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



1. Do not happen that frequently



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



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



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



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



Post Encroachment Time (PET)



Speed



Speed





Speed

- 1. Momentary Speed
- 2. Average Speed



• Automated PET Detection and Calculation Module

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Characteristics

• Decoupled

• Automated PET Detection and Calculation Module

- Decoupled
- Realtime/Continuous

• Automated PET Detection and Calculation Module

- Decoupled
- Realtime/Continuous
- Precise

• Automated PET Detection and Calculation Module

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- Fault tolerant

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

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Background

Literature Review, Related Works



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	author: M. H. Zaki, mz	 Corresponding author. E-mail addresses: sohail.zange 	kevin.manaugh@mcgill.ca	anatysis would introduce lisions are relatively rar	through in-vehicle dev	6	Canada. Corresponding author:	sponding author: T. Fu, ting.fu	COLLINGIT © 2020 DI SI ENCER MADDOX
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- Easy to use
- Fault tolerant

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 Corresponding E-mail address 0968-090X/S - see http://dx.doi.org/1 	Transportación Ressert No. 2030; Transportación D.C., 2013; pp. 073-64 D.D: 10.3141/2383-01 DD: 10.3141/2383-01	jillian atrasostimailmegili.e. (J. S. (J.F. Miranda: Morreno), nicolassa http://dx.doi.org/10.1016(g.aup.20 0001-4573/i0.2015 Ebevier Int./	https://doi.org/10.1016/j.t Available online 26 Octobe 1361-9209/ © 2018 Elsevé	Received to December 2013. A. Kassim, K. Ismail, and Corresponding author. Al Can. J. Cir. Eng. 41: 605–614 (between driver chara Others have extracted lance cameras and e		Transportación Research Recorc No. 2280, Transportación Resear D.C., 20102, pp. 184–97 D.C., 10.3141/2280-03	Transportation Research Ree No. 2588, Inserportation Re DD: 10.3141/2586-10	

 Focus on the Automated SSM Module





- Focus on the Automated SSM Module
- Decoupled

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USING AUTOMATED VIDEO PROCESSING TO IDENTIFY PEDESTRIAN-VEHICLE CONFLICTS

> A Dissertation Presented to The Academic Faculty

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

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

Automated measuring of cyclis encroachment time at signalize Ali Kassin, Karim Ismili, and Yasser Hassan	t – mo ed inte	otor vehicle pos ersections	ARTICLE
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- Focus on the Automate Module
- Decoupled
- Realtime/Continuous
- Precise



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

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USING AUTOMATED VIDEO PROCESSING TO IDENTIFY PEDESTRIAN-VEHICLE CONFLICTS

A Dissertation

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

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

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USING AUTOMATED VIDEO PROCESSING TO IDENTIFY PEDESTRIAN-VEHICLE CONFLICTS
Case Studies

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

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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

- 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
- 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 Detection/Calculation Module

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
- 5. Easy to use
- 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
- 3. Precise
- 4. Generalized
- 5. Easy to use
- 6. Fault tolerant



• 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: Det Timestamp





PET: Det Timestamp

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• 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



























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





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



t1

t2

t3

Obil

Use ConflStore info



Obj 1





####






Timestamp







• Conflict candidates need to be validated by some filters:

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

- Conflict candidates need to be validated by some filters:
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 - 2. The Angle of the conflict is acceptable

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 - 4. Object is not conflicting with the previous conflicted object

- Conflict candidates need to be validated by some 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 (will be discussed later)

PET: Noise Cancellation

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



1. False positive detection of objects





- 1. False positive detection of objects
- 2. Inaccurate bounding boxes

- 1. False positive detection objects
- 2. Inaccurate bounding bo



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

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

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



Delayed SIUs





- 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

Fault Tolerance: False positive detection of objects



















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



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



ements

False positive detection of objects: Validating Turning Movements











Combiner (Wait for the inputs)




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

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









Fault tolerance: Inaccurate object class type

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

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

PET: Ground 1

• Hard task to do an special software for



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

• Video clip player with shortcuts for changing the frame rates, skipping and Of clips



- Video clip player with shortcuts for changing the frame rates, skipping and Of clips
- Records the clicked position



- Video clip player with shortcuts for changing the frame rates, skipping and Of clips
- Records the clicked position
- Captures the timestamp of the click



- 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



- 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

	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



Exp 2: Delaved Frame Setting

- Effects of de performanc
- Length of a not a constate 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.

Exp 3: processing speed

- Goal is to evaluate the effects of different noise removal modules on the processing time of the data
- Splitted the to 3 bins to testing macl

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

• Tested on a computer with 4 GB of Ram and a Core i5 Intel CPU.

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

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- Shared the video clip of data with our annotator and asked them to annotate 400 through movement

- Only through movements were possible to validate
- 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



- 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

Turning Movement	Nort
Count	
AVG Speed (km/h)	4
AVG Speed GT (km/h)	46
Average Abs Speed off (km/h)	1

through m	Turning Movement	North-South	South-North	East-West	West-East	Total
through m	Count	143	65	95	92	395
Using the	AVG Speed (km/h)	47.50	43.87	43.13	45.35	45.35
Using the	AVG Speed GT (km/h)	46.021	43.89	43.37	45.46	44.90
time of the	Average Abs Speed off (km/h)	1.84	1.14	1.21	1.08	1.40
region, cal	Error %	4.06	2.48	2.36	2.75	3.09
an object						

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


References

• XXX

Speed: Validating Average Speed

 We mapped the region on google maps and using the distance measures tool we

Using the time of the region, cal an object

Turning Movement	North-South	South-North	East-West	West-East	Total
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15:15 - 15:30 pm				567.75
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Total Seconds				1787.15

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5	25	19	76%	79.16%	77.55%
Ground truth	24	<u> </u>	-	_	2 <u>1</u> 1

- Effects of de performanc
- Length of a not a consta the sensor a

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20	22	19	86.36%	79.16%	82.60%
Ground truth	24	2	-	-	-

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40	20	19	95%	79.16%	86.36%
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Ground truth	24	-	-	-	-

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Ground truth	24	-	122	_	-

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Matched					-
False PET					-
Missed PET					-
Precision					-
Recall					-
F1-score					-

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Matched	75				-
False PET	656				-
Missed PET	4				-
Precision	10.25 %				-
Recall	94.93 %				-
F1-score	18.50%				-

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