Motivation 000000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results 0000	Summary
	Evaluation of a ne system using hard	ew intelligent sp Iware-in-the-loo	eed advisory p simulation	

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International Conference on Connected Vehicles and Expo 2013, Las Vegas, Nevada, USA

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Motivation 000000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results 0000	Summary

Motivation

- Intelligent Transportation Systems
- Methodologies for Evaluation
- Our proposal
- 2 The Proposed Advisory System
 - First stage: Traffic scenario determination
 - Second stage: Speed and distance recommendations
- 3 SUMO-phone Integration
 - The simulation platform
 - HIL capabilities

4 Experimental Results

- Simulation Setup
- Tests







Motivation ●00000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results 0000	
Intelligent Tra	nsportation Systems			
Trai	nsportation systems			
٥	<u>TS:</u> vehicles $+$ infrastr	ructure + human co	mponent.	
•	Problems: congestion,	carbon emissions, r	outing, safety.	
•	Trivial solutions: build new physical infrastruc	ing additional capac cture.	ity, incorporating	

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Intelligent	Transportation Systems			
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Motivation 0●0000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results 0000	Summa
Intelligent Tra	nsportation Systems			
Trar	nsportation systems			
۲	Intelligent solutions: In communication system	nformation Technolo is.	ogies + wireless	
	Intelligent Transp	ortation Systems (I	TS): flexibility,	

adaptation, scalability, better-informed decisions.

Intelligent Transportation Systems (ITS)

- <u>Advanced Traveler Information:</u> Real-Time Traffic Information.
- ITS-based Transportation Pricing: Electronic Toll Collection.
- Advanced Public Transportation: Electronic Fare Payment.
- <u>Fully integrated systems (VII + V2V integration)</u>: Intelligent Speed Adaptation.

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- Intelligent solutions: Information Technologies + wireless communication systems.
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- Voluntary: Speed Advisory System.
 - Static: fixed/localised speed limits.
 - Dynamic: real-time environmental information.
- Mandatory: Cooperative/Adaptive Cruise Control.









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Motivation ○○○●○○	The Proposed Advisory System	SUMO-phone Integration	Experimental Results 0000	
Methodologies	for Evaluation			
Real	-world tests			
۲	Pros:			
	• Realistic results, sti	raight conclusions.		
٠	Cons:			
	Impractical: AvailabRisks of damage: v	bility and costs of req ehicle collision, huma	uired resources. n injuries.	
Sim	lation-based tests			

• Cons:

Accurate mathematical models/representations are required
 Unrealistic conclusions from a non-comprehensive setup.

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• Pros:

- Quicker, safer and cheaper tests.
- More comprehensive tests (more quality).
- Results easily reproducible.
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Methodologies for	r Evaluation			

Type of simulations

- Traditional simulation:
 - Ideal situations (sometimes not very realistic).
 - It does not include real components in the simulation.
- Hardware-in-the-loop simulation:
 - Includes real components in the simulation: on-line human feedback, signals from real devices.
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Our proposal

Our previous work [1]:

[1] R. Ordonez-Hurtado, W. Griggs, K. Massow and R. Shorten. Intelligent Speed Advising Based on Cooperative Traffic Scenario Determination. Lecture Notes in Control and Information Sciences, Springer, accepted.

- An dynamic advisory ISA system:
 - First stage: Traffic scenario determination supported on vehicle-to-vehicle (V2V) communication.
 - <u>Second stage:</u> Recommended parameters calculation supported on the determined traffic scenario.
- Evaluation using a off-line simulation:
 - The target vehicle and all the other vehicles are simulated.

The current work:

- Evaluation using a hardware-in-the-loop simulation:
 - The target vehicle is a real car embedded into a real-time simulation [2], and all the other vehicles are simulated.
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First stage:	Traffic scenario determination			
Tra	affic determination			
	 Depends on both space 	e and time.		
	 Thus, a reference in sp 	bace and time is nee	eded.	
		\		

(HV), i.e. a point in the future trajectory of the HV









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Trat	ffic determination			
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Nex	t point of interest (NP)		

• The NPI is a spatial-temporal reference for the Host Vehicle (HV), i.e. a point in the future trajectory of the HV.









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First stage:	Traffic scenario determination			
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Next point of interest (NPI)

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Motivation 000000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results 0000	Summary
First stage: Tr	affic scenario determination			

The NV is a vehicle representing the NPI. It can be a real vehicle or a virtual vehicle.

Real NV

The nearest vehicle to the NPI inside a radius *r_N*.

Virtual NV

Placed at the NPI if no one vehicle is inside a radius r_N .



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lt is	estimated using inform	nation from V2V cor	mmunication [3]:	
		$\delta = \frac{n_r + 1}{A}$		
n _r is area	the number of vehicle	s inside a radious r_L	, A is the "polling	
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Polling area

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	Polling area				
	If $2r_D \leq W_R$				
	$ = \underbrace{ \begin{pmatrix} v_{12} \\ W_{R} \end{pmatrix}}_{A^{2} = \pi r_{D}^{2}} \underbrace{ \begin{pmatrix} \vdots \\ W_{R} \end{pmatrix}}_{W_{R}} \underbrace{ \begin{pmatrix} \vdots \\ W_{R} \end{pmatrix}}_{W$	yr.			

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Po	olling area			
	If $2r_D > W_R$			

 $A = 2r_D W_R$

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First s	stage: Tra	ffic scenario determination			
	Final	lly			
	Traff	ic scenario is determine	ed with a rule-based	l inference engine	:
	•	Inputs: density $(\bar{\delta}_H, \bar{\delta}_N)$) and speed (\bar{V}_H, \bar{V}_I)	$_{\rm V},\Delta \bar{V}_{\rm H})$ information	on.
	۰	Outputs: Free Traffic (Congested Traffic (CT Congestion (LC).	FT), Approaching), Passing Bottlened	Congestion (AC), ck (PB) and Leav	ing
	۲	28 IF-THEN rules:			
		<u>R_9</u> : IF \bar{V}_H , \bar{V}_N , $\bar{\delta}_N$ ar	e LOW and $\bar{\delta}_H$ is HI	GH and $\Delta \overline{V}_H$ is NE	G
		THEN (CT is YES	and FT, AC, PB,	LC <i>are</i> NOT) (1.0	
	The	the scenario is given	by:		_

 $f = \operatorname{argmax}(FC, AC, CT, PB, LC)$

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Then, the scenario is given by:

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First st	age: Traffic scenario determination			
1	Finally			
	Traffic scenario is determin	ned with a rule-based	l inference engine	::
	• Inputs: density $(\bar{\delta}_H, \bar{\delta}_H)$	V) and speed $(ar{V}_H,ar{V}_H)$	$_{N},\Deltaar{V}_{H})$ informati	on.
	 Outputs: Free Traffic Congested Traffic (CT Congestion (LC). 	(FT), Approaching Γ), Passing Bottlenee	Congestion (AC), ck (PB) and Leav	'ing

• 28 IF-THEN rules:

<u> R_9 </u>: **IF** \bar{V}_H , \bar{V}_N , $\bar{\delta}_N$ are LOW and $\bar{\delta}_H$ is HIGH and $\Delta \bar{V}_H$ is NEG

THEN (CT is YES and FT, AC, PB, LC are NOT) (1.0)

Then, the scenario is given by

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Motiv 0000	Ition The Proposed Advisory System 00 000000	SUMO-phone Integration	Experimental Results 0000	Summary
First s	tage: Traffic scenario determination			
	Finally			
	Traffic scenario is determin	ed with a rule-based	l inference engine	:
	• Inputs: density $(\bar{\delta}_H, \bar{\delta}_N)$) and speed (\bar{V}_H, \bar{V}_I)	$_{\rm W},\Deltaar{V}_{H})$ informati	on.
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Then, the scenario is given by:

 $T = \operatorname{argmax}(FC, AC, CT, PB, LC)$

Motivation 000000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results 0000	Summa
Second stage	e: Speed and distance recommendations			
Vir	tual vehicle dynamic			
Po: its	sition of the Virtual NV speed?	is given by the NPI	, but what abou	Jt
	e speed model			

A simple model is used:

$$V(t) = \alpha V(t-1)$$

In our case we have:

 $V_{N}\left(t
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ight)V_{N}\left(t-1
ight)$, Speed limit)

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Second	stage: Speed and distance recommendations			
	Virtual vehicle dynamic Position of the Virtual NV i	s given by the NPI	, but what abo	ut
	its speed?			

The speed model

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ight)$, Speed limit)

Traffic scenario	FT	AC	СТ	PB	LC
α _{NV}	1.4	0.7	0.9	0.9	1.4

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Motivation	The Proposed Advisory System	SUMO-phone Integration	Experimental Results	Summary
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Second stage: Sp	peed and distance recommendations			

Recommended speed

Our speed recommendation is a time-variant weighted sum of V_H and V_N :

$$V_{R}(t) = \alpha_{R}(t) V_{N} + (1 - \alpha_{R}(t)) V_{H}$$

Traffic scenario	FT	AC	СТ	PB	LC
α _R	0.7	0.7	0.7	0.45	0.7



Motivation	The Proposed Advisory System	SUMO-phone Integration	Experimental Results	Summary
	0000000			
Second stage: Sp	eed and distance recommendations			

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Motivation 000000	The Proposed Advisory System ○○○○○○●	SUMO-phone Integration	Experimental Results 0000	Summar
Second stage:	Speed and distance recommendations			
Safe	e distance			
Dist	ance recommendation is	s based on a policy	for safe distance:	
	$D_{R}\left(t\right)=h_{0}+h_{1}$	$V_H(t) + h_2\left(V_H^2(t)\right)$	$-V_{N}^{2}\left(t ight)$	
•	h_0 is the minimum safe	e distance,		
۹	h_1 is the reaction drive	er time,		
٥	h_2 is a design parameter	er.		
Dist	ance recommendation			

Finally, we use $e = D_{H-V} - D_R$ and the following convention for the distance recommendation:

• If e > 0, then distance is OK.

• If $-1m < e \le 0$, then distance is "Close".

• If $-2m < e \leq -1m$, then distance is "Very close".

Motivation 000000	The Proposed Advisory System ○○○○○○●	SUMO-phone Integration	Experimental Results 0000	Summary
Second stage:	Speed and distance recommendations			
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	$D_{R}(t) = h_{0} + h_{1}$	$V_{H}(t) + h_{2}\left(V_{H}^{2}(t)\right)$	$-V_{N}^{2}(t))$	

- *h*⁰ is the minimum safe distance,
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Motivation 000000	The Proposed Advisory System	SUMO-phone Integration ●○○	Experimental Results 0000	Summary
The simulation p	latform			

• A HIL simulation to evaluate the performance of the proposed advisory system.









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The simulation pl	atform			

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Motivation 000000	The Proposed Advisory System	SUMO-phone Integration ○●○	Experimental Results 0000	Summary
HIL capabilities				

Interconnection of components









Motivation 000000	The Proposed Advisory System	SUMO-phone Integration ○●○	Experimental Results 0000	Summary
HIL capabilities				

Interconnection of components











Motivation 000000	The Proposed Advisory System	SUMO-phone Integration ○●○	Experimental Results 0000	Summary
HIL capabilities				

Interconnection of components












Motivation 000000	The Proposed Advisory System	SUMO-phone Integration ○●○	Experimental Results 0000	Summary
HIL capabilities				

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HIL capabilities				

Interconnection of components













Motivation 000000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results	
Simulation Setup				

SUMO

<u>The road:</u> A street circuit around the North Campus, National University of Ireland -Maynooth.



Parameters.

- Simulated vehicles: 23.
- Attributes of vehicles:



Motivation 000000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results	
Simulation Setup				

SUMO

<u>The road:</u> A street circuit around the North Campus, National University of Ireland -Maynooth.



Parameters

- Simulated vehicles: 23.
- Attributes of vehicles:

Туре	А	В	C	D
Accel	2.15	5.5	4.54	50
Decel	1.22	5.0	4.51	30
Length	1.75	6.1	4.45	40
Max.S.	2.45	6.1	4.48	50



Motivation 000000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results 0●00	
Simulation Setup				

Smartphone

The phone:

SU

Hamilton Institute

- Samsung Galaxy S III mini (GT-I8190N),
- Android Jeally Bean (V 4.1.2), Torque Pro.

The updating rate: 1 second.



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Host Vehicle

<u>The real vehicle:</u> 2008 Toyota Prius 1.5 5DR Hybrid Synergy Drive.

The OBD2 adaptor: Kiwi Bluetooth (PLX devices).

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Motivation 000000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results ○●○○	
Simulation Setup				

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Motivation 000000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results ○○●○	Summary
Tests				











Motivation 200000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results	Sun
raphical result	IS			
Follo	wing/ignoring the reco	ommendations		
youd read		PT scenario AP scenario Cf scenario Pf scenario Distance recommended Distance recommendation		0#-
0	6 105 110 120	105 140 150	Mp 1/0	9

Hamilton Institute







Motivation 000000	The Proposed Advisory System	SUMO-phone Integration	Experimental Results 0000	Summary

Summary

- HIL simulation let us evaluate non-obvious issues:
 - frequency/format of recommendations,
 - technical problems (e.g. synchronisation),
 - evaluation in risk conditions using a scenario under control.

- Future work
 - general paper: detailed setup, more illustrative examples.





R.H. Ordonez-Hurtado etal.

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