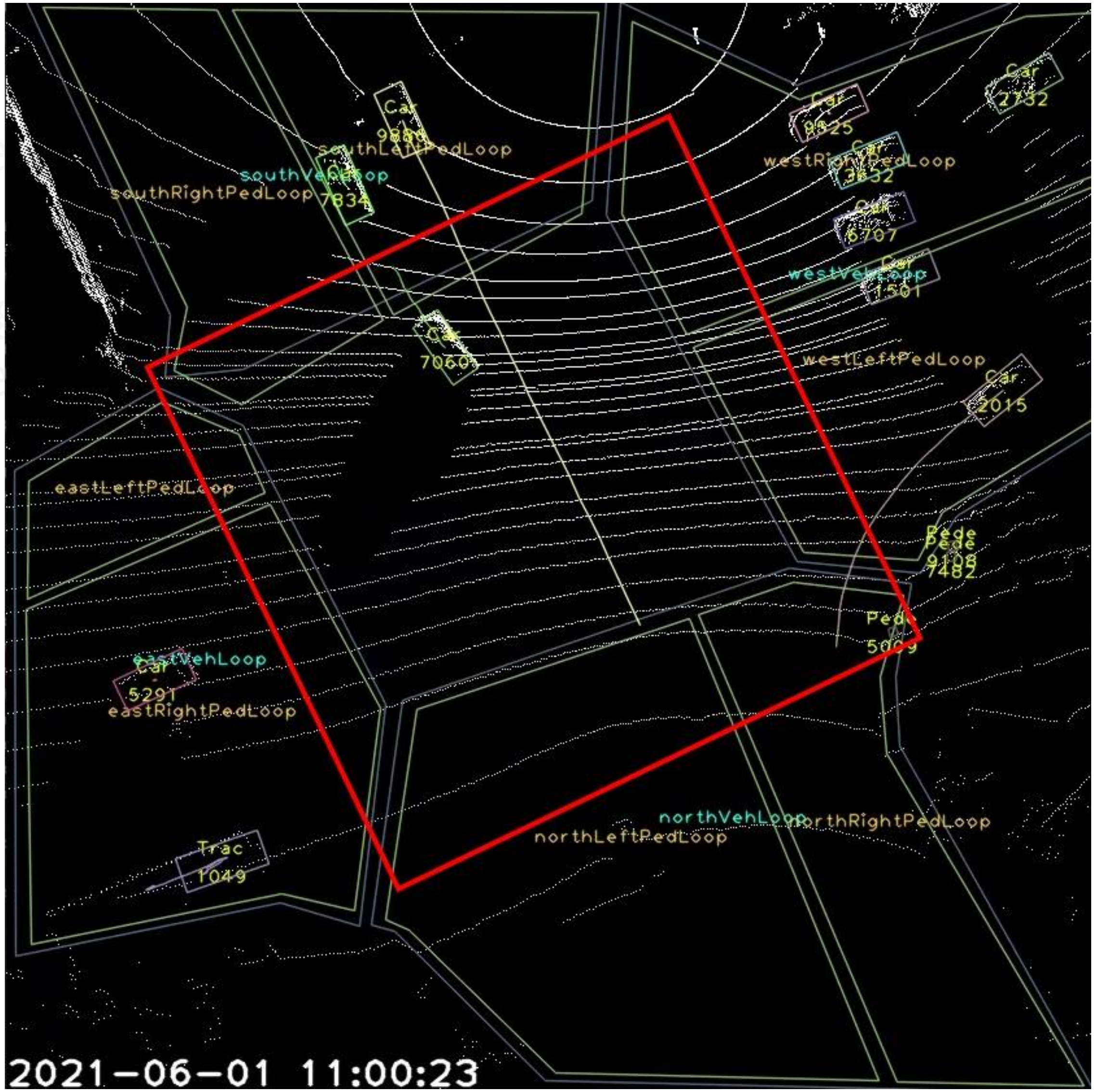

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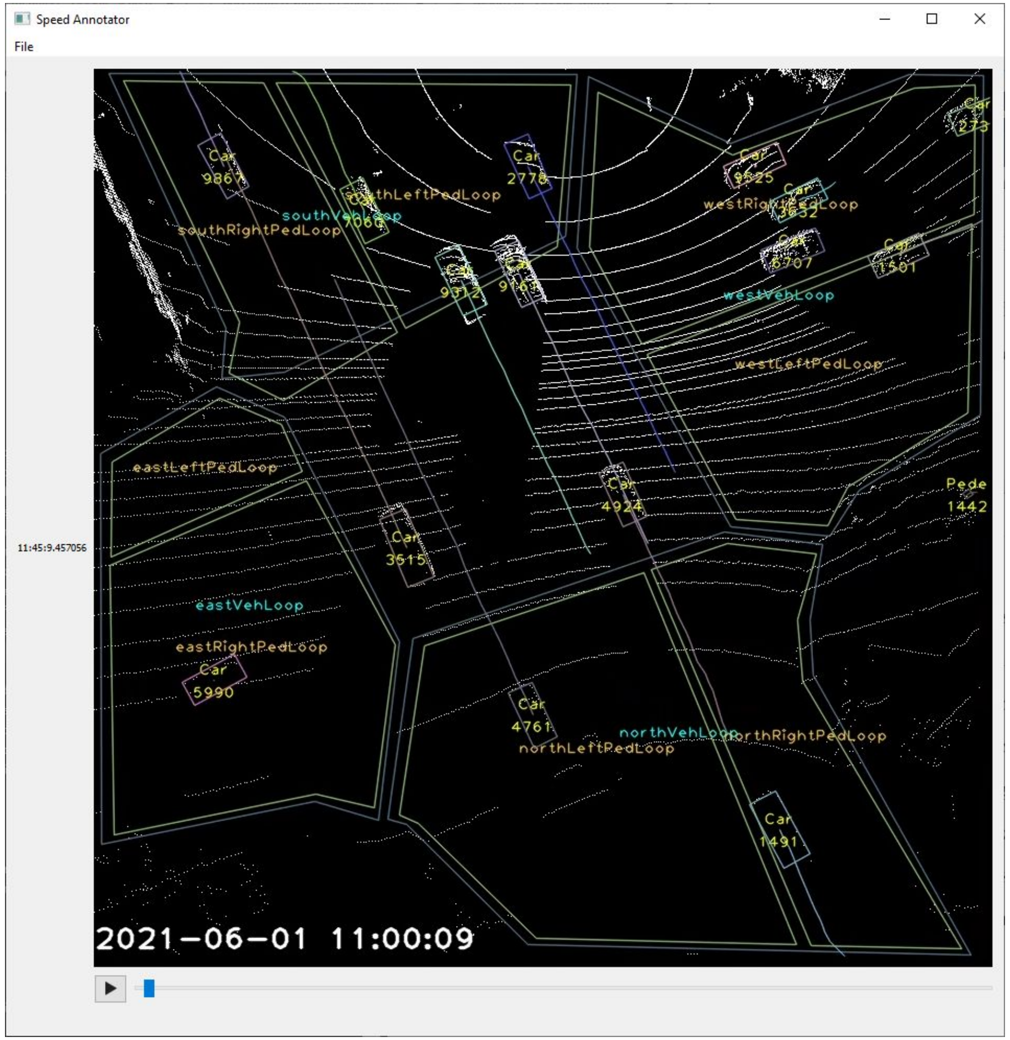
- Needed to define a region to calculate average speed in that region
- Shared the video clip of data with our annotator and asked them to annotate 400 through movement
- Created a custom annotation software for capturing entrance and exit time of object in region



Speed: Validating Average Speed

- We mapped the region on google maps and using the distance measures tool we calculated the distance of each through movements
- Using the entry time and exit time of the object to the region, calculated the speed of an object
- We removed the outliers

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Turning Movement	North-South	South-North	East-West	West-East	Total
Count	143	65	95	92	**395**
AVG Speed (km/h)	47.50	43.87	43.13	45.35	**45.35**
AVG Speed GT (km/h)	46.021	43.89	43.37	45.46	**44.90**
Average Abs Speed off (km/h)	1.84	1.14	1.21	1.08	**1.40**
Error %	4.06	2.48	2.36	2.75	**3.09**

Conclusion

1) Introduction	Traffic Safety, SSA and SSM, PET and Speed, Our Contribution
2) Background	Literature Review, Similar Approaches, Short Comings of Other Works
3) Approach	PET Detection and Calculation Module, Average and Momentary Speed Module
4) Validation	PET Validations and Experiments, Speed Validation Experiment

Thank you

References

- XXX

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25	20	19	95%	79.16%	**86.36%**
30	20	19	95%	79.16%	**86.36%**
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55	17	17	100%	70.83%	82.92%
60	10	10	100%	41.66%	58.82%
65	4	4	100%	16.66%	28.57%
70	4	4	100%	16.66%	28.57%
75	4	4	100%	16.66%	28.57%
80	3	3	100%	12.5%	22.22%
85	2	2	100%	8.33%	15.38%
90	1	1	100%	4.16%	8%
95	1	1	100%	4.16%	8%
100	1	1	100%	4.16%	8%
Ground truth	24	-	-	-	-

Exp 2: Delayed Frame Setting

- Effects of de
performance
- Length of a r
not a consta
the sensor a

n_1	No. Detected PET	No. Matched PET	Precision	Recall	F1
5	25	19	76%	79.16%	77.55%
10	25	19	76%	79.16%	77.55%
15	22	19	86.36%	79.16%	82.60%
20	22	19	86.36%	79.16%	82.60%
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90	1	1	100%	4.16%	8%
95	1	1	100%	4.16%	8%
100	1	1	100%	4.16%	8%
Ground truth	24	-	-	-	-

Exp 2: Delayed Frame Setting

- Effects of de… performance…
- Length of a r… not a consta… the sensor a…

n_1	No. Detected PET	No. Matched PET	Precision	Recall	F1
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Ground truth	24	-	-	-	-

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Ground truth	24	-	-	-	-

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Ground truth	24	-	-	-	-

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100	1	1	100%	4.16%	8%
Ground truth	24	-	-	-	-

Exp 1: PET Performance

- Tested in 4 different modes:
  1. Without any noise cancelation
  2.
  3.
  4.

	No Filter	Delayed Frame	Turning Movement	All Filters	Ground truth
Detected PET	731	213	122	68	79
Matched	75	66	66	64	-
False PET	656	147	56	4	-
Missed PET	4	13	13	15	-
Precision	10.25 %	30.98%	54.09%	**94.11%**	-
Recall	**94.93 %**	83.53 %	83.54 %	81.01 %	-
F1-score	18.50%	45.11%	65.66%	**86.29%**	-

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F1-score	18.50%	45.11%	65.66%	**86.29 %**	-

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F1-score	18.50%	45.11%	65.66%	**86.29%**	-

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F1-score	18.50%	45.11%	65,66%	**86.29 %**	-

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F1-score	18.50%	45.11%	65,66%	**86.29%**	-