Intelligent Systems for Smart Cities

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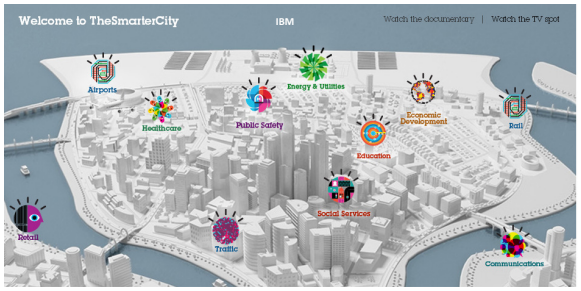
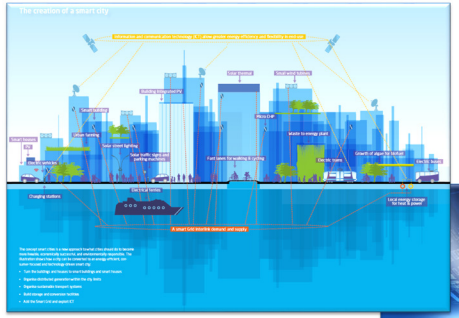
Smart cities: unique features



- HOLISTIC
- TECHNOLOGY
- INFORMATICS
- TELECOMS
- MULTIDISCIPL.
- CITIZENS
- MANAGERS

Introduction	Healthcare	Education
Traffic	Airports	Rail
Energy & Utilities	Social Services	Public Safety
Retail	Communications	Economic Development

Many views: potential targets



THINK BIG

THINK SMALL

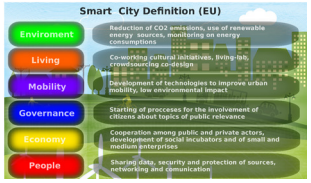
Many views: applications and infrastructure

FOCUS ON SERVICES

FOCUS ON ARQUITECTURE

Many views: institutional in Europe

- Eleven priority areas defined in the Strategic Implementation Plan of the European Innovation Partnership on Smart Cities and Communities:
  - Sustainable Urban Mobility
  - Sustainable Districts and Built Environment
  - Integrated Infrastructures and processes across Energy, ICT and Transport
  - Citizen focus
  - Policy and Regulation
  - Integrated Planning & management
  - Knowledge Sharing
  - Baselines, Performance Indicators & Metrics
  - Open data governance
  - Standards
  - Business Models, Procurement and Funding



- For the time being, 8 of the 11 priority areas are covered by the Action Clusters

Many views: IT and intelligence

Smart cities: challenges

Unique features mean unique challenges:

- Large scale, every is really big
- Time consuming and real time
- Dynamic, everything changes in time
- Uncertainty in all tasks and phases
- Complex relations, interdependences
- Several goals at the same time
- Human preferences and interfaces
- Lots of restrictions (legal, technical…)
- Mobile plus desktop applications

Bioinspired techniques and more

- Research in biologically inspired techniques applied to complex problems
- Focus on any technique helping to get efficient and accurate results
- Even advanced methods cannot deal with complex instances of real problems: high dimension, constrains, epistasis, uncertain data, real time, …
- Traditional methods put so many constrains and simplifications to the problem (in order to solve it) that the found solution is no longer valid

METAHEURISTIC

- Heuristic: information or procedure used to guide the search of algorithms
- Meta: high level structure containing operators later tailored to problems
- Many scientific fields involved: computer science, and also mathematics, operations research, industrial engineering, physics, …

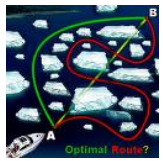
Metaheuristic versus the rest of solvers

How they work ⇨

Exhaustive

Advanced

Metaheuristics



What this means ⇨

Others cannot...

MetaH CAN!

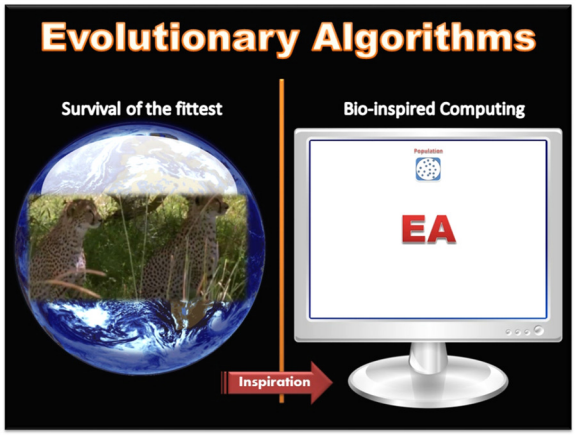
Classic Techniques

Metaheuristics

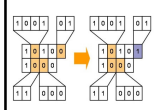
Advanced

efficiency

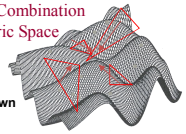
Efficient, accurate, and even Nature-inspired!



...but all of them run in a computer as programs



Convex Combination
Metric Space



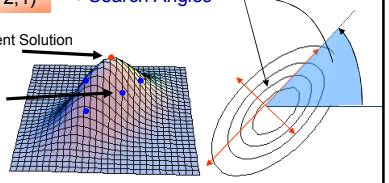
```
procedure ACOMetaheuristic
    ScheduleActivities
        ConstructAntsSolutions
        UpdatePheromones
        DaemonActions // optional
    end ScheduleActivities
end procedure
```

Inspiration

(0,2; -1,4; 3,5) → Solution Vector
(1,0; 10,3; 7,2) → Standard Deviation
(1,7; 0,3; 2,1) → Search Angles

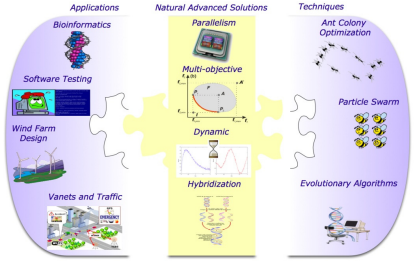
Present Solution

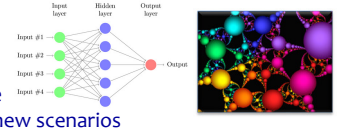
New Solution



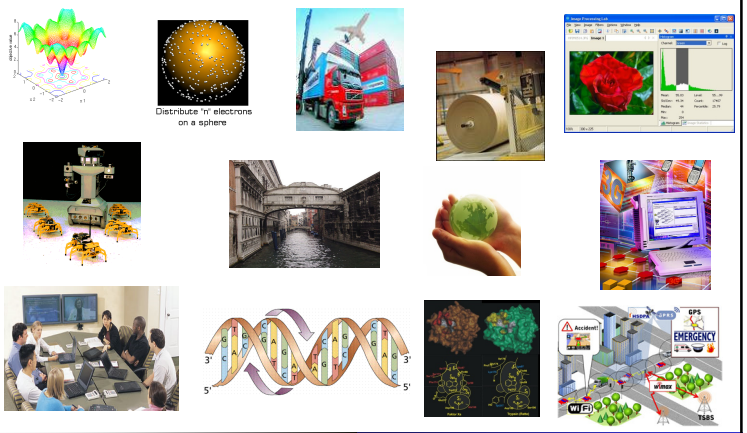
Advanced techniques needed

- Four main ways of upgrading in **efficiency** and **accuracy**:
  - **Parallelism:** Clusters, Cloud computing, multicores, FPGAs, GPUs...
  - **Hybridization:** Combining algorithms, operators, representations: problem knowledge
  - **Multiobjective:** Modelling explicitly several conflicting objective functions with Pareto's concept of dominance
  - **Dynamism:** Solve a problem that changes in time and adapt previous solutions to the new scenarios





Multidisciplinary experience is common here



Scientific success reported in journals...

Companies and city administrations are deeply involved

Applications (I)

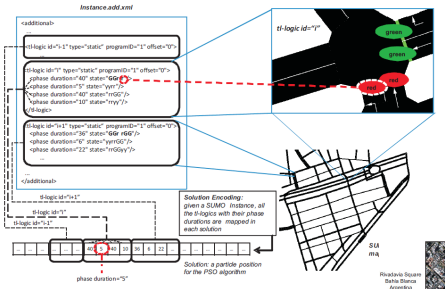
Smart Mobility

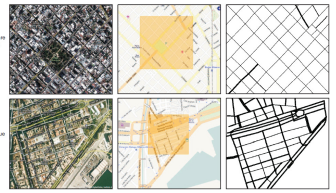
http://roadME.lcc.uma.es

Smart semaphores control: approach

- A software tool for the control center, using a bio-inspired engine, to assist the experts on the semaphore scheduling, for a given urban area or the whole city
- By means of simulation and other software facilities used in the Traffic Control Center of the city, we can generate optimized traffic schedules and efficient strategies of smart mobility for semaphores
- Optimized schedules can then be later applied to real traffic management, after verification tests with such a simulated program (off-line plus on-line)

Smart semaphore control: technologies

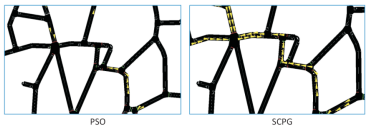


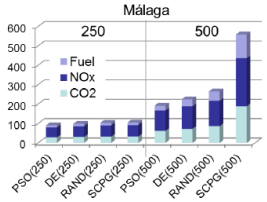


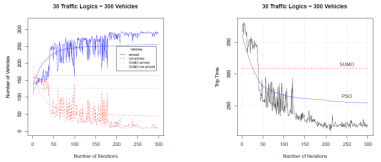
- High dimension problem
- Considering the whole city details
- Maps, locations, driving rules, vehicles…
- Comprehensive simulations with real data
- Long processing times

Smart semaphore control: results

- Optimized semaphore schedules have benefits in terms of:
  - Traffic congestion control
  - Prevention of severe traffic jams
  - Reduction of CO_2 emissions and fuel consumption
  - Driver/pedestrian safety
- A tech/tech combination
- Successful scientific results



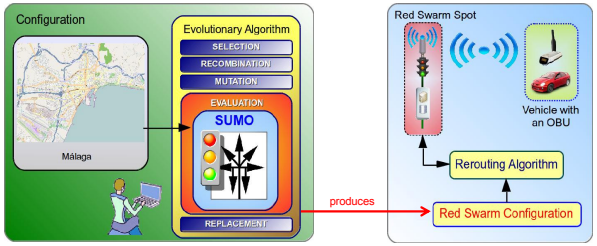




Smart Red Swarm: approach

- Smart road traffic optimization to avoid traffic jams and manage the city
- Red Swarm Spots have computation and comm. abilities (infrastructure)
- Vehicles use onboard units, smartphones or tablets
- It distributes traffic based on the probability of congestion: citizen-city balance
- Customized service for every driver
- First design, then use in real time
- Routes is just one use
- Other uses involve big data apps:
  - collecting info from passing vehicles
  - create math models of the city
  - off plus on line merged management

Smart Red Swarm: arquitecture



CENTRALIZED OFFLINE ONLINE DISTRIBUTED

An evolutionary algorithm searches for a configuration for the Red Swarm spots

The configured Red Swarm spots are deployed in junctions of the city

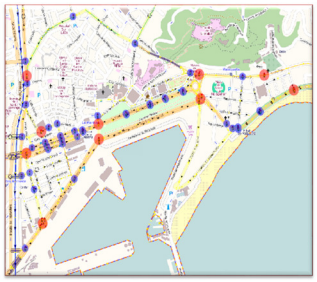
GOAL: smart mobility

Reduce travel times, gas consumption, and pollution

Smart Red Swarm: technical details

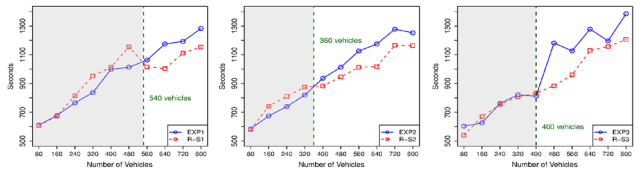
MÁLAGA (SPAIN)

- Real Scenario
  - 261 traffic lights
  - 10 Red Swarm spots
  - 800 vehicles
  - 4 vehicle types
  - 3 different traffic patterns (*Scen1*, *Scen2* & *Scen3*)



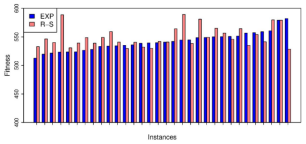
Our goal is to reduce the travel time of the vehicles in high density conditions, and then pollution

Smart Red Swarm: some results on travel times

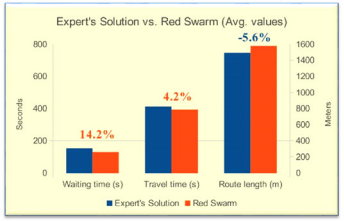


Show videos...

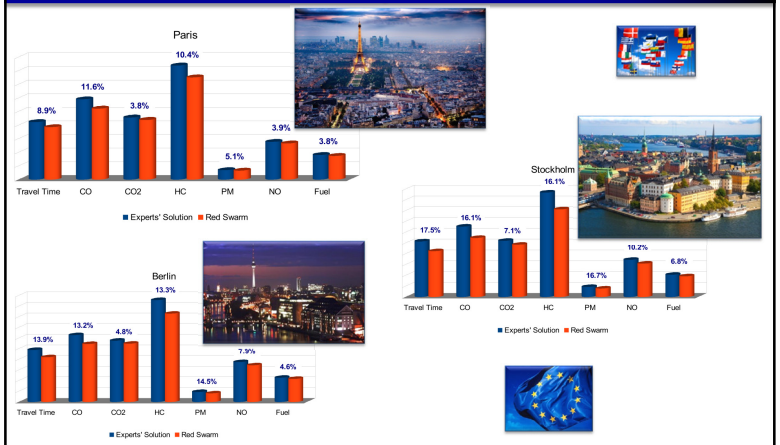
It works in unseen scenarios



Red Swarm reduces travel and waiting times



Smart Red Swarm: ecofriendly results



Vehicular Ad-hoc Networks: how to comm in cities?

- Communication and computation are the bases for smart cities
- Wireless communications are preferred (flexible, ubiquitious…)
- All communications rely on broadcasting and routing protocols
- Existing protocols do not work in VANETS: new and tuned ones are needed
  - (i) **V2V: vehicle to vehicle**
  - (ii) **V2I: vehicle to infrastructure**

Optimizing communication protocols in cities

- VANET Protocol Optimization:

  - VANET communications imply: highly dynamic topology, limitations in coverage, bandwidth, and energy consumption, network congestion, frequent disconnections, and others…

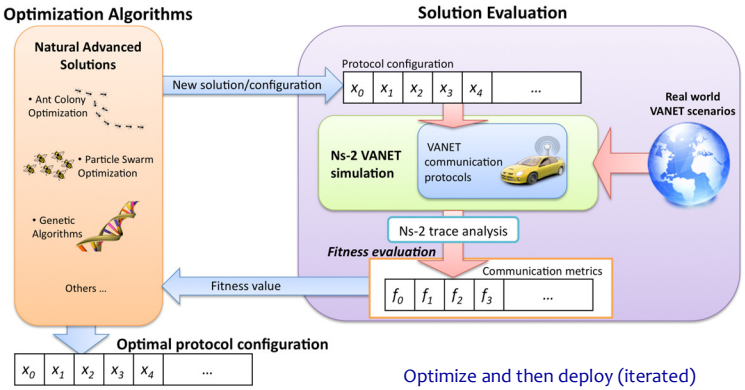
  - An optimal configuration of the communication protocols can improve the quality-of-service (QoS) of the network: a must in this domain

  - Using intelligent automatic techniques to face the huge number of possible protocol configurations

AODV RFC 3561

Parameter	Default Values	Range
ACTIVE_ROUTE_TIMEOUT	3.0 s	1.0 ··· 10.0
ALLOWED_HELLO_LOSS	2 HELLO packets	1 ··· 10
MY_ROUTE_TIMEOUT	2.0×ACTIVE_ROUTE_TIMEOUT	1.0 ··· 10.0
NET_DIAMETER	35 nodes	1 ··· 50
NODE_TRAVERSAL_TIME	0.04 s	0.01 ··· 1.0
NET_TRAVERSAL_TIME	2.0×NODE_TRAVERSAL_TIME ×NET_DIAMETER	1.0 ··· 10.0
RREQ_RETRIES	2 tries	1 ··· 10
RREQ_RATELIMIT	10.0 kbps	1.0 ··· 10.0
TTL_START	1.0 s	1.0 ··· 10.0
TTL_INCREMENT	2.0 s	1.0 ··· 10.0
TTL_THRESHOLD	7.0 s	1.0 ··· 20.0

Optimization by using simulators fed with real data

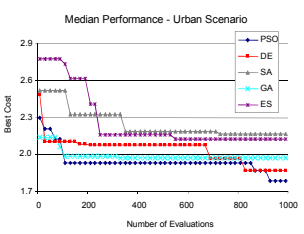


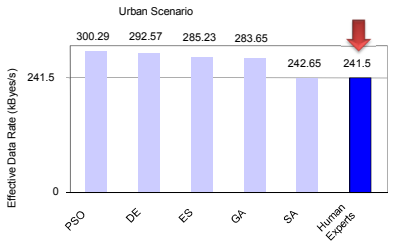
Optimize and then deploy (iterated)

Broadcasting optimization: QoS in VANETs

$$fitness = w_1 \cdot (-PDR) + w_2 \cdot NRL + w_3 \cdot AEED \cdot C$$

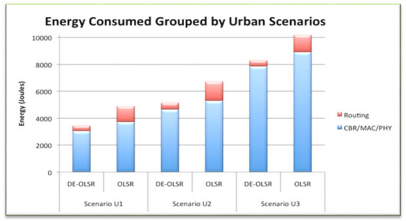
Packet Delivery Ratio — Network Routing Load — Average End-to-End Delay

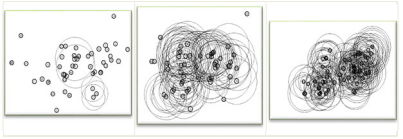




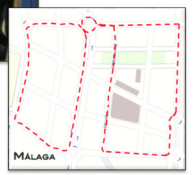
Green communications: optimizing energy

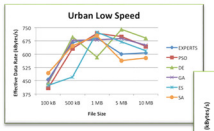
fitness = energy_consumption

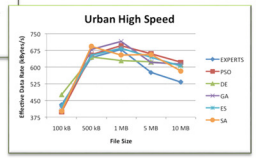


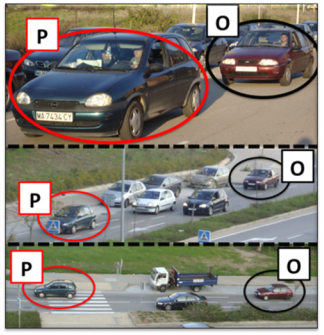


Real world tests









- From simulation to real world results:
  - The real world test results confirm the (ns-3) simulated ones

Smart panels (I)

- Smart panel services are needed to advise users on the path to reach major places in town, minimizing travel time, fuel consumption, and noise
- The advises are available in information panels at strategic points in the city: traffic lights, parking lots, stop signals, etc.
- The system takes into account traffic state and future predictions, CO_2 levels and noise level

Smart panels (II)

- Benefits for the citizen:
  - Save driving time
  - Avoid traffic jams
  - Saves fuel
- Benefits for the city:
  - Reduce traffic jams
  - Reduce CO_2 emissions
  - Save energy (fuel)
  - Reduce noise pollution

Smart bus scheduling (I)

- The generalized utilization of the smart cards in city buses and new services of free transfer between buses allow to gather a lot of interesting data: more common transfers, rush hour per line, …
- Applications could allow to use all those data to generate a better flexible scheduling of buses lines, doing an optimal utilization of the available fleet of buses

	ORIGEN	HORARIO
LABORALES	MALAGA CENTRO	6.00 - 7.00 / 7.20 / 7.40 / 8.00 / 8.20 / 8.40 / 9.00 / 9.20 / 9.40 / 10.00 / 10.20 / 10.40 / 11.00 / 11.20 / 11.40 / 12.00 / 12.20 / 12.40 / 13.00 / 13.20 / 13.40 / 14.00 / 14.20 / 14.40 / 15.00 / 15.20 / 15.40 / 16.00 / 16.20 / 16.40 / 17.00 / 17.20 / 17.40 / 18.00 / 18.20 / 18.40 / 19.00 / 19.20 / 19.40 / 20.00 / 20.20 / 20.40 / 21.00 / 21.20 / 21.40 / 22.00 / 22.20 / 22.40 / 23.00
	AEROPUERTO	7.00 / 7.40 / 8.10 / 8.30 / 8.50 / 9.10 / 9.30 / 10.00 / 10.30 / 11.00 / 11.30 / 11.40 / 12.00 / 12.30 / 13.00 / 13.30 / 14.00 / 14.30 / 15.00 / 15.30 / 16.00 / 16.30 / 17.00 / 17.30 / 18.00 / 18.30 / 19.00 / 19.30 / 20.00 / 20.30 / 21.00 / 21.30 / 22.00 / 22.30 / 23.00 / 23.30 / 24.00
SABADOS	MALAGA CENTRO	6.30 / 7.00 / 7.30 / 8.00 / 8.30 / 9.00 / 9.30 / 10.00 / 10.30 / 11.00 / 11.30 / 12.00 / 12.30 / 13.00 / 13.30 / 14.00 / 14.30 / 15.00 / 15.30 / 16.00 / 16.30 / 17.00 / 17.30 / 18.00 / 18.30 / 19.00 / 19.30 / 20.00 / 20.30 / 21.00 / 21.30 / 22.00 / 22.30 / 23.00 / 23.30 / 24.00
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FESTIVOS	MALAGA CENTRO	8.00 / 8.30 / 9.00 / 9.30 / 10.00 / 10.30 / 11.00 / 11.30 / 12.00 / 12.30 / 13.00 / 13.30 / 14.00 / 14.30 / 15.00 / 15.30 / 16.00 / 16.30 / 17.00 / 17.30 / 18.00 / 18.30 / 19.00 / 19.30 / 20.00 / 20.30 / 21.00 / 21.30 / 22.00 / 22.30 / 23.00 / 23.30 / 24.00
	AEROPUERTO	7.00 / 7.40 / 8.05 / 8.30 / 9.00 / 9.30 / 10.00 / 10.30 / 11.00 / 11.30 / 12.00 / 12.30 / 13.00 / 13.30 / 14.00 / 14.30 / 15.00 / 15.30 / 16.00 / 16.30 / 17.00 / 17.30 / 18.00 / 18.30 / 19.00 / 19.30 / 20.00 / 20.30 / 21.00 / 21.30 / 22.00 / 22.30 / 23.00 / 23.30 / 24.00

EMT

Smart bus scheduling (II)

- The scheduling generated by the proposed application is flexible and it also allows to small changes (few minutes) in the departures of the buses to adjust their scheduling to the current situation. For example:
  - Quite a number of passengers (mainly students) of lines 20 and 22 do a transfer to line 5. The scheduling of line 5 can be online tuned (only a few minutes) if a delay is detected in lines 20 or 22

A small delay in line 20 will ask for a small delay in the departure of buses in line 5 and help bus transit

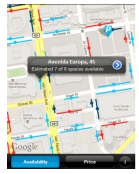
- Customized new services for sharing vehicles or for getting on the fly demands for home pick up and delivery

Smart EV management

- Electrical vehicles (EVs) have a reduced autonomy and battery. Tools for quick reaching/location a station are needed (traffic jams, unexpected events)
- Smart phone applications are needed to locate nearest charging stations considering time, prices, queues of early clients and citizen's preferences

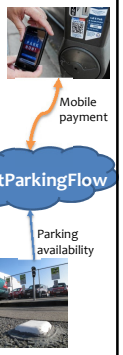
Smart surface parking (I)

- Smart parking services provides drivers with real-time information about parking availability according to a given destination
- Parking rates are adjusted according to the parking availability (flexible pricing)
  - Reducing the prices in the areas with more free parking places
- Allows mobile payment

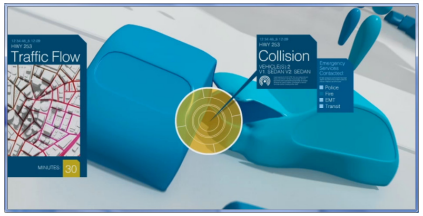


Smart surface parking (II)

- Benefits for the citizen:
  - Make finding and paying for parking faster and easier
  - Find the parking place anywhere with smartphones
  - Save driving time, and therefore, transport time
  - Avoid dangerous traffic situations
- Benefits for the city:
  - Distribute road users through different parking areas
  - Improve business by easing the parking
  - Reduce traffic jams
  - Reduce CO_2 emissions and noise pollution

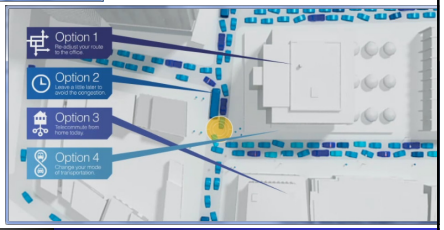


Smart signs



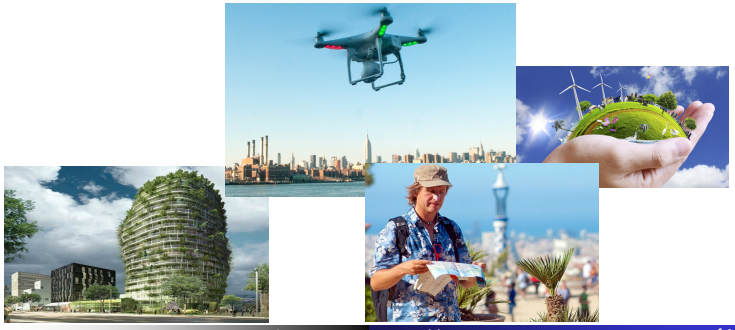
- Everything is better with WiFi !

- "Policemen near to you, ask for help"



Applications (II)

Energy, buildings and much more

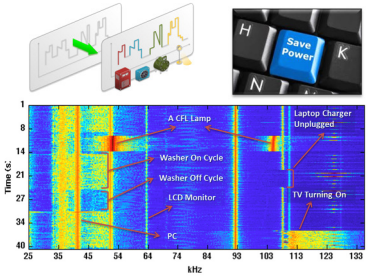


Smart energy systems

- Energy applications: generation, transportation, forecasting, and consumption
- Tremendous importance for companies, cities, and users!

Wind Farm Design

Disaggregation and Savings



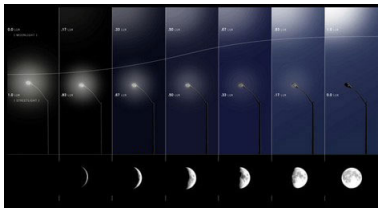
Smart lighting (I)

- Smart Lighting manages the city lights in order to reduce the energy consumption. It gives the correct illumination intensity for the city in an adaptive, collective, and intelligent way
- Benefits:
  - Reduce energy consumption
    - public lighting represents between 40% and 70% of the electricity bill of municipalities
  - Increase lifetime of city lights
    - a 5% reduction in operating voltage will more than double the life of a traditional bulb
  - Minimizes light pollution
  - Join the green revolution!
    - the least polluting energy is the one that is not used

- Requirements: few sensors and connectivity to city lighting

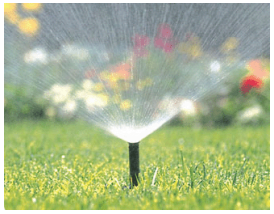
Smart lighting (II)

- Sensors detect the ambient lighting in different areas of the city. Public lighting adapt its intensity as needed
- Intelligent management of public lighting has a huge impact in energy consumption, saving a lot of money
- Málaga has 239 LED street lamps, with seven different technologies. The challenge is to fine tune their parameters to improve efficiency



Smart water jet systems (I)

- This smart garden watering system improves gardening activities in the city by minimizing the waste of water



Smart water jet systems (II)

- It saves water by sensing the humidity of gardens
- It chooses the best moment of the day depending on the water pressure, temperature, etc.
- The optimizations of resources is based on swarm intelligence technologies
- It keeps a record of the activities to report the amount of water saved
- It can be easily integrated in the existent facilities of the city

Smart residuals gathering (I)

- New services for the optimal planning route to collect all trash containers in a city. You will know whether the trash containers are full and when they should be gathered
- Benefits:
  - Clean city (many millions of euros savings)
  - Save in unnecessary collection visit
  - Less noise in our streets
  - Less bad smells
  - Avoid traffic jams (use of traffic information)
  - Service: "Pay as you throw"
- Only Need: GPS, RFID, and sensors
- Recycling creates four jobs for every one job created in the waste management and disposal industries

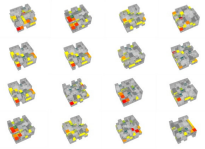
Smart residuals gathering (II)

- With WSN and RFID tags you can monitor the trash. The central system receives petitions when the on-site gather is required ( )
- With Optimal Routes you will save money, time and avoid contamination. Avoid the collection of 2 trash containers means 3.3 km less in this route

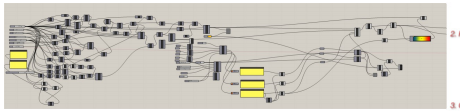
Traditional Route: 5.3km

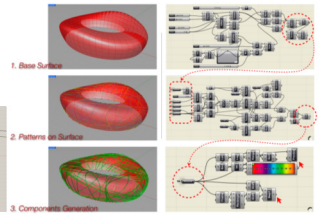
Optimal Route: 2km

Smart building construction: the approach



- Safer, sustainable, modern design principles
- Complex simulations needed
- Optimization and machine learning needed

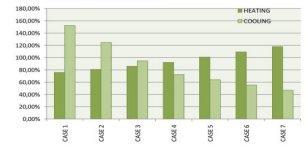


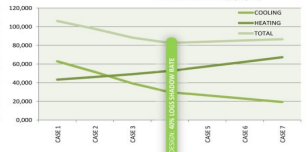


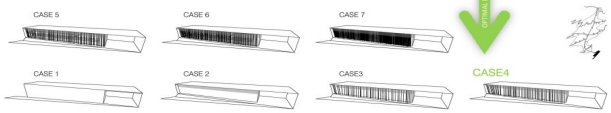
Smart building construction: techniques and technologies

ENERGY DEMAND ANALISYS (kWh/sqm)

		PROJECT			REFERENCE			%		LIMIT
		HEATING	COOLING	TOTAL	HEATING	COOLING	TOTAL	HEATING	COOLING	TOTAL
CASE 1	NO SHADOWS	43,290	62,920	106,210	57,006	41,282	98,288	75,94%	152,42%	100,00%
CASE 2	NO LOGS JUST PROJECTINGS	46,129	51,458	97,587	57,006	41,282	98,288	80,92%	124,65%	100,00%
CASE 3	25% LOGS SHADOW RATE	49,110	39,164	88,274	57,006	41,282	98,288	86,15%	94,87%	100,00%
CASE 4	40% LOGS SHADOW RATE	52,634	29,917	82,551	57,006	41,282	98,288	92,33%	72,47%	100,00%
CASE 5	50% LOGS SHADOW RATE	57,493	26,406	83,899	57,006	41,282	98,288	100,85%	63,97%	100,00%
CASE 6	75% LOGS SHADOW RATE	62,352	22,896	85,248	57,006	41,282	98,288	109,38%	55,46%	100,00%
CASE 7	100% LOGS SHADOW RATE	67,211	19,385	86,596	57,006	41,282	98,288	117,90%	46,96%	100,00%







Smart tourism (I)

- Smart Visit offers to city visitors a self-adaptive city trip planner that improves tourist experience

- The recommender system considers the users profile and up-to-minute sights information (queue timeouts, remaining capacity, …) in order to compute the travel itinerary that best fits the visitors at that precise moment

- The traveler can select the most convenient tour from the ones proposed by the application. This tour will be rated by the user in order to update and improve the recommender system

Smart tourism (II)

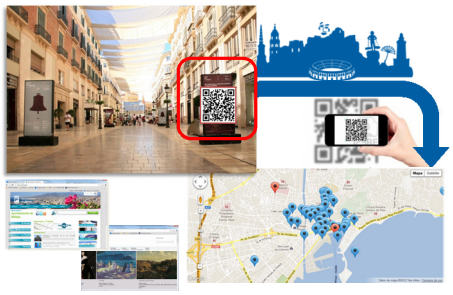
- Benefits for the city:
  - City sights are not overflowing with people
  - Authorities gather real-time visitors satisfaction information
  - Increasing tourist's satisfaction

- Benefits for the city visitors:
  - Save tour times avoiding long queues
  - Never get lost thanks to the GPS
  - Multilingual and multimedia sights description and events information
  - Increasing safety avoiding tourist traps

Smart QRinfo (I)

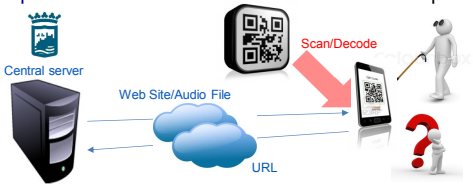
- Smart QRInfo allows new visitors to easily access to detailed city information in the context of where they are located
- QR-Code panels distributed in interesting points throughout the city can be captured by smartphones to directly serve information to the user with just one "click"
- A central web service will redirect dedicated links to real time information:

touristic places, events, welcome messages, administrative procedures, voice info-links, recommendations, activities, video-streaming, etc.



Smart QRinfo (II)

- With Smart QRInfo it is possible to redirect visitors' smartphones to official web sites, applications, and voice messages in a straightforward way
- The central service will gather and generate statistic information for a decision making process, such as: most visited links, sequence of captured QR-Codes in the city, the nature of demanded information…
- Voice messages delivering to blind people
- Low cost implementation: a minimum infrastructure is required



Smart monitoring (I)

- Smart measuring and surveillance of city spots

- Drones equipped with sensors can take images or capture data to be processed in a control center and then take actions

Smart monitoring (II)

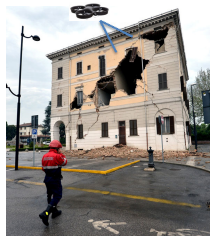
- Benefits:
  - Support to decisions by taking data from the city
  - Precise information of weather and environmental conditions
  - Better weather forecast in the city
  - Garbage in streets, beach…

Smart hawkeye (I)

- Smart building hawkeye allows the remote damage analysis of buildings and large structures
- Drones equipped with cameras can help detecting any cracks in the wall
- Different sensors can take additional accurate measures at precise points (temperature, humidity, …)
- Proprioception, swarm intelligence, autonomous control…

Different measurements

Building and structures analysis by authorities



Smart hawkeye (II)

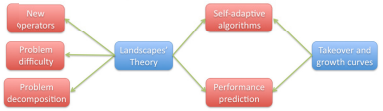
- Benefits:
  - Precise information of the building status
  - Working safer for technicians responsible for civil assessment
  - Avoiding traffic jams caused by the use of large crane trucks

Some projects: vehicular communication networks

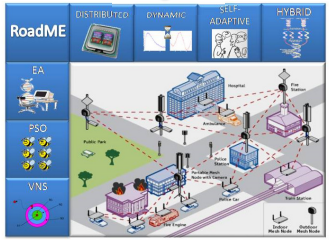
roadME

http://roadme.lcc.uma.es

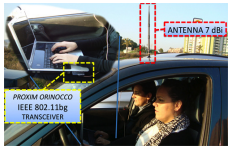
New techniques: from theory to practice

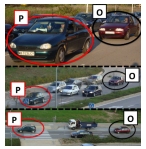


At a glance



Real life testing





Some projects: intelligent applications

http://maxct.lcc.uma.es

C T P A T H

F.E.D.E.R.

H I T U L

- App for drivers (Android & iOS)
- Central server + apps by 3G
- Central server + open data (FIWARE)
- Complete route vs. step-by-step
- Pure gathering of information (GINF)
- Interactive maps + open data
- Profiles of drivers (clustering)
- Hardware search and installation

- Desktop application
- Know and describe present policies
- Simulate Málaga and other cities
- Weekly and peak hours analyses
- Use of available open data
- Tests with the traffic control center
- Comparisons with existing tools
- Interactive maps of TRL

Some projects: holistic Intelligence

http://eip.lcc.uma.es

European Innovation Partnership 2014-2016

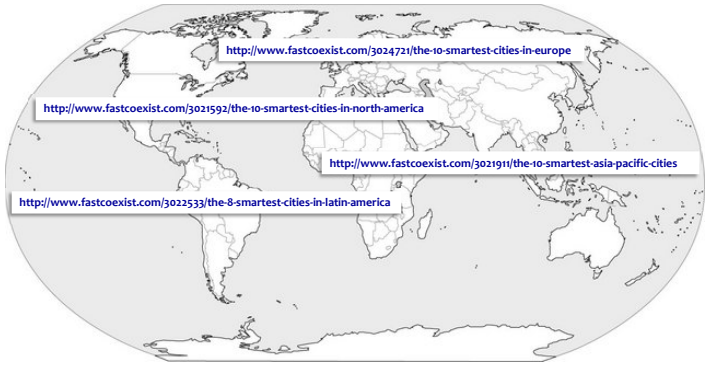
The place for smart cities in Europe

https://eu-smartcities.eu

#RESOURCES

Networking and Emerging Optimization 2015

Rankings on Smart cities



http://eponline.com/articles/2015/02/18/the-top-5-global-smart-cities-of-2015.aspx

Networking and Emerging Optimization 2015

Summary

- Smart cities need efficient and effective modern problem solvers
- We can use existing information and procedures to improve them (a must!)
- We can build small/large, context-aware and adaptive applications
- Here, solutions are both vertical (specialized) and horizontal (integral)
- We must face multiple levels at smart cities: citizens, districts, city, routes, infrastructure, city council, public/private companies…
- We can exploit open/big data to build unseen new services
- Incorporating a business model is mandatory: so how to make research?
- An amazing domain for new ideas and collaborations !!!

ACKNOWLEDGEMENTS

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¡Gracias!

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