ICAR 2011 WORKSHOP

Urban Service Robotics: Challenges and Opportunities

THE 15TH INTERNATIONAL CONFERENCE ON ADVANCED ROBOTICS

June 20, Tallinn

The DustCart service robot at work in the town of Peccioli: focus on social and legal challenges

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ISTITUTO ITALIANO

Scuola Superiore Sant'Anna
di Studi Universitari e di Perfezionamento

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- Study of legal bottlenecks
- DustCart testing in Peccioli
- Results and lessons learned from Peccioli testing
- What's next?

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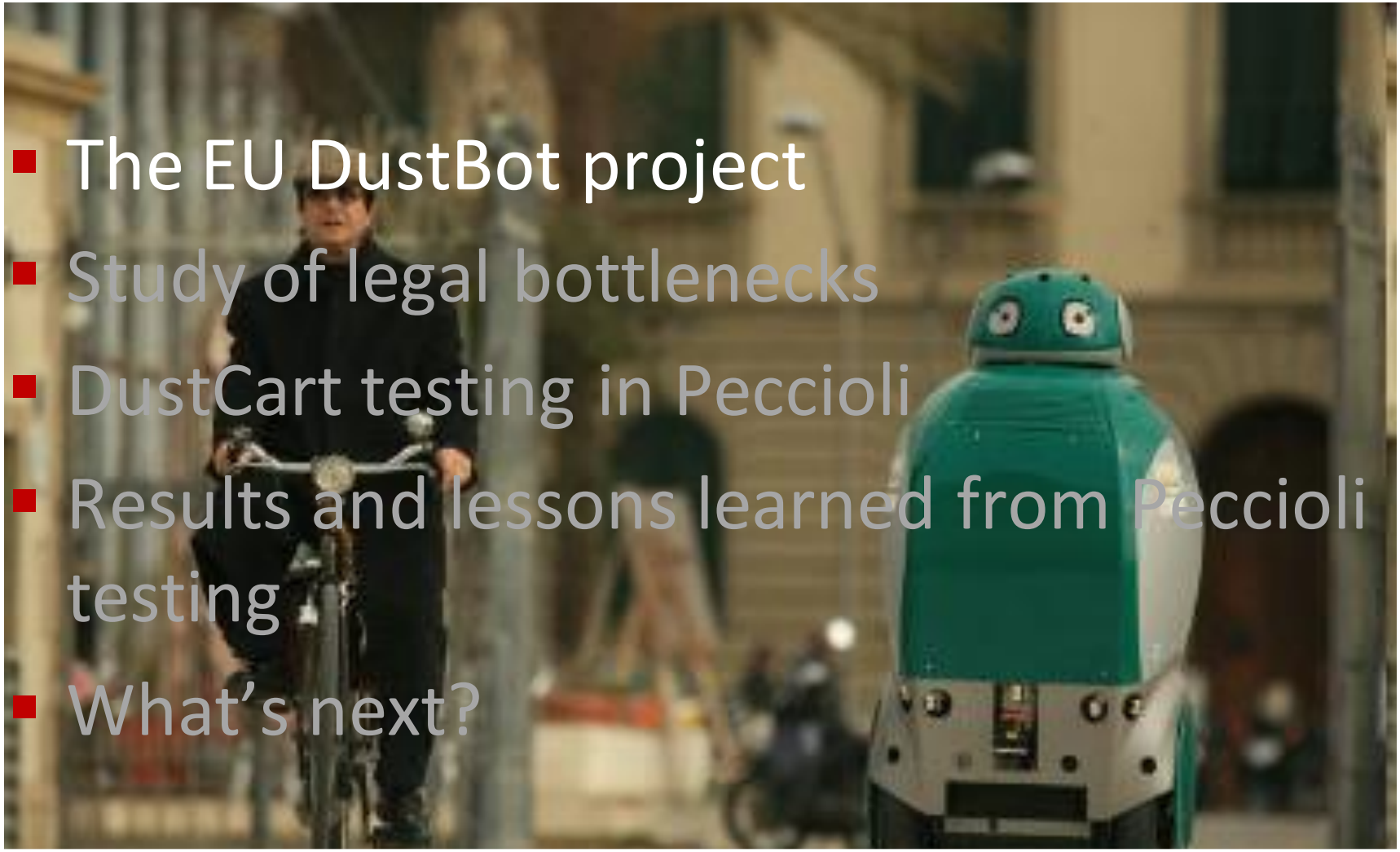

- The EU DustBot project
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DustBot

Networked and Cooperating Robots for Urban Hygiene

FP6-045299

The DustBot project is aimed at designing, developing, testing and demonstrating a system for improving the management of urban hygiene based on a network of autonomous and cooperating robots, embedded in an Ambient Intelligence infrastructure.

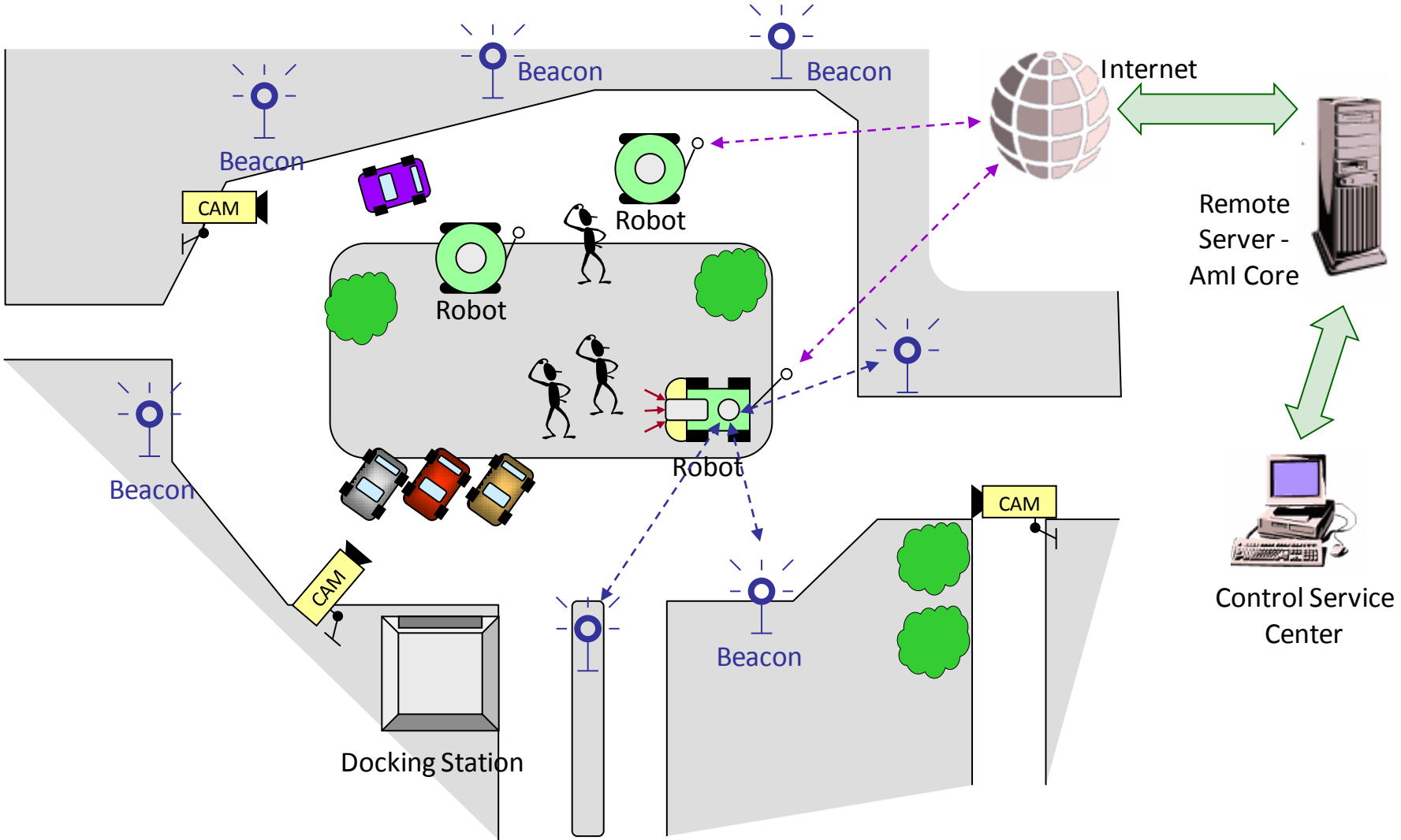
Information Society Technologies

Project Details
Start Date: 01-12-2006
End Date: 30-11-2009
Duration: 36 months

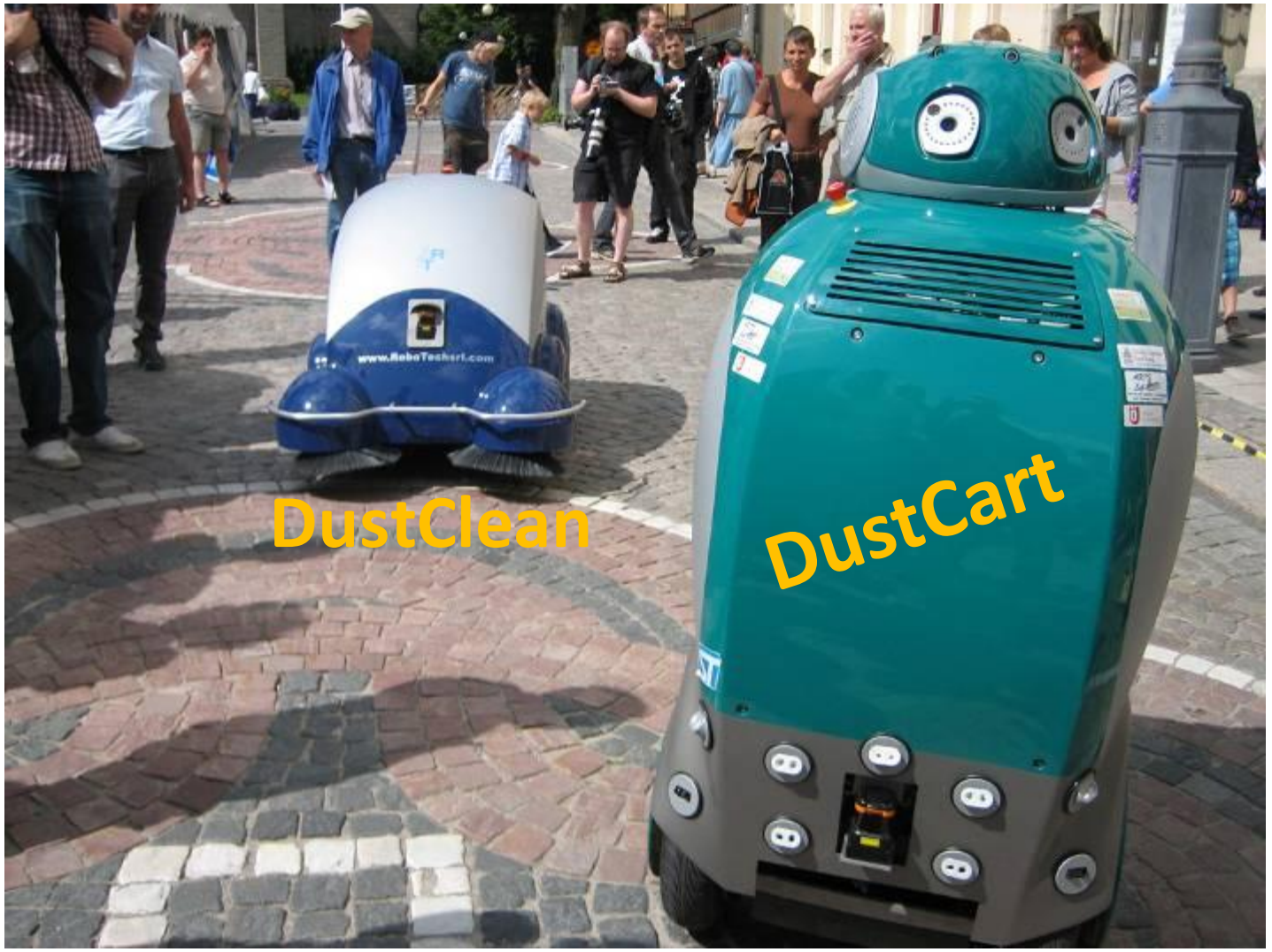
www.dustbot.org

DustBot Objectives

*The DustBot Project aimed at designing, developing and testing a system for improving the management of **urban hygiene**, based on a **network of autonomous robots**, embedded in an **Ambient Intelligence** infrastructure.*



The robots



Problems addressed by DustBot project

1. Door-to-door separate waste collection in central areas with difficult access by vehicles
2. Street cleaning in central areas with difficult access by vehicles
3. Air quality monitoring in pedestrian areas

Current solutions

Collection of garbage at home (door to door - Kerbside collection)

- How it works:

  Citizens have to prepare their garbage, properly separated, and deliver them **at given times in given areas**. Figure below shows an example of method for the separate collection of **dry recyclate**, **biodegradable materials**, **mixed material**, and **residual waste** from household waste. The method refers to the one currently used by the Pontedera Town Hall (Italy) in the city centre areas. The different colours refer to the different kinds of waste that is possible to dispose in the specified days. **Householders are asked to put the garbage outside the door in the morning from 8 to 9.** Later disposals or wrong disposals by householders will not be collected by urban operators.

The problem addressed by DustCart

- The robotic solution aims at improving door to door separate waste collection service:
  - Inadequacy of the services: **few collection per days** per week, family should keep garbage at home for many days

→ **The robot collects garbage on demand at home**

  - During collection **days garbage remains outside the door** in the street producing problems related to hygiene

→ **The robot transports immediately garbage away to the garbage collecting station**

The integrated urban waste cycle

Waste producers (e.g. citizens)

Information & Education

Generation

Waste selection

Urban Hygiene Companies

Collection

Recovering & Recycling

Disposal

Source: DustBot User Group

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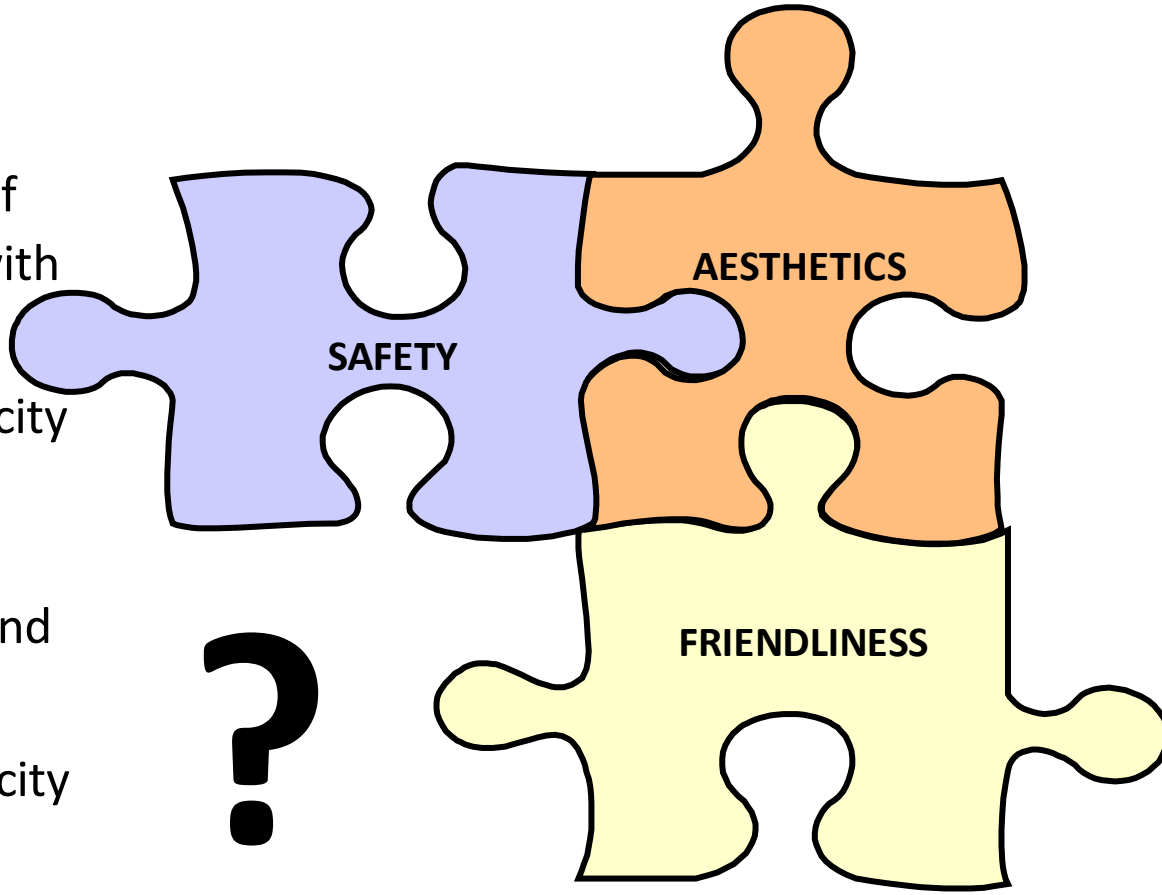
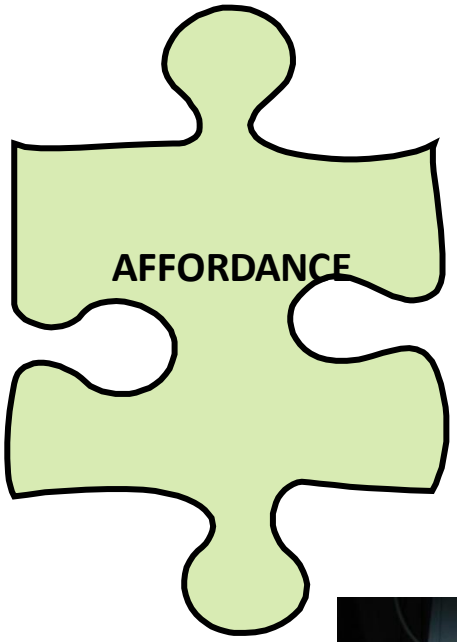
Design guidelines

1. **Perceived safety**: the level of danger perceived by users with regards to the robot
2. **Aesthetics:** the robot's capacity to be pleasant to the senses (especially to the sight) and elicit feelings of familiarity and pleasure in the user
3. **Friendliness:** the robot capacity to elicit an emotional engagement
4. **… ?**



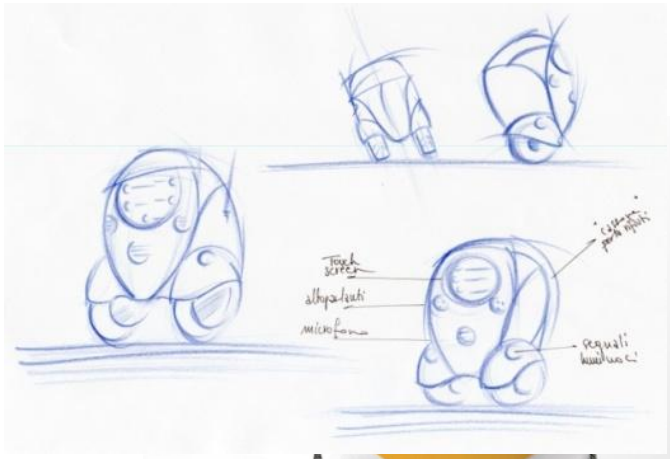
The concept of “affordance”

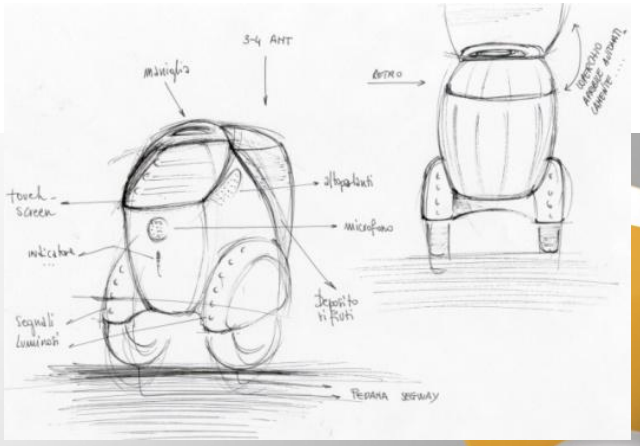


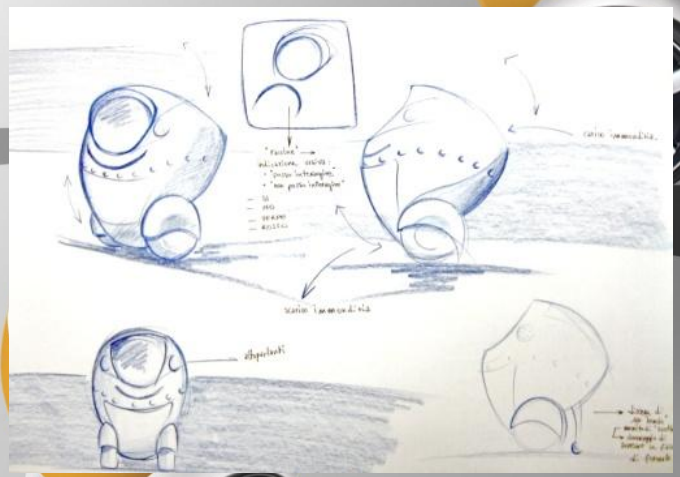
Affordance: The perceived and actual properties of an object that determine how it could possibly be used.

J.J. Gibson, *The ecological approach to visual perception,* 1966

Version A: aesthetics

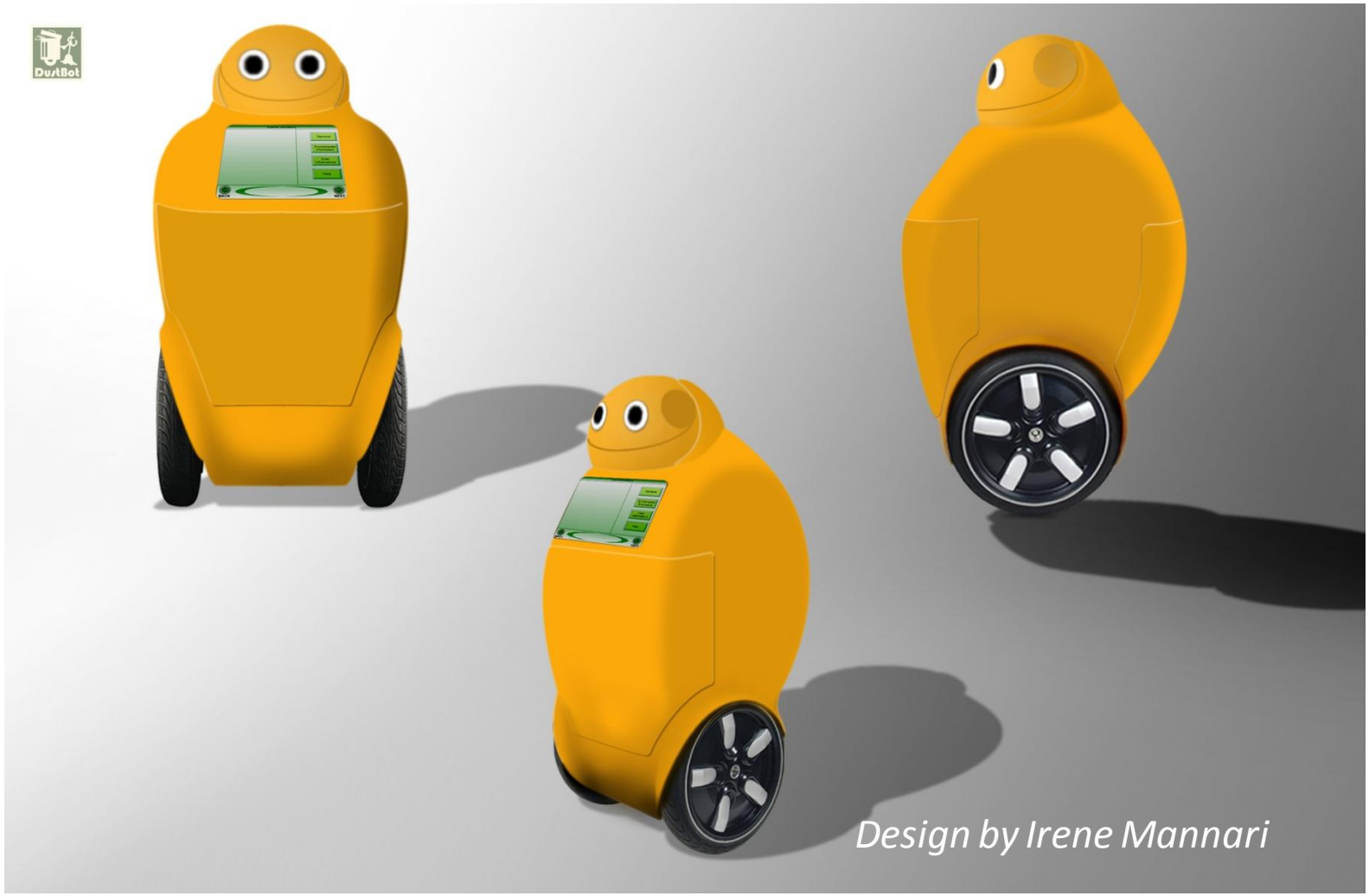




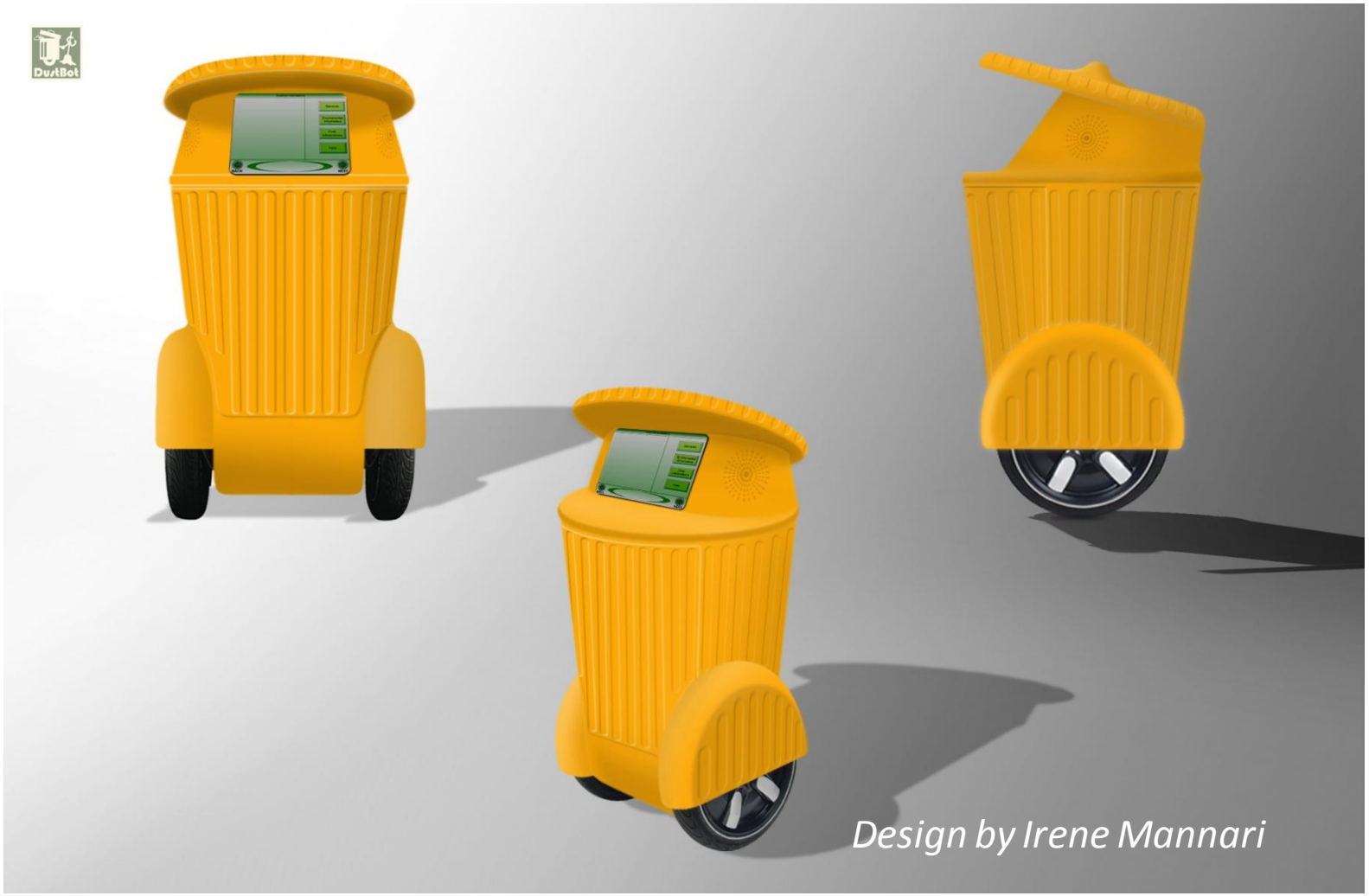


Design by Irene Mannari

Version B: friendliness

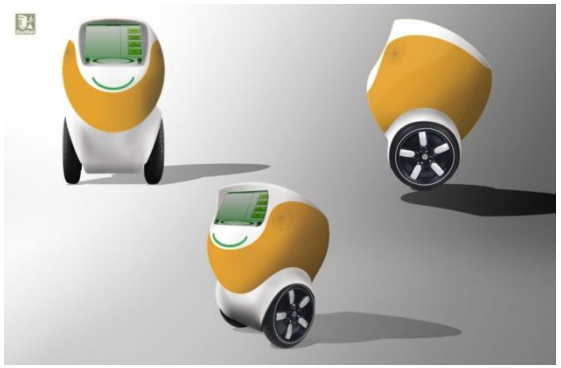


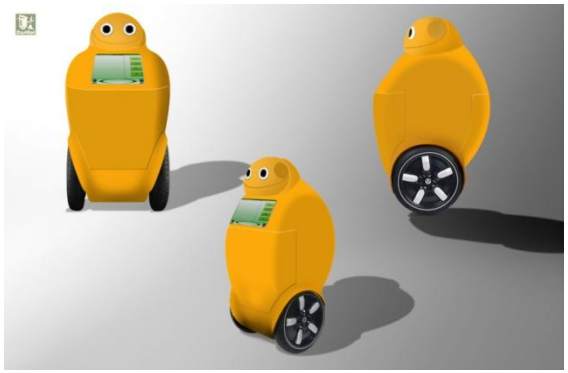
Version C: affordance

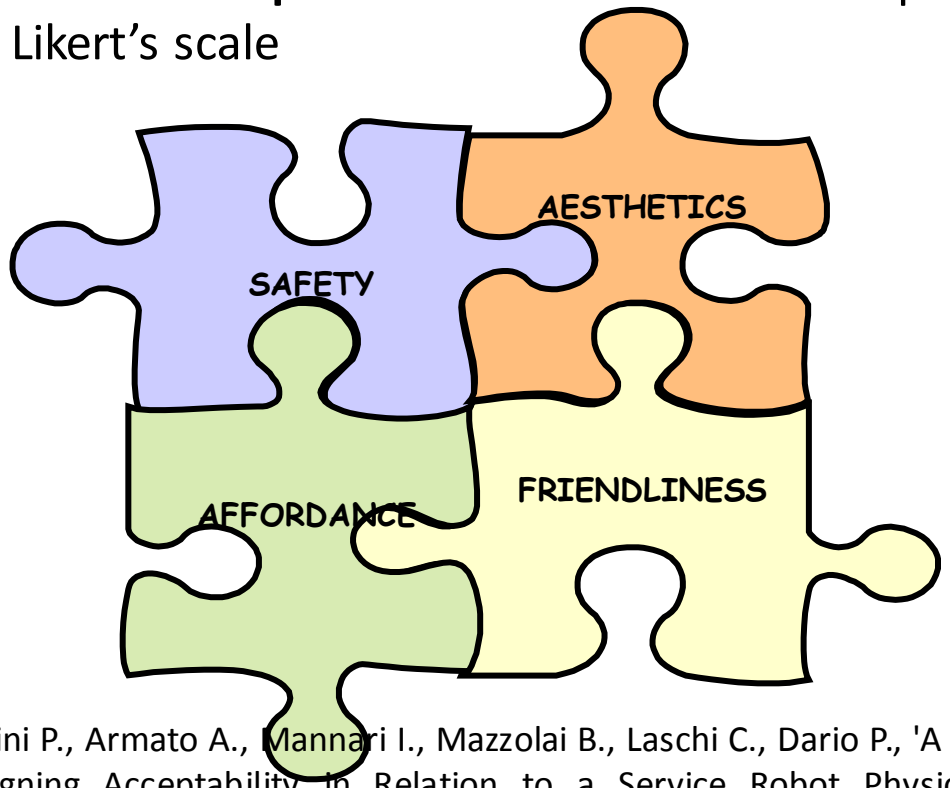


Test of paper prototypes with final users

- The survey consisted of:
  - **a written questionnaire** with general questions concerning the user (age, education, gender, attitude towards new technologies, etc.)
  - **group interviews** led by a moderator (two phases)
  - **a written questionnaire** with closed questions in Likert's scale

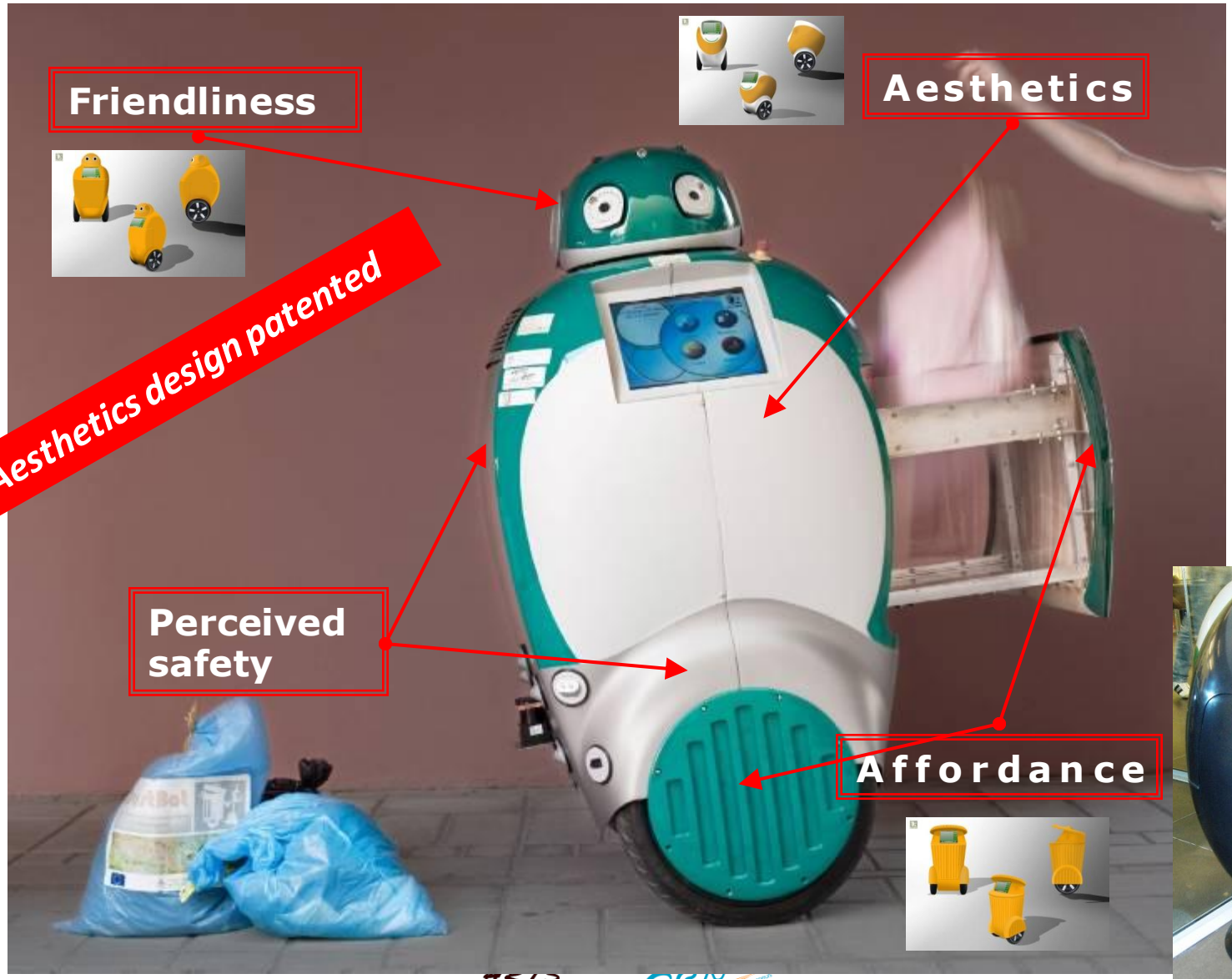






Salvini P., Armato A., Mannari I., Mazzolai B., Laschi C., Dario P., 'A Methodology for Designing Acceptability in Relation to a Service Robot Physical Appearance', Proceedings of the 8th International Workshop on Human-friendly Welfare Robotic Systems, KAIST, Daejeon, Korea, October 21-23, 2007.

Design for acceptability



The DustBot Scenario

Asking for DustCart services ...

... Just put your bag, as you do with an ordinary bin!

Please, press the button on the screen corresponding to the kind of garbage you wish to dispose!

Goodbye, thanks for using my services!

The DustBot Control Station

The workplace will be provided of these devices:

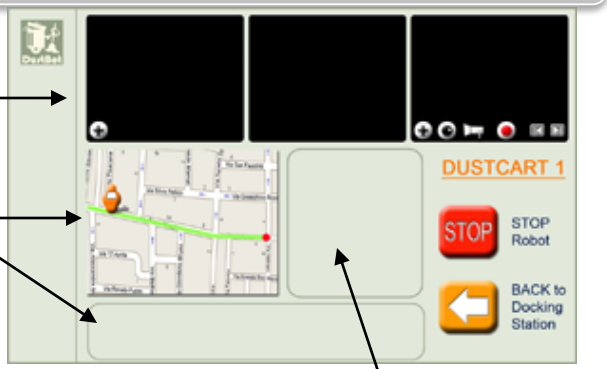
SCREEN 1

CITY MAP VIEW_ in this screen the operator can visualize, by means of an electronic cartography, all the robots working in the environment.

SCREEN 2

VIEW FROM EXTERNAL CAMERAS
in this screen are displayed in real time the images captured by the cameras distributed in the environment.

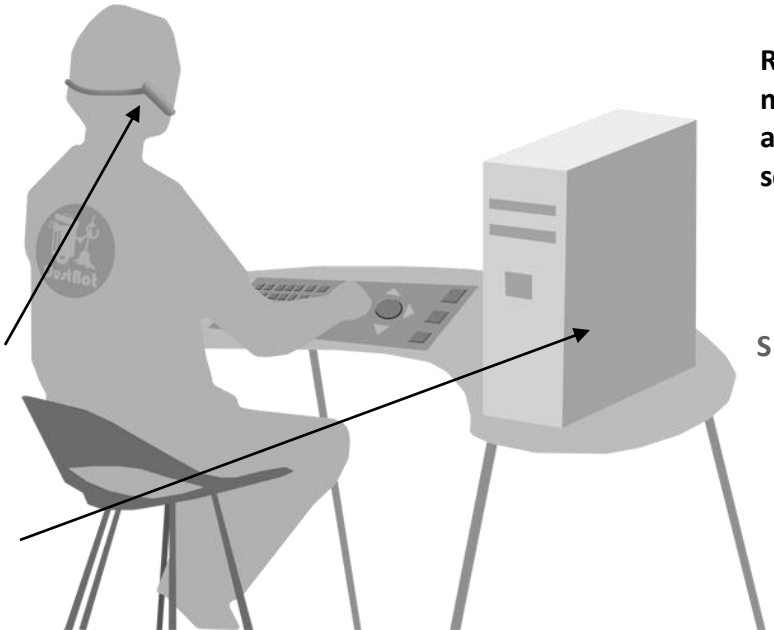
SCREEN 3



Images from the robot onboard cameras.

Robot movements map and list of appointments scheduled.

Robot general status (energy levels, etc.).



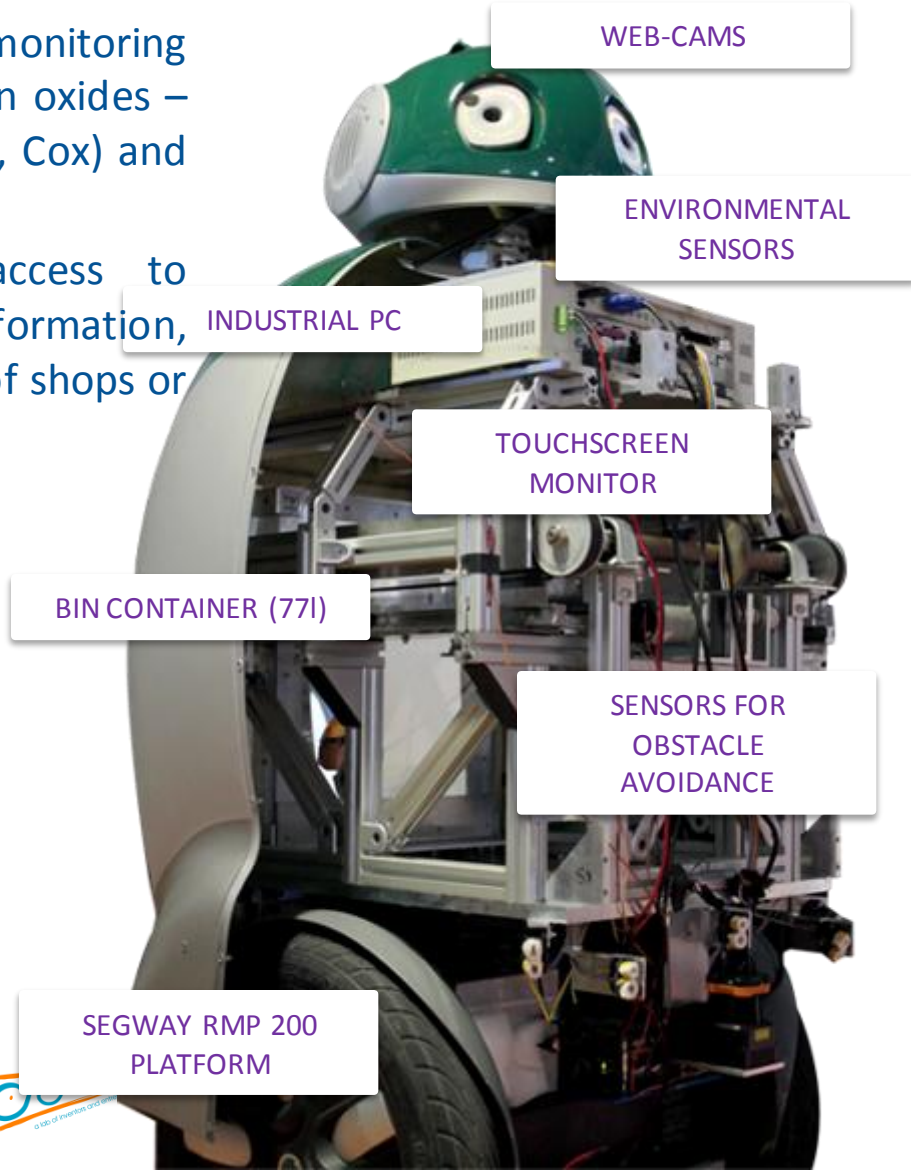
Phone devices

Control station computer

SPECIFIC SCREEN_ This screen is used for monitoring each single robot. The screen is divided into two main sections: one side allows to visualize the robot position by means of an electronic cartography while the other side is used to display information related to the robot current destination, level of battery) and visualize the images coming from onboard cameras.

Main functions of DustCart robot

- **Garbage collection:** to collect and transport small quantities of domestic garbage, on demand, from a user's home to an appropriate Garbage Discharge area
- **Air quality monitoring:** mobile station for monitoring different kinds of atmospheric pollutants (nitrogen oxides – NOx-, sulphur oxides –SOx-, ozone -O3-, benzene, Cox) and to measure air humidity and temperature
- **Information totem:** providing users with access to information on City services (maps, tourist information, buses and trains timetables, opening and closing of shops or offices, etc.)



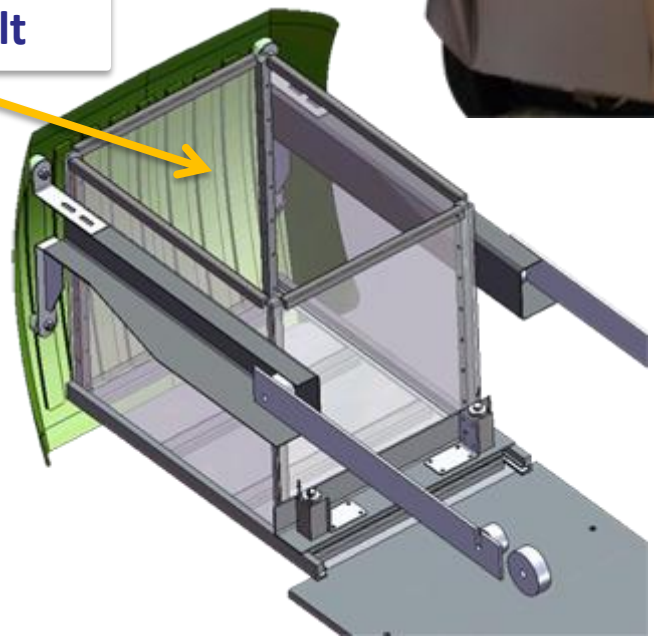
Garbage collection system

GARBAGE COLLECTION

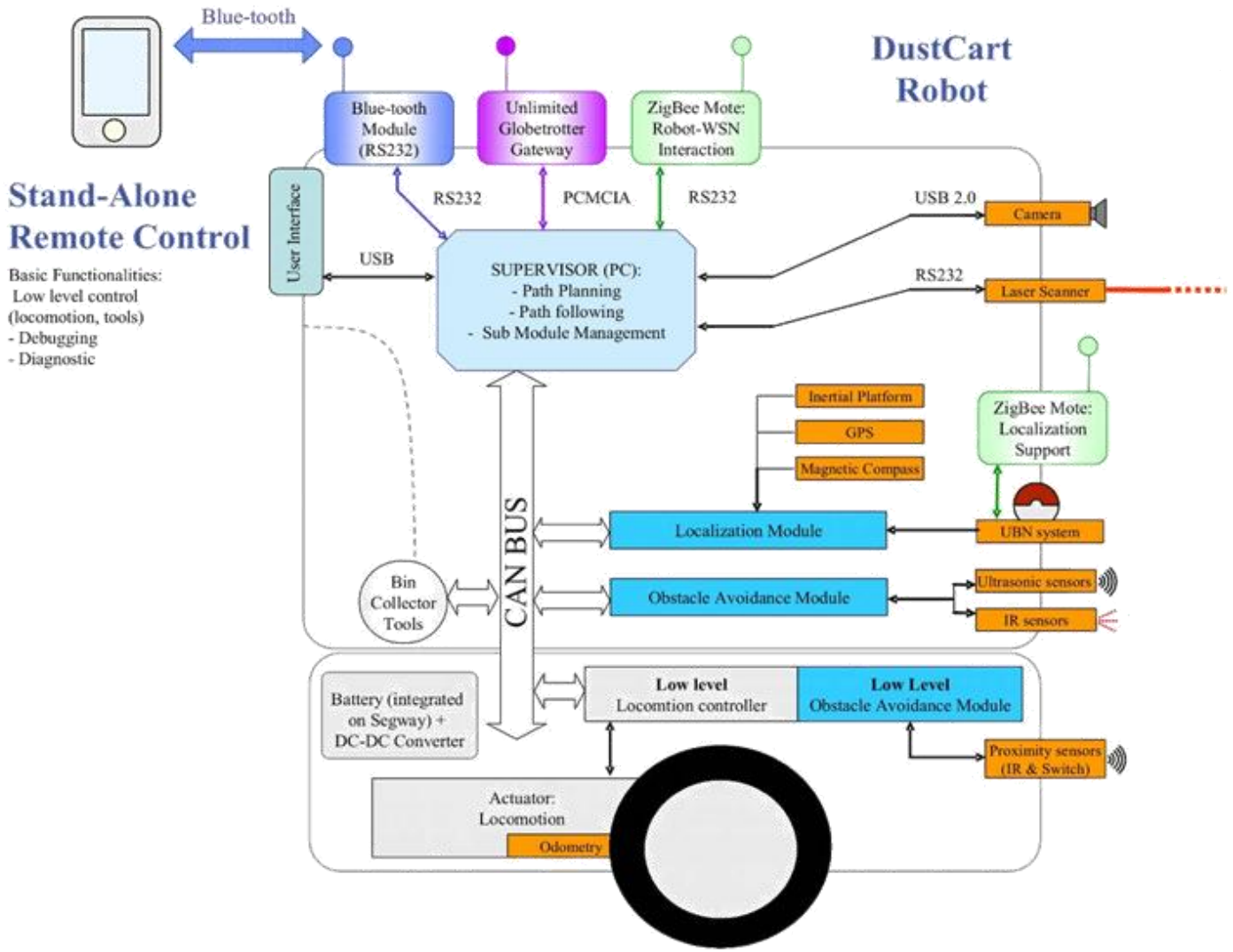
GARBAGE DISCHARGE

Inside the robot is a sliding bin container that is used to collect, transport and discharge a garbage bag.

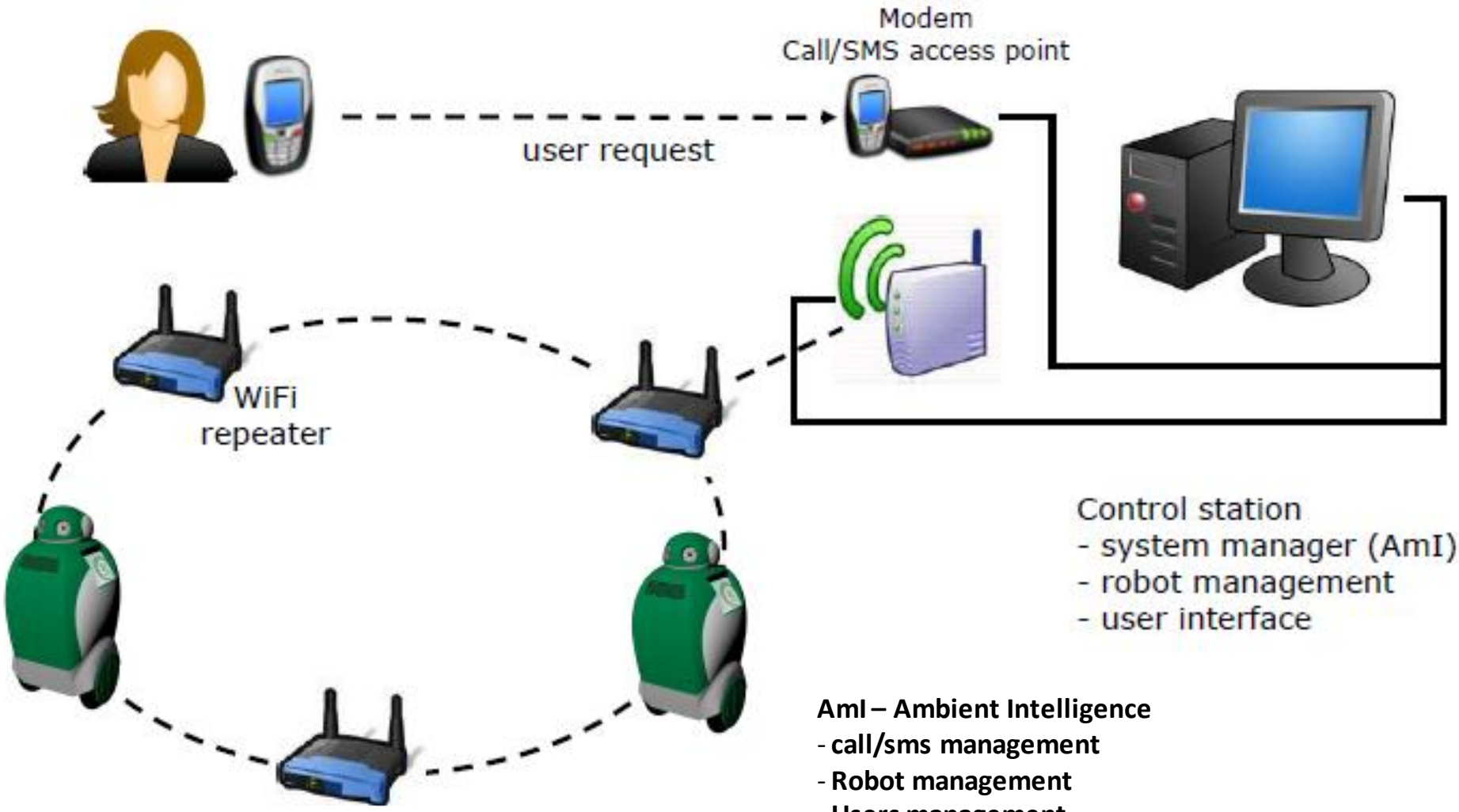
GARBAGE BIN
capacity: 77 lt



The DustCart Architecture



The DustBot Architecture



Control station
- system manager (AmI)
- robot management
- user interface

AmI – Ambient Intelligence
- **call/sms management**
- **Robot management**
- **Users management**
- **robot activity scheduling**
- **Operator GUI**

Our Design Strategy

Sharing intelligence between the robots and the environment

Clear advantages (**performance and safety**): for the robot, for the users, for the local administration….

Problems addressed by DustBot project

1. Door-to-door separate waste collection in central areas with difficult access by vehicles
2. Street cleaning in central areas with difficult access by vehicles
3. Air quality monitoring in pedestrian areas


Designing the
DustClean Robot to
provide 24 H a day
cleaning and
sweeping service

Design and development of DustClean

- **Cleaning and sweeping** of pedestrian areas in urban environments. It is equipped with brushes and sprays and operates on a daily basis in pedestrian streets and squares, removing small quantities of garbage from the ground, and keeping the area tidy.
- **Air quality monitoring** mobile station for monitoring different kinds of atmospheric pollutants (nitrogen oxides –NOx-, sulphur oxides –SOx-, ozone -O3-, benzene, Cox) and to measure air humidity and temperature

Problems addressed by DustBot project

1. Door-to-door separate waste collection in central areas with difficult access by vehicles
2. Street cleaning in central areas with difficult access by vehicles
3. Air quality monitoring in pedestrian areas

Current solutions

Air quality monitoring

Mobile stations

Fixed stations

Added Value of Robotic Solution

Air quality monitoring

Mobile robots provided with environmental sensors can move in pedestrian areas and monitor the air quality where people live, walk, work, etc.

"All the News That's Fit to Print"

The New York Times

National Edition

VOL. CLVI . . . . No. 53,973 TUESDAY, JUNE 12, 2007 Price in Italy - Euro

Parents and Health Experts Try to Ease Italy's Pollution

Carmakers' Lobby Resists Changes

By ELISABETH ROSENTHAL

MILAN — This part of northern Italy is renowned for fashion, food, Fiat. But now it has another, less welcome claim to fame: the cities here have the worst air pollution in Europe.

By mid-May, Milan had already exceeded European Union and World Health Organization limits for particle pollution in the air on 89 days. Last year was bad, too. By the end of March, Milan had 64 such days, Turin had 77, Bologna 51 and Venice 49.

Particulate pollution is tied to heart disease and respiratory ailments like asthma, and poor lung development in children.

While Europe's other big polluters — Germany and Poland — have reduced emissions since 1990, Italy's emissions have increased. This year, the European Commission deemed Italy's plan for emission reduction to be inadequate, and the country faces billions of euros in fines unless it corrects the problem.

And so, when a coalition of parents and scientists fitted teenagers with portable monitors that measure ultrafine particles last November, it

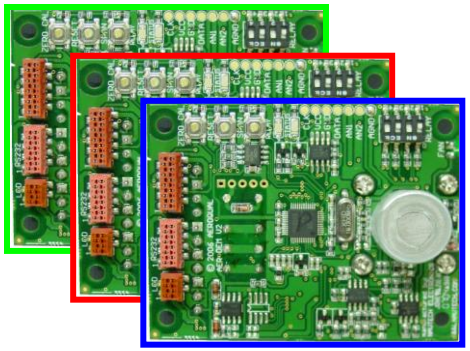
David Vinder for The International Herald Tribune

EU EuroLifeNet Project

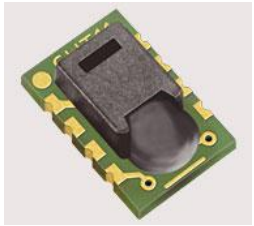
- Monitoring personal exposition to atmospheric particulate matter (PM2.5).
- Resulting measured values much higher than daily average values measured by fixed monitoring stations

Sensors integrated in DustBot

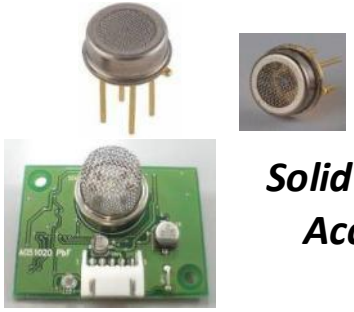
aeroQUAL



Preconditioned sensors for
CO (0-100ppm)
NO_2 (0-200ppb)
O_3 (0-500ppb)
Accuracy 10%



Temperature and Humidity sensor

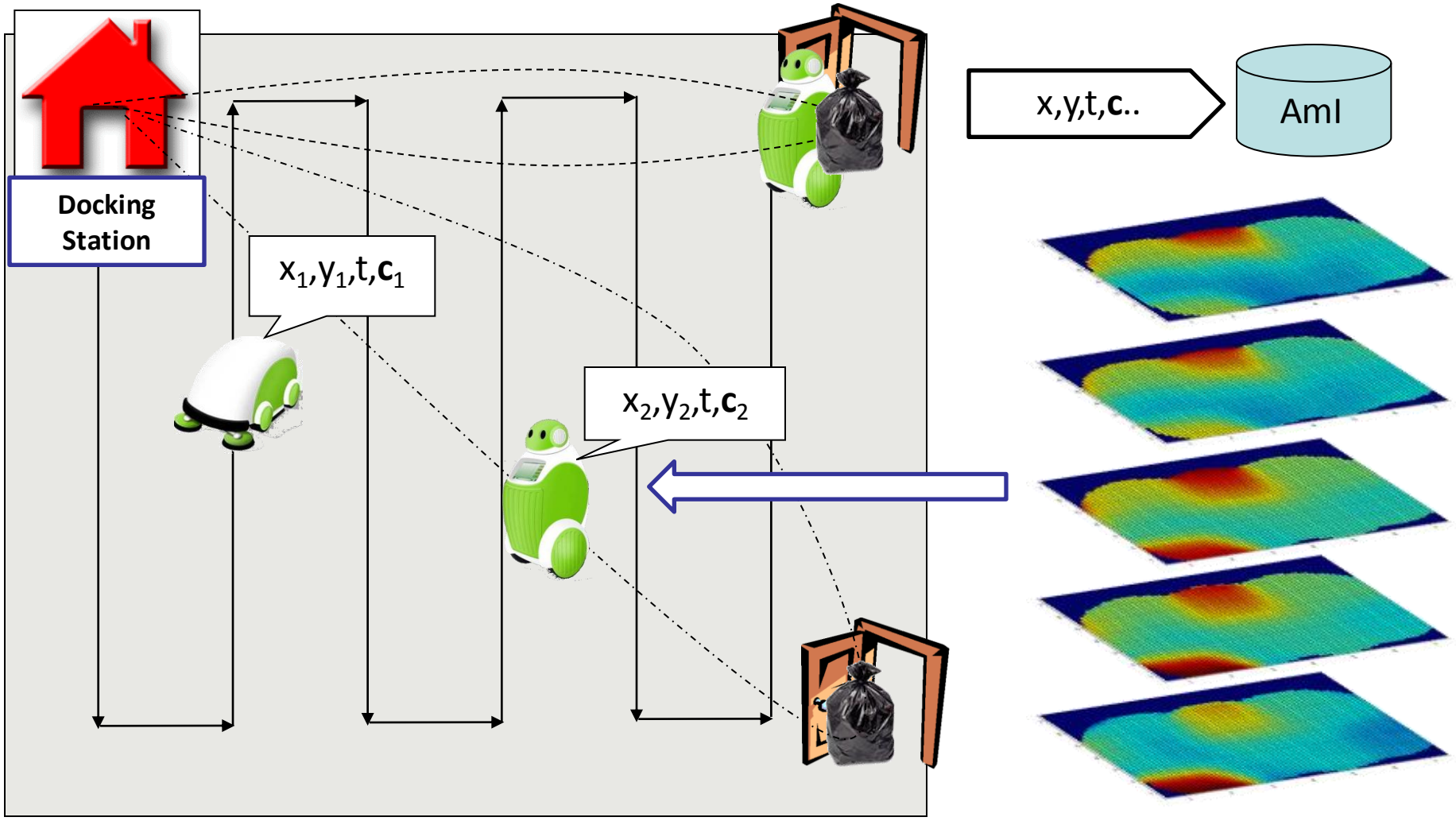


Solid State Sensors
Accuracy >20%

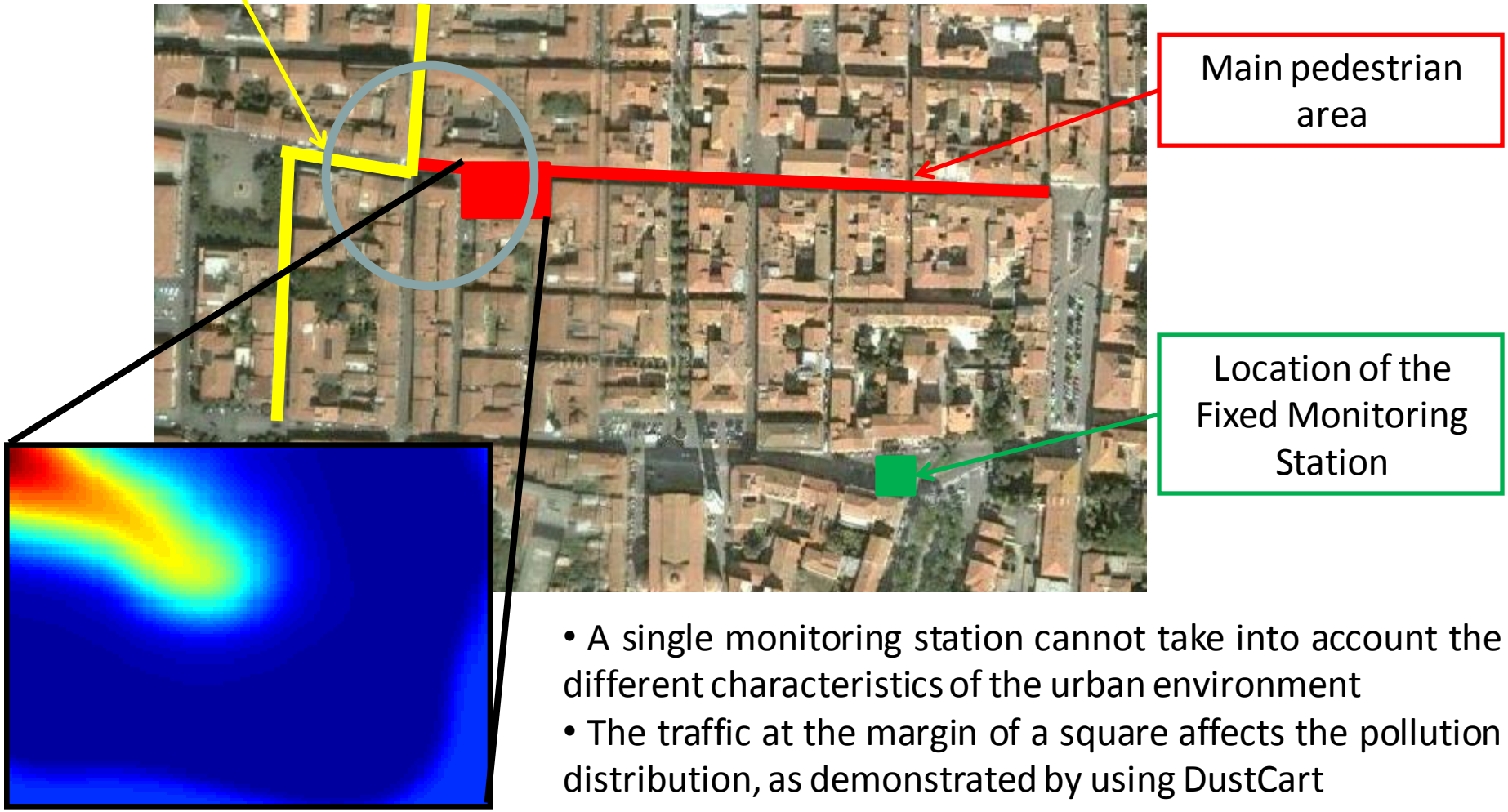
PM2.5-10 analyzer
Accuracy 10%

- High accuracy sensors to have a reliable reference measure for the monitored area
- High speed (low accuracy) sensors for mapping
- Development of a Plug&Play interface to allow an easy interchangeability of the sensors within the robot

Air mapping during the rubbish collection tasks

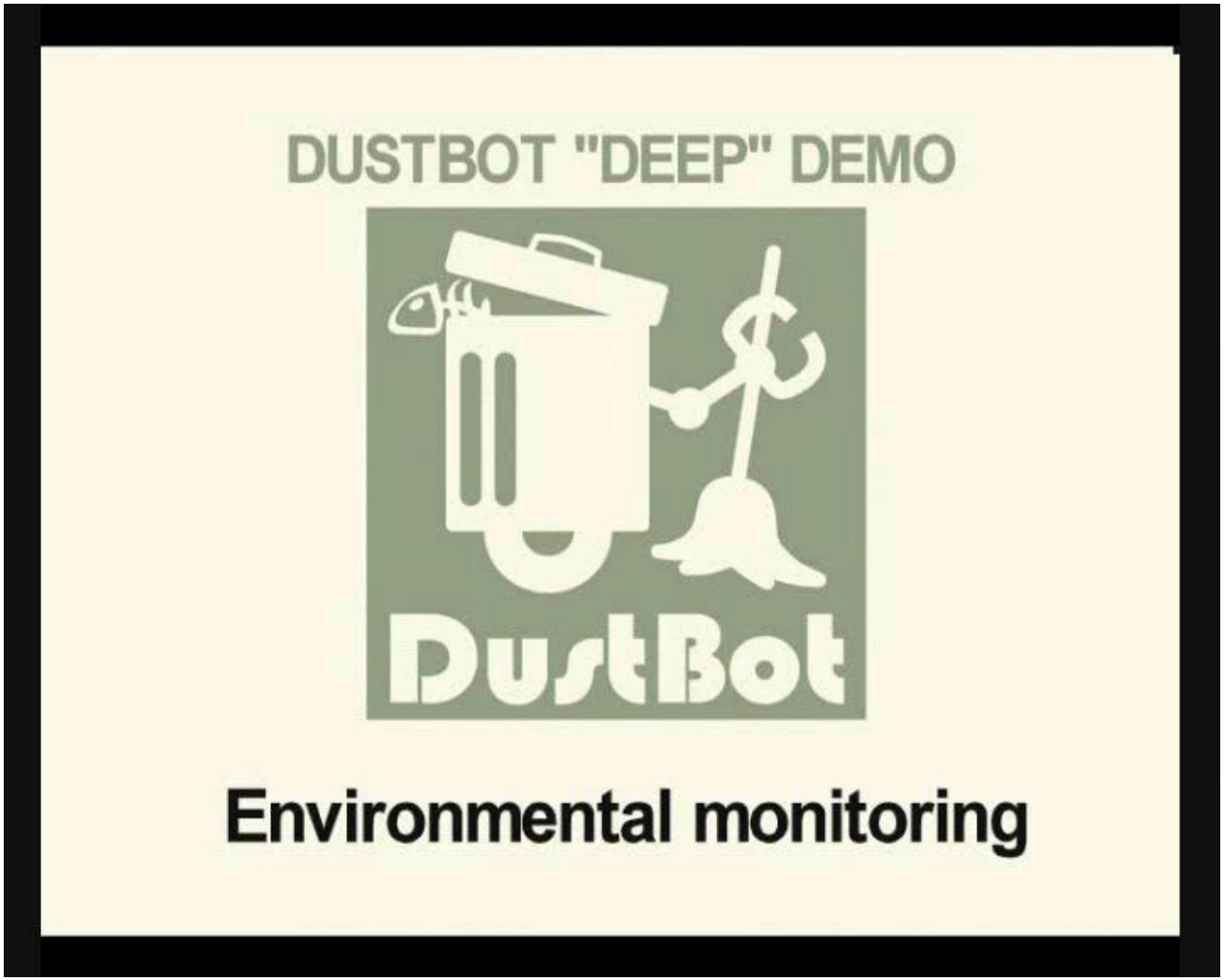


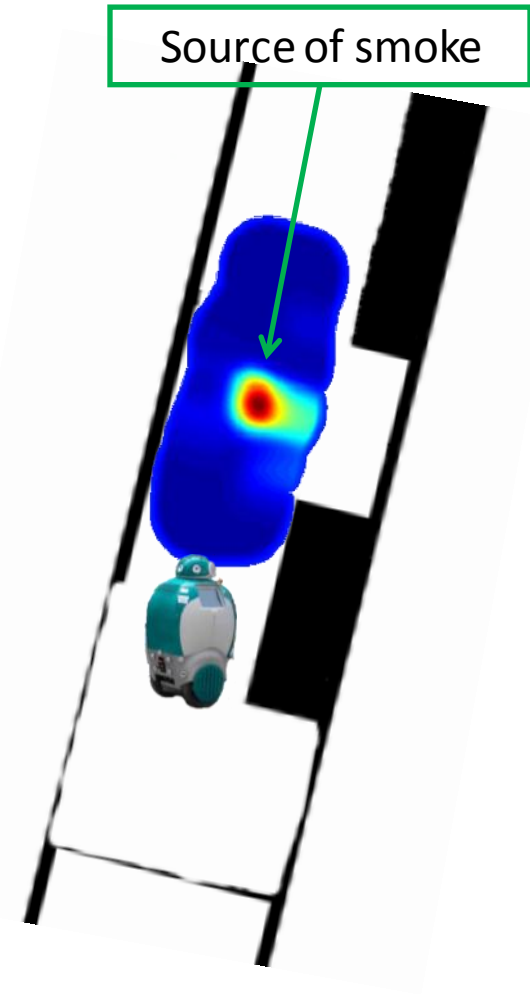
Tests with DustCart in the central square of Pontedera (Italy)



- A single monitoring station cannot take into account the different characteristics of the urban environment
- The traffic at the margin of a square affects the pollution distribution, as demonstrated by using DustCart

Tests with DustCart in Livorno (Italy)





The DustBot Demos

Additional Demos

The demo aimed at using **DustCart** to carry a baggage given by a human user.

This was expected to test how services given by different types of robots are sensed by human users. The NRS system is composed by a localization system and different humanoid robots (**Robovie**).

Demo in Osaka, Japan - 28-29/01/09

Ministero per la Pubblica Amministrazione e l'Innovazione

italia degli innovatori

innovazione selezionata expo shanghai 2010

DustCart@Shanghai Expo 2010
Italian Pavilion

WHAT WE HAVE

Real impressive the number of requests by magazines, televisions, interests…

WHAT WE HAVE TO DO

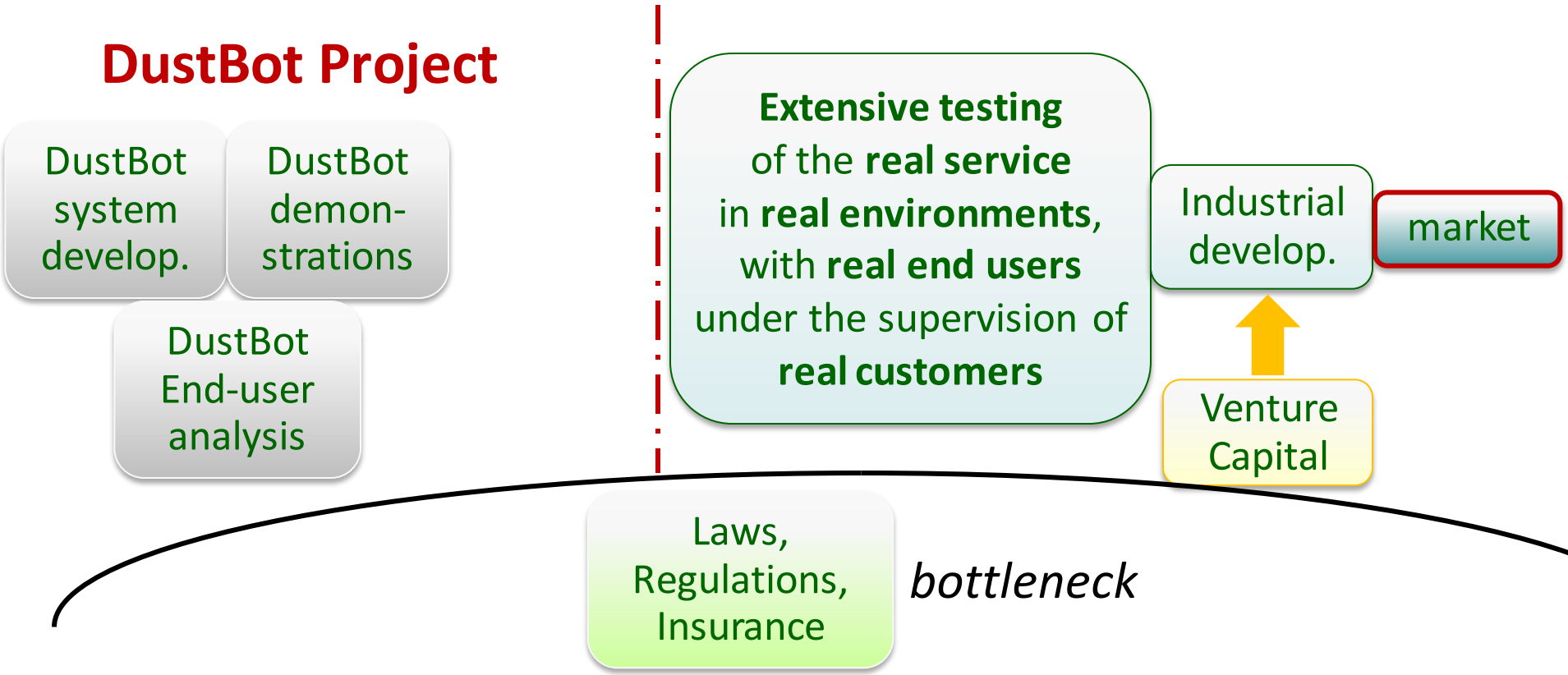
TO TURN THE EXCELLENT RESULT OF AN EU PROJECT…

INTO A SUCCESSFULL ENTREPRENEURIAL CASE

Our vision

- In order to ultimately deploy service robots, **we need robot platforms for extensive testing**, but also realistic and open environments to test such platforms
- The environment should include **real infrastructures** (homes, buildings, factories, streets, squares, etc.), and above all **real people** ("living lab")
- We need to identify **concrete application domains** (starting from a specific need and thus potential market, and together with users/ stakeholders) and to carry on extensive tests in the above realistic environment

DustBot Exploitation Plan



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What is the legal status of service robots using public roads

- **Article 8 of the Vienna Convention on Road Traffic** (1968) the convention states that each moving vehicle, including animals, *shall have a driver*

This article has been acknowledged, for instance, by:

- **Article n. 46 of the Italian Traffic Law:**
  - A vehicle is any machine of any kind circulating on roads *driven by a human being*

Safety standards

- Lack of specific risk evaluation methods and of safety standards for service robots (impossibility to rely only on existing EU Directives, such as Machinery Directive 2006/42/EC, and EU regulations for vehicles using public roads, that is Directive 70/156/EEC and Directive 92/61/EEC)
- ISO is investigating safety standards for personal care robots

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ICRA2009

2009 IEEE International Conference
on Robotics and Automation
Kobe, Japan, May 12-17, 2009

Half Day Workshop

Service Robots in Urban Environments: Legal and Safety Issues

May 13, 2009, Kobe, Japan

Workshop Programme

09.00 - 09.10	***Workshop Opening*** Pericle Salvinig and Takayuki Kanda
09.10 - 09.35	**Dependable robots physically interacting with humans** Eugenio Guglielmelli (Universtià Campus Bio-Medico, Italy)
09.35 - 10.00	**Automated vehicles on the road: the necessary future or a dream?** Michael Parent (INRIA-IMARA, France)
10.00 - 10.25	**Special Zone for Robot Development and Practical Testing in Japan** Atsuo Takanishi (Waseda University, Japan)
10.25 - 10.40	*Coffee Break*
10.40 - 11.05	**Toward the Human-Robot Co-Existence Society: On Legislative Consortium for Social Robotics** Yueh-Hsuan Weng (Administrative Cadre Conscription Agency, Ministry of the Interior, Taiwan)
11.05 - 11.30	**Safety Guidelines and International Standards for Robots in Contact with Humans** Yoji Yamada (Nagoya University, Japan)
11.30 - 11.55	**How to Conduct Field Experiments with Service Robots in Urban Settings?** Takahiro Miyashita (ATR, Japan)
11.55 - 12.00	*Workshop Conclusions*

***Advanced Robotics*, No. 24, Vol.13**

Special Issue on Legal and Safety Constraints for Service Robots Deployment

Guest Editors: Pericle Salvini and Cecilia Laschi

VSP

Advanced Robotics 0 (2010) 1–17

ADVANCED ROBOTICS
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Review

An Investigation on Legal Regulations for Robot Deployment in Urban Areas: A Focus on Italian Law

Pericle Salvini [a,*], Giancarlo Teti [b], Enza Spadoni [a], Emiliano Frediani [c], Silvio Boccalatte [d], Luca Nocco [e], Barbara Mazzolai [f], Cecilia Laschi [a], Giovanni Comandé [e], Emanuele Rossi [c], Paolo Carrozza [c] and Paolo Dario [a]

[a] ARTS Laboratary, Scuola Superiore Sant'Anna, Pisa, Italy
[b] RoboTech srl, Peccioli, Italy
[c] Centro WISS, Scuola Superiore Sant'Anna, Pisa, Italy
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[e] LIDER Laboratory, Scuola Superiore Sant'Anna, Pisa, Italy
[f] Italian Institute of Technology, Genoa, Italy

Received 6 November 2009; accepted 2 April 2010

Abstract

Thia paper investigates the administrative, criminal and civil aspects of Italian law in [illegible] to find out whether and how current legal regulations impact on robot deployment in urban enviro[illegible]ner is based on a case study. The objects of this study are two autonomous mobile robots [illegible] urban hygiene services in pedestrian areas. The paper points out a major problem in [illegible] of legal qualification for autonomous mobile robots operating on public roads. On [illegible], no relevant implications are identified with regard to Italian criminal and civil [illegible]ct, although autonomous, the robots that are at the center of this study can still be co[illegible]and,

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TheDustBot system tested in Peccioli (Italy)

Peccioli became one of the first places in the world where a robot **was used** (not demonstrated)

The test campaign:

- started on 15th June and finished on 7th August 2010
- in the very heart of the town, with people and cars!
- with real users: 24 families and 10 business activities

R&D and experimental activities in Peccioli, Tuscany (Italy)

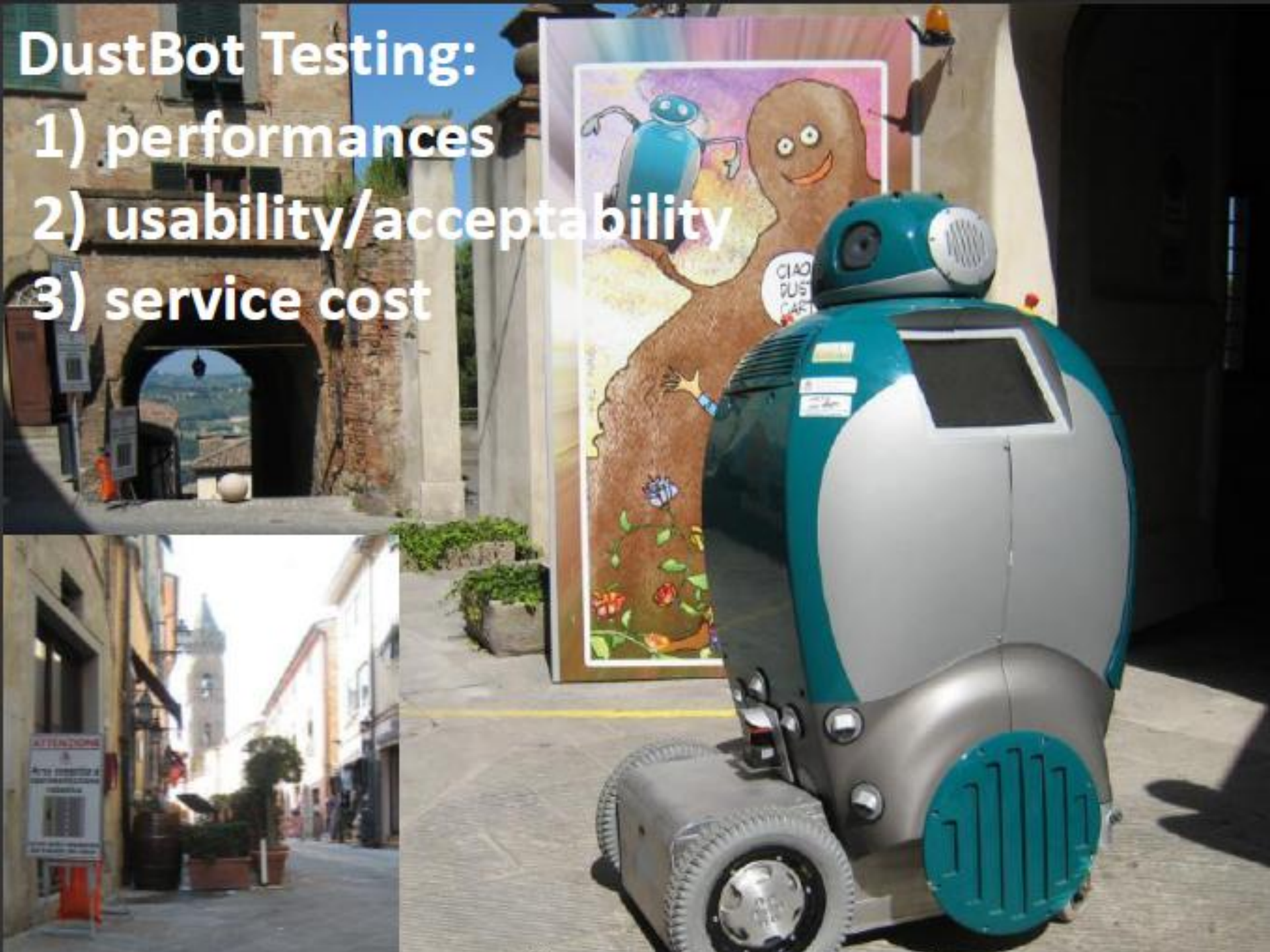
- Peccioli is a small and ancient village in Tuscany (Italy), low populated (about 5.000) and with a high percentage of elderly people (25% are over 65).
- **Since 1995** the Municipality of Peccioli has been collaborating with Scuola Superiore Sant'Anna and supporting the **R&D of innovative ICT-based solutions** in the field of assistive and robotic technology for elderly and disabled people.

The town centre

- The agreement with the municipality and institutions is crucial for availability of:
- all **infrastructures** involved in the experimentation
- the **technical, administrative and financial support**
- the **legal authorizations and insurance**
- the **Peccioli social service centre**

DustBot Testing:

1) performances
2) usability/acceptability
3) service cost



DustCart : main modifications for testing period

DustBot Demonstrations
April-August 2009

DustBot testing
June-August 2010

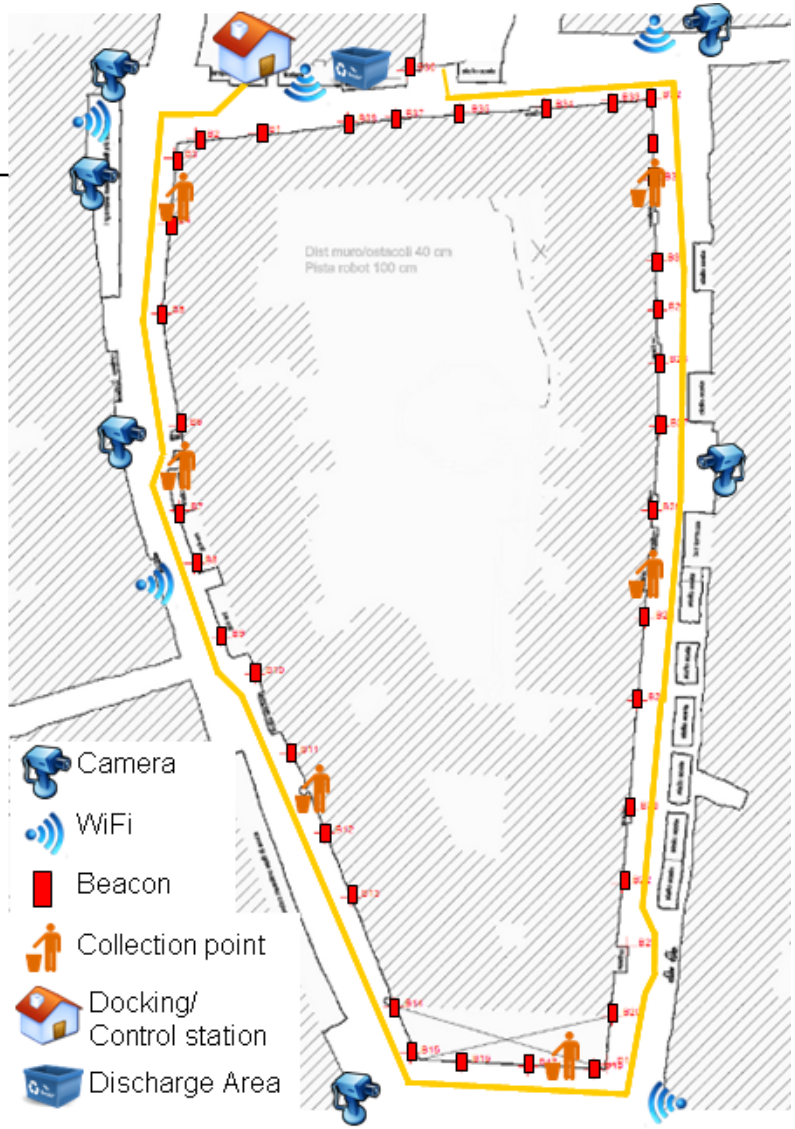
New mobile base: 4 wheels to increase stability and deal with slopes

New powerful batteries, up to 10 hours endurance

The Service provided by DustCart

The service provided by DustCart during the test period in Peccioli was on-demand door-to-door waste collection. The robot was configured to collect three types of waste: **undifferentiated, paper, and plastic**. The service was in operation from Monday to Sunday, from 8:00 a.m. to 8:00 p.m. except on Tuesday, when the service was in operation only from 3:00 p.m. to 8:00 p.m. owing to the local market present in the experimental area.

DustBot testing site in Peccioli



The total length of the path was approximately 300 m

Peccioli testing are: *new road signs*

'Attention. Area subject to robotic testing. Yellow lane used by robots'.

'Attention. Robot crossing. Yellow lane used by robots'.

Peccioli testing area: *the robot lane*

- The **robot lane** is a special strip, in yellow colour, drawn on the left side of the roads. It was decided that the robot should travel inside the lane, on the left side, always in the same direction of cars. The “robot lane” was meant to avoid as much as possible interferences with car traffic. Since the robot was not able to give way to cars, three stops were devised in each road in order to avoid traffic congestion.

Robots insurance in Peccioli

- SSSA insurance policy (**SAI company**) covers any research activities, including demos, carried out with our prototypes by the institution personnel in any place of the world.
- However, due the peculiar nature of Peccioli testing, the insurance company requested the payment of an additional insurance premium (**850 € for 2 MONTHS**).
- The robots were ensured against **any liability resulting from their activities**
- **The insurance did not cover damages to the robot**

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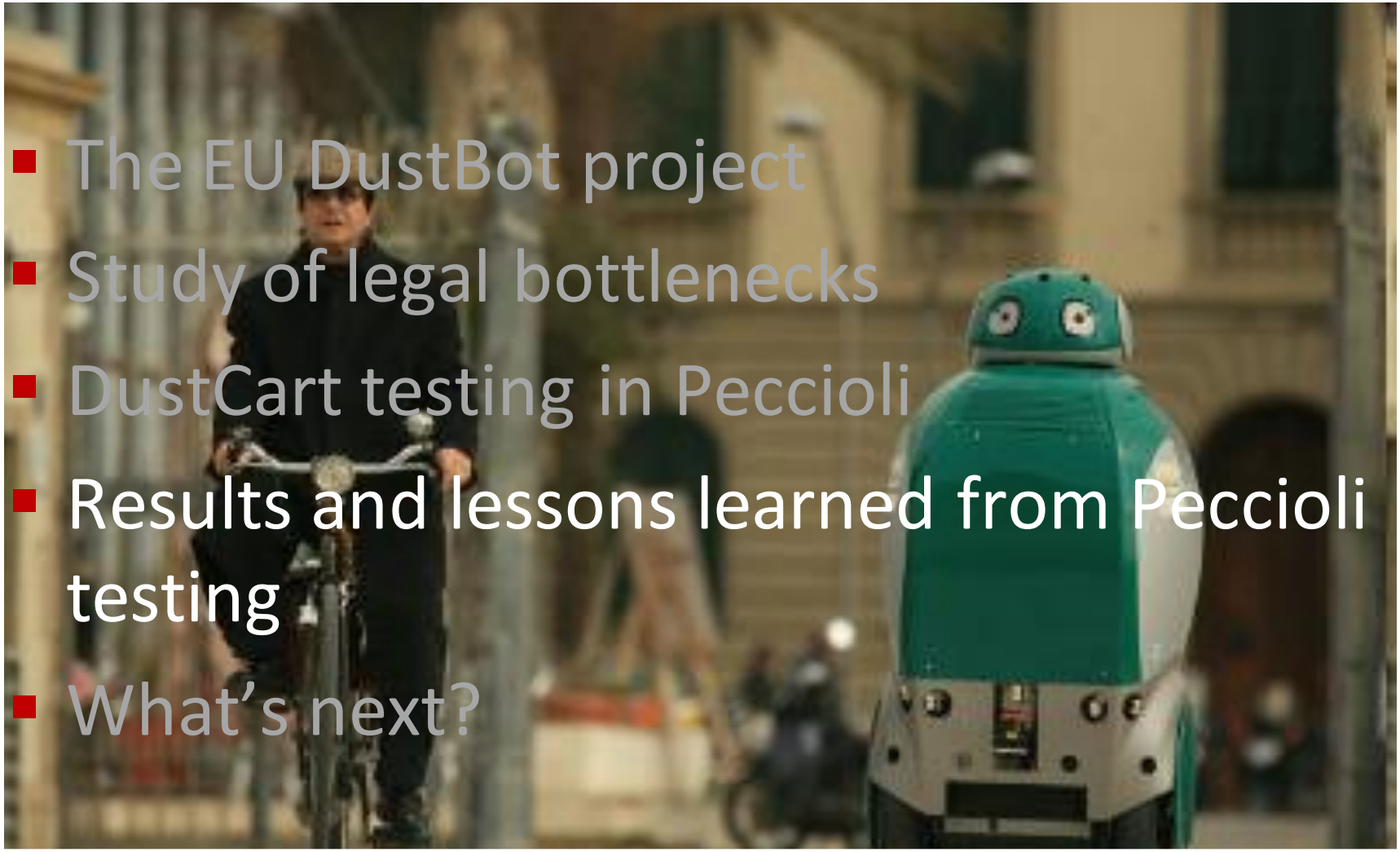
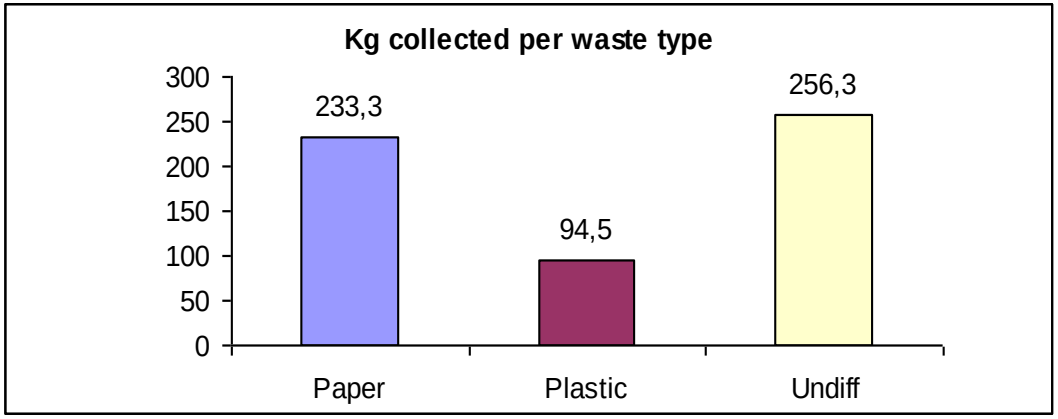
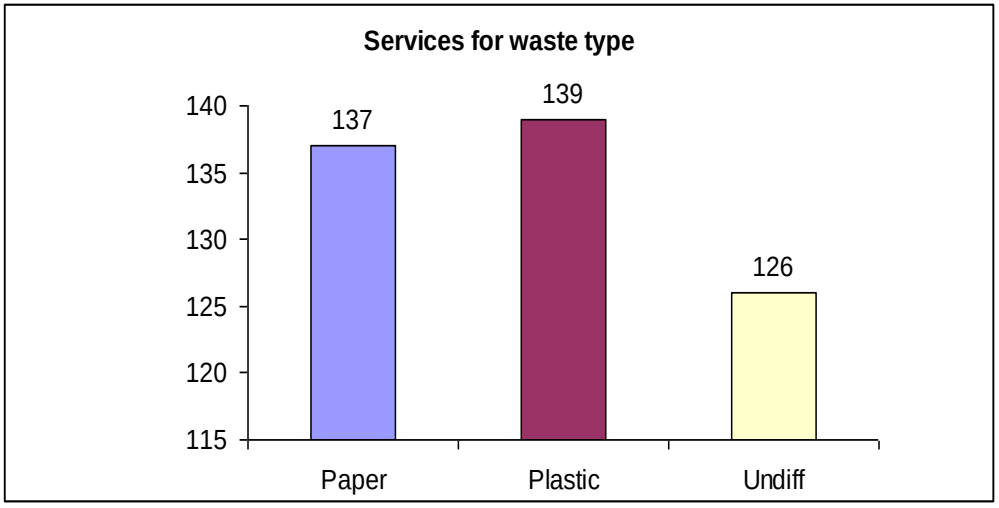


- The EU DustBot project
- Study of legal bottlenecks
- DustCart testing in Peccioli
- Results and lessons learned from Peccioli testing
- What's next?

DustBot testing results

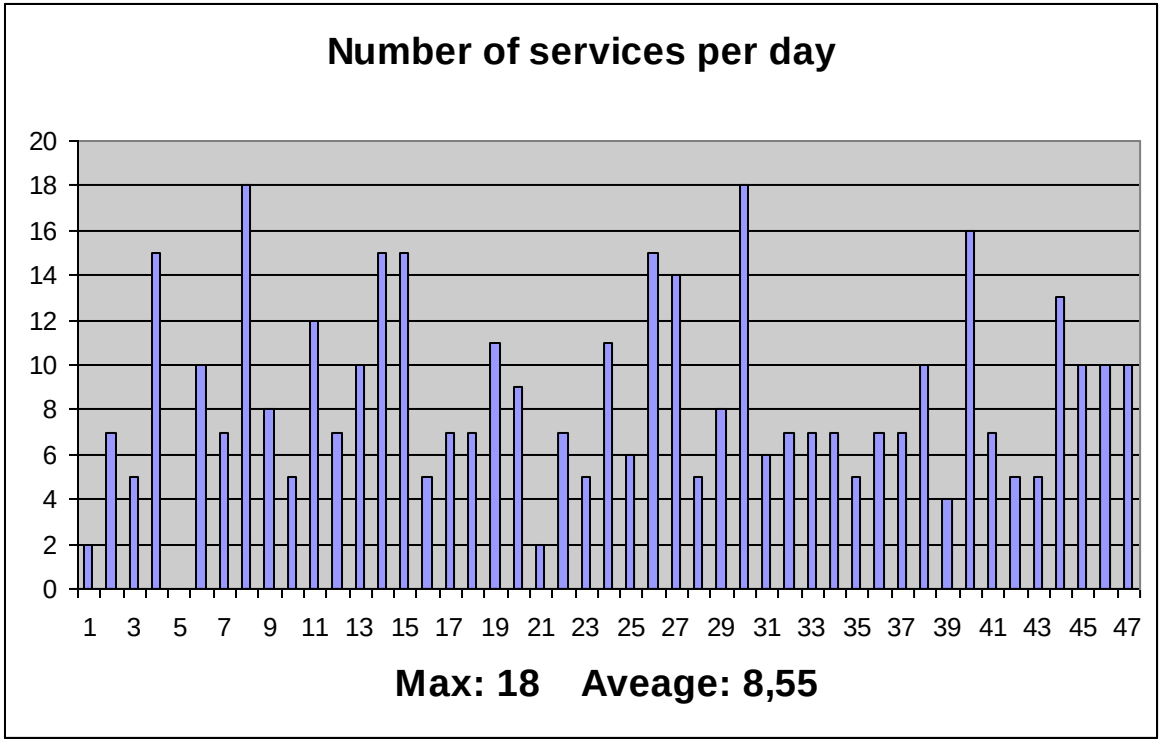
- Total service time:
  - **47 days**
  - **454 hours**
- Total services: **402**
- Total Km covered: **120.6**
- Total Kg collected: **584.1**



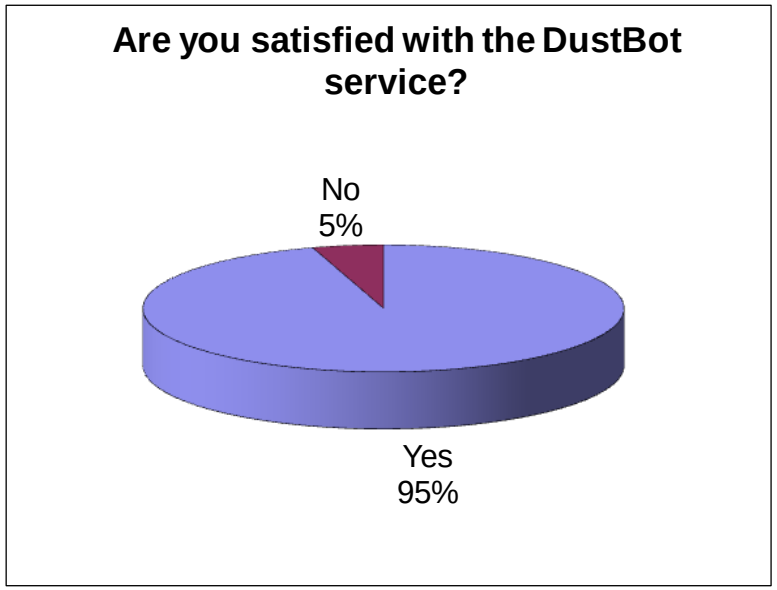


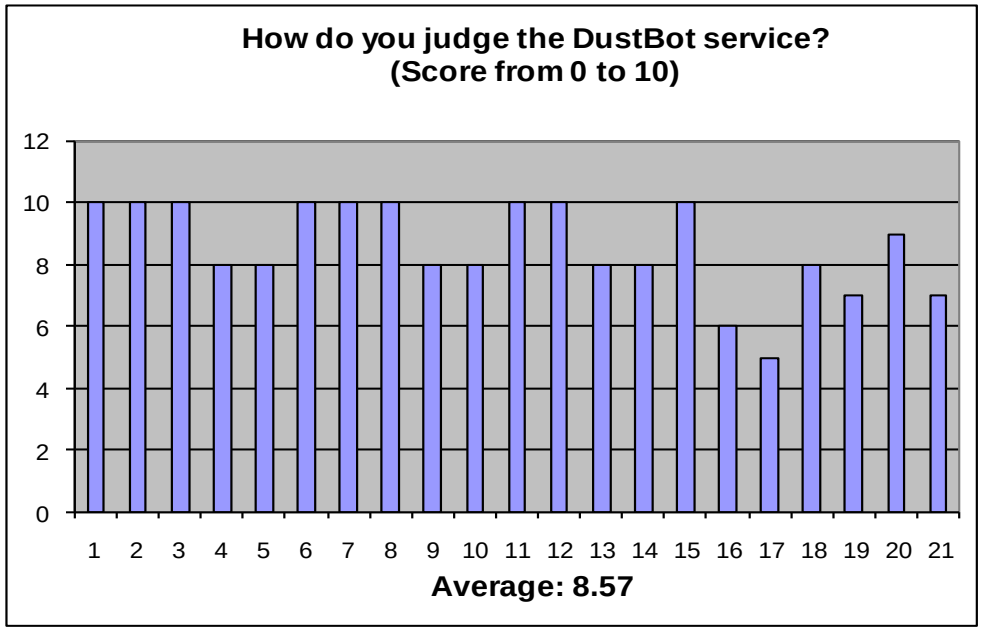
DustBot testing: results

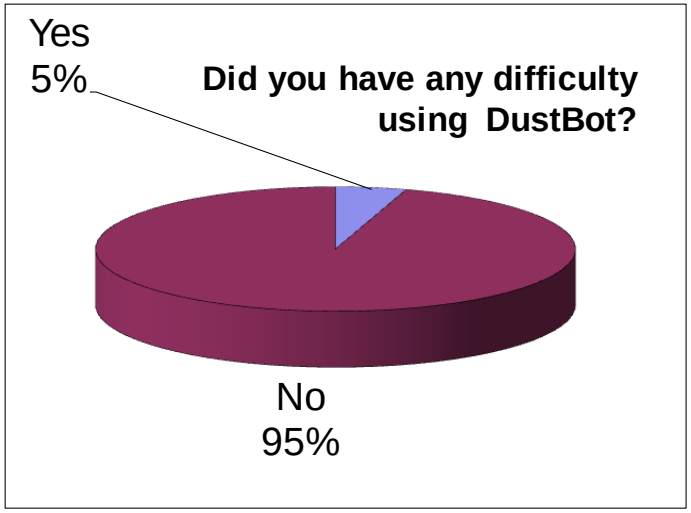
- Average duration of a collection service: 18 min
- Average waiting time from the call: 18 min
- Favorite time to call:
  - 9:00-12:00
  - 15:00-19:00



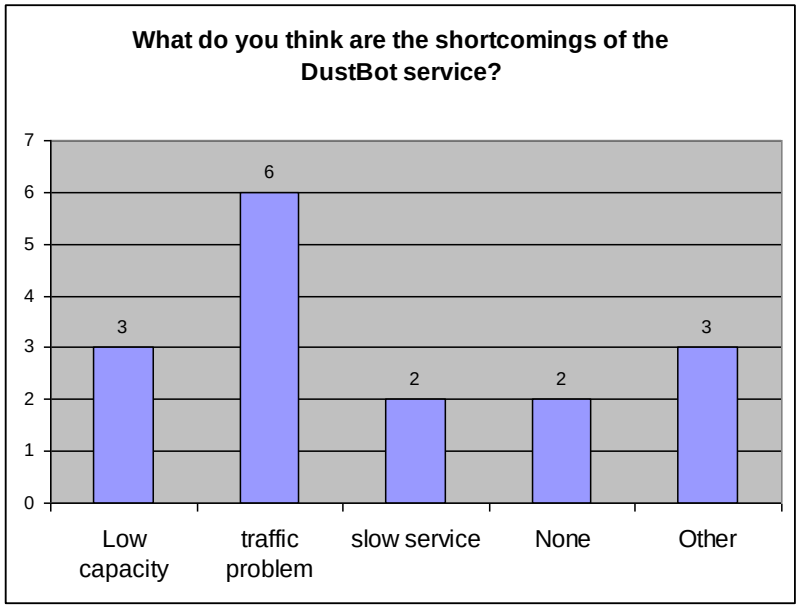
DustBot testing: results
User questionnaires

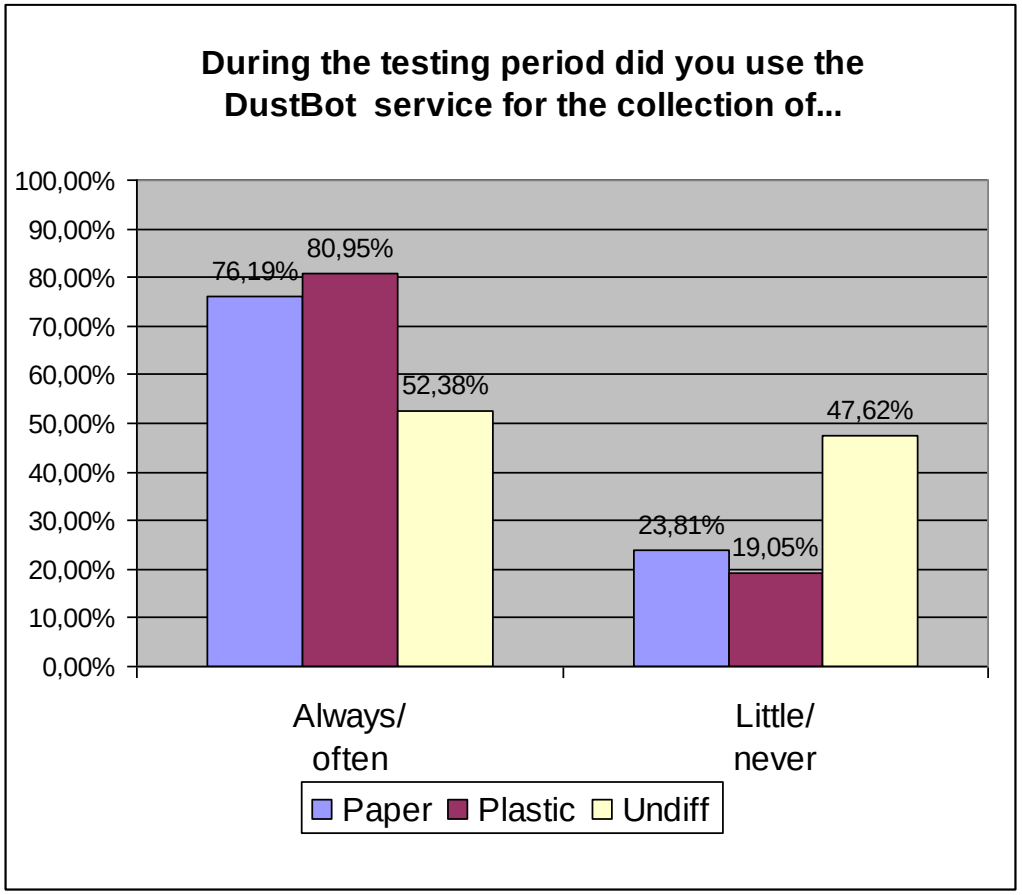






DustBot testing results
User questionnaires





DustBot testing in Peccioli

IEEE Robotics & Automation MAGAZINE

The Robot DustCart

By Pericle Salvini, Giancarlo Teti, Enza Spadoni, Cecilia Laschi, Barbara Mazzolai, and Paolo Dario

Peccioli, a small medieval town in Italy, became one of the first places in the world where a robot was used (not demonstrated) to carry out a public service in the urban environment (from 15 June 2010 to 7 August 2010). Thirty-five real users *accepted* to trash their domestic waste using the robot DustCart, a mobile robot designed to collect, transport, and discharge rubbish bags in complete autonomy. During the testing period, the robot safely traveled along the public streets of Peccioli, carrying out its daily service and sharing the urban environment with the passers-by, bicycles, and cars, without causing any problems. Drawing on this unique event, in which the authors also participated, the article addresses some of the implications originating from the actual deployment of autonomous mobile robots in urban areas. Our reflections will gravitate around two major issues: legal regulations and social acceptance. More specifically, we will report on the legal solutions adopted for deploying DustCart in the streets of Peccioli and the activities carried out to increase the social acceptance of the robot.

Lessons learned

- The testing of DustBot system in Peccioli has demonstrated that:
  - **It is possible to get our robots out of the lab!!**
  - service robots can be deployed in real urban settings
  - insurance companies take the risk at a very acceptable price
  - co-existance of current robots with real people for a reasonable long period of time (2 months continuous operation) is possible with no reciprocal damages

Lessons learned: considerations on the service

- The service was evaluated as **very good** by users.
- The advantages offered by the service were:
  - Possibility to get rid of garbage bags at home
  - Reduction of quantity of garbage to be stored at home
- The service was **moderately used** by users
- The service was used: **very little** for **undifferentiated garbage** and **very often** for **differentiated garbage**
- The main disadvantages produced by the service were:
  - Traffic congestion
  - Little capacity of the robot bin container
  - Slow service

Lessons learned: considerations on technologies

- The **HMI** was evaluated **very good** by users.
- 37% of services required the operator's intervention, because of problems in terms of
  - Localization system, WiFi network, electronic boards, obstacles, ultrasound system, AmI software, slippage
  - Open S/T issues mainly related to localization and navigation in unstructured environment
    - Low cost and robust solutions are needed

Lessons learned: economic considerations

- The cost of traditional door to door garbage collection is 682.728 € per year and per 10.000 people (Source: Rapporto Rifiuti Urbani 2009 – ISPRA)
- The traditional door-to-door garbage collection is still 4 times more convenient than the robotic service characterized by the current performance
- Faster robot (**4 Km/h instead of 2 Km/h**), larger garbage container (**4 bags instead of 1 bag**), and **more robust navigation system and dependable robot** will increase the number of services per day, the efficiency of the system, and, so, the competitiveness of the robotic service

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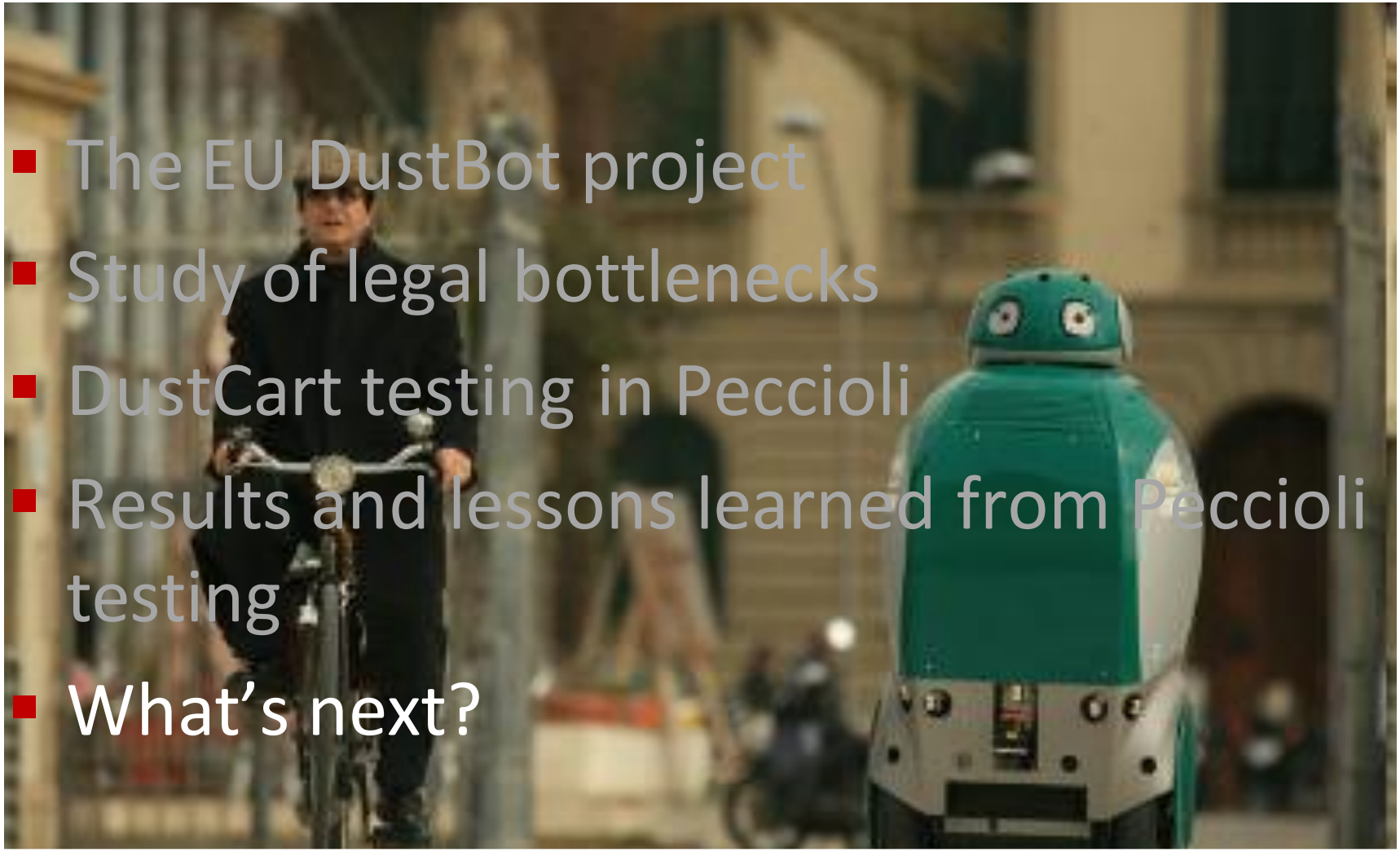

- The EU DustBot project
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Other scenarios

DustCart:

- accompanying elderly people outdoor for walking, shopping, supporting and safety and for transporting goods in urban areas
- education and entertainment
- robots for management of urban hygiene by cleaning streets and transporting home garbage
- transport of drugs and biological samples in hospitals

DustClean:

- indoor cleaning (large malls, airports, stations,..)

Conclusions

- Important lessons learned on design and acceptability of service robots in real settings
- Legal and insurance issues can be overcome
- Bullying and vandalism investigated (but not encountered in the DustBot tests in Peccioli)
- Ways to the market identified
- Companies currently considering industrialization
- Growing interest shown by citizens and other customers
- Local administrations increasingly committed and willing to make service robotics a Flagship

Thank you for your attention

Peccioli (Italy):
15 June – 07 August, 2010