

Pervasive Systems

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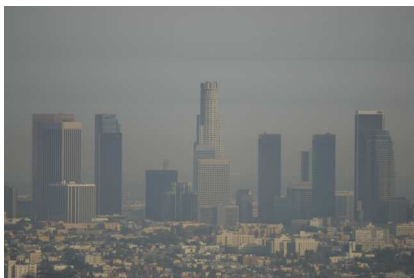
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Lecture 3:
Participatory Sensing



An Example: Monitoring Pollution

- Important environmental issues in cities
- (long term) health, social and economic impacts
- An increasing problem, especially in developing countries
- Growing public concern & effort (European Directive -2002)
- but limited success of environmental policies.
- Complexity of monitoring the real exposure of the population.



Los-Angeles



Mumbai



Data gathering: a general problem

- **Water:** "U.N. has a limited success to get accurate information on water infrastructure and treatment systems".
 - Poor data, weak agencies hamstringing U.N. environmental oversight, NY Times, 2009.
- **Food:** "Agricultural statistics has deteriorated over time" - weak estimation of global rice/wheat productions - fisheries data outdated.
 - Food and Agriculture Organization, Audit 2009.
- **Health:** "Exposure measures are sometimes completely lacking, frequently incomplete or otherwise uncertain".
 - Uncertainty and Data Quality in Exposure Assessment, World Health Organization, 2008.



Issue #1: People are not exposed to data

- Modeling Emission vs Modeling Exposure
- Location-based Exposure vs Population-based Exposure
- Sparsity of deployments
- Uncertainty of results
- Infrastructure Costs



Issue #2: Peoples' role in pollution management

- Urban pollution is an anthropogenic effect
- No real citizens participation despite international agreements
- Need to involve the people in the loop:
 - to get a better representation of their environmental conditions,
 - to interact in a more direct and powerful way.



Opportunity of Participatory Sensing

- Growing public concern.
- Access to powerful, rich-sensor mobile devices.
- Cultural shift in digital world (Web 2.0).
- Addresses Issue #1
 - Low cost adaptive sensor network,
 - Collecting fine-grained real data,
 - Supplying real exposure data.
- Addresses Issue #2
 - Citizen empowerment,
 - Citizens in the loop: reporting directly their environmental conditions,
 - Building collective maps of their shared exposure to noise.



Participatory Sensing

- Individuals and Communities
 - use mobile phones and cloud services,
 - collect data,
 - analyze data.
- Wide range of application scenarios:
 - Health and wellness,
 - Sustainability: transportation, consumption habits,
 - Governance: smart citizens, civic engagement.

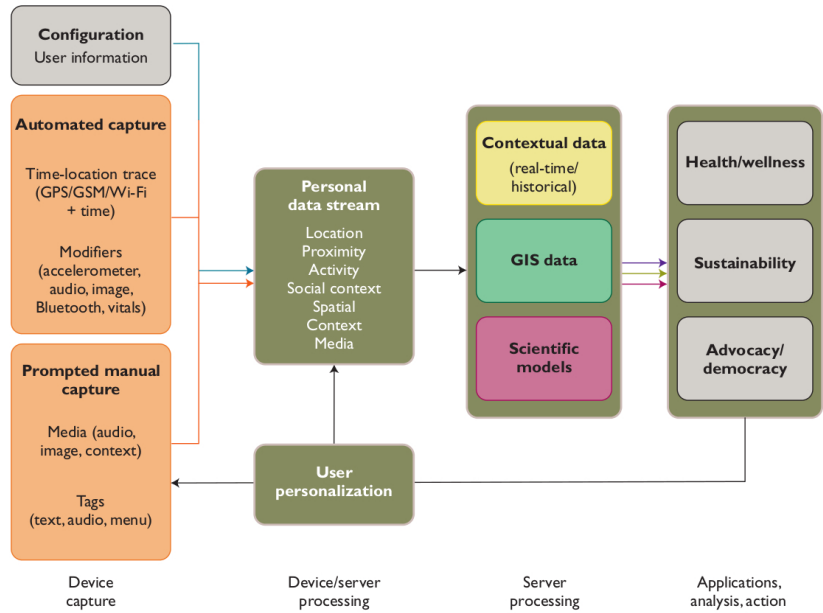


Essential Components

- Ubiquitous Data Capture
 - Mobile phones collect data using sensors (image, audio, video, motion, proximity, location)
 - Context-aware data collection
- Data Processing and Management
 - Local processing at mobile phones
 - Cross-user data sources at cloud
 - Current data vs Historic
 - Simple data can be used to infer complex phenomena about individuals and groups.
- Personal Data Vault
 - Highly individualized, personal nature of data.
 - Protection of user privacy.



Common Architecture Components



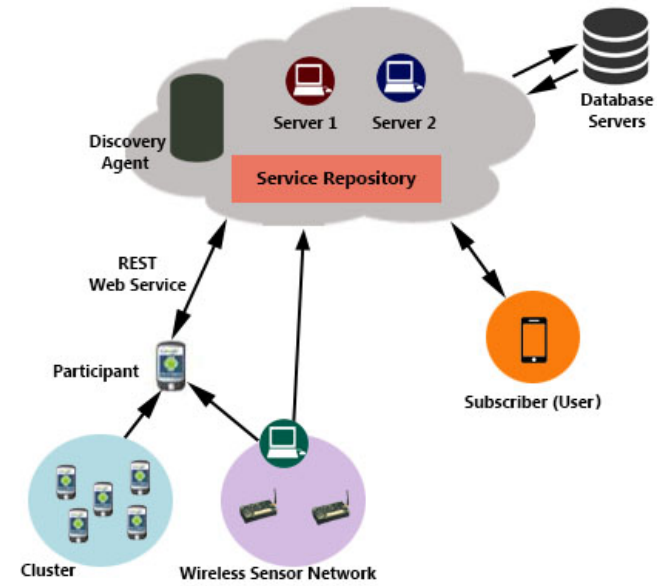
Noise

Among the leading causes for illness in urban areas

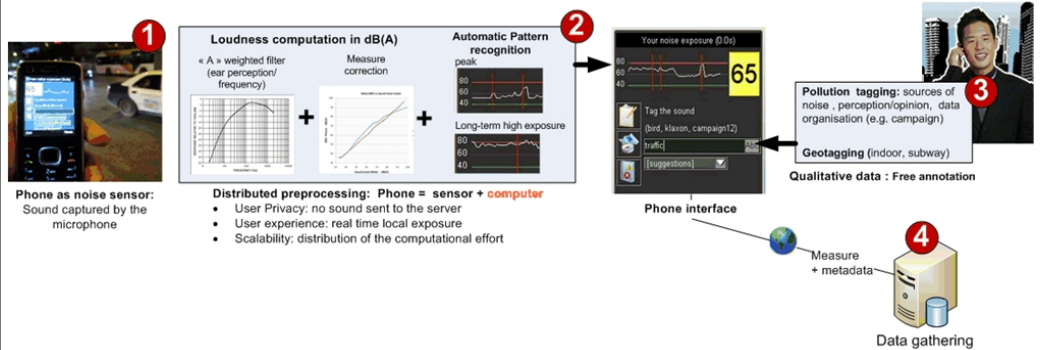
- 1 Stress
- 2 Poor sleep
- 3 Reduced life quality
- 4 Increased risk for hypertension
- 5 Hearing loss
- 6 Lower cognitive performance



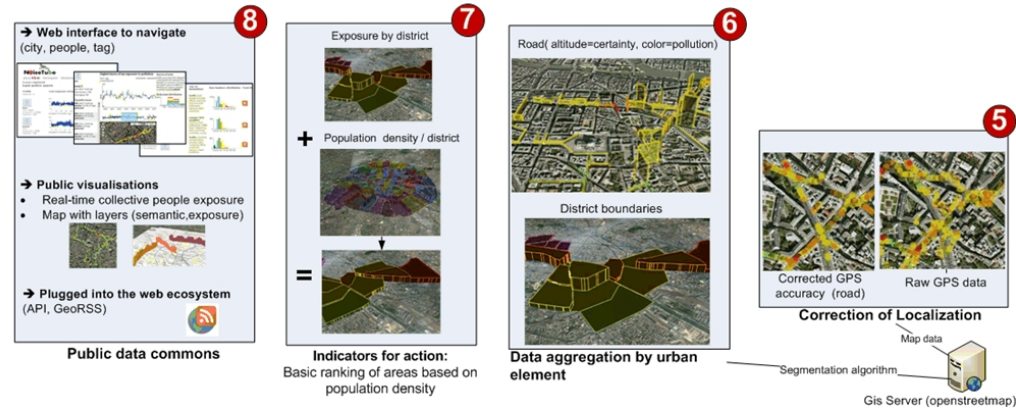
Network Architecture



NoiseTube: Citizen Sensor network for noise pollution



NoiseTube: Citizen Sensor network for noise pollution

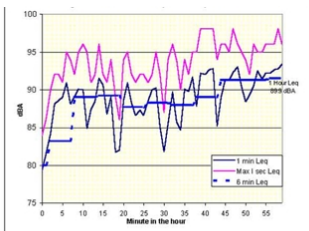


Challenge 2: Contextualizing environmental data

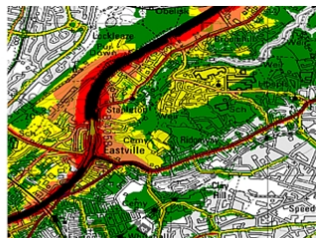
Why do we need the context?

Add meaning to raw data.

- Hard to search in numerical datasets for humans.
 - Meaning of 75 dB(A): bad /good?
 - Lat,Lng=2.34, 12.5: which street?
- Hard to identify the source of pollution with only numerical data.



Measurement done by real sensors



Simulated map



Challenge 1: Accuracy

Phone as noise sensor

Signal processing algorithm to compute $L_{eq}(A)$

A-weighted filter

$L_{eq} = 10 \log \frac{1}{T} \int_0^T \frac{p^2}{p_0^2} dt$

Leq

Phone specific correction function

Experiments to evaluate accuracy

Phone in hand	Handsfree kit	Phone in pocket
± 2.5 dB	± 4.5 dB	± 6.5 dB

Bruitparif
Observatoire National du Bruit en France



People as semantic sensors for pollution

- New tagging usage.
- Great idea ...
- but limited (amount of) contextual information



Challenge 3: Visualization

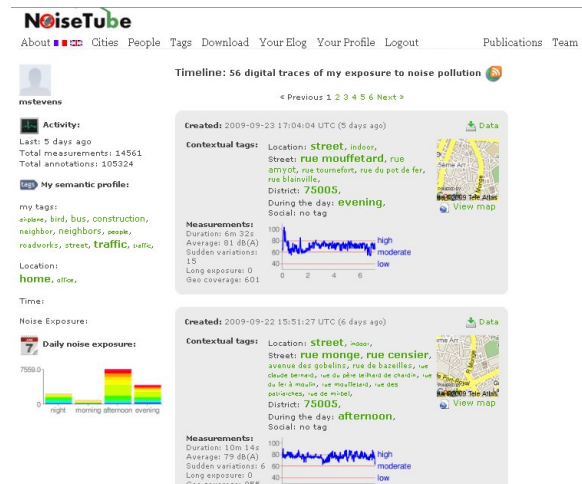
- Exposure layer
- Semantic layer
- Contextual information
- Contribution layer



Challenge 4: Sharing

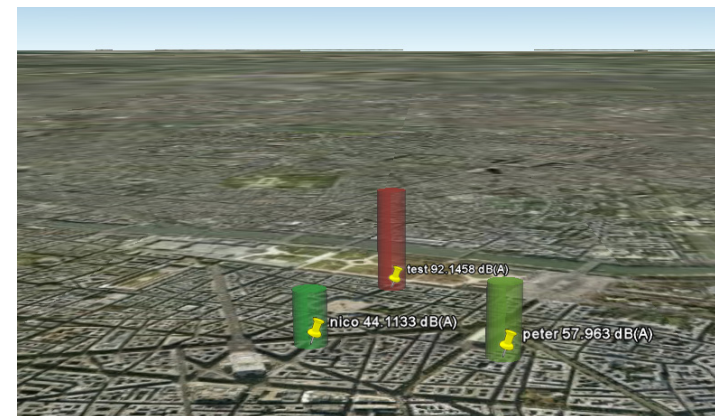
ELog: Environmental log

“See the digital traces of my exposure to pollution”



Challenge 3: Visualization

- Real-time collective exposure
- Google Earth and Web-based



Challenge 4: Sharing

New Grid for personal environmental information: Spreading environmental information through Social Network (Twitter)

ghly the insight of 3 attention-related papers in 3 different economics, attention in sociology, attention in information

by the lecture I suggest you to read the original sources. ide can be completed with a 4th case in a former post[1] (in rganizational theory-based view of Digg.com, a social news

lution

For the first case, I will mention the most obvious case: the problem of information overload we have from decades and the fact that information system designers still do not react to this trend. David A. Bray [5] pointed out the (not new) analogy between information overload and environment ecological problem. “ Similar to the limits of Earth’s “environmental load” with regard to human-made pollution, some of the technologies we have built have led (unforeseeably) to increased information pollution. This pollution is beginning to manifest itself in terms of lost work hours, and decline in true “vacation” times disconnected ness leaders implementing technology solutions also have an corporate technology use and priorities with the innate emotional yees for time with nature and with friends, free of technologi-

first one predicting the information overload problem several



Case study: Exposure to noise in mass transit system

Science daily, June 2009

recent [US] public health studies have identified several sources of environmental hazards associated with mass transit, including excessive noise, a large and growing problem in urban settings.

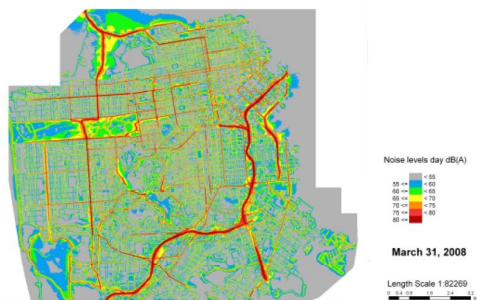
- Paris Subway - 2008
- No public information about exposure to noise
- Building exposure map of 2 lines



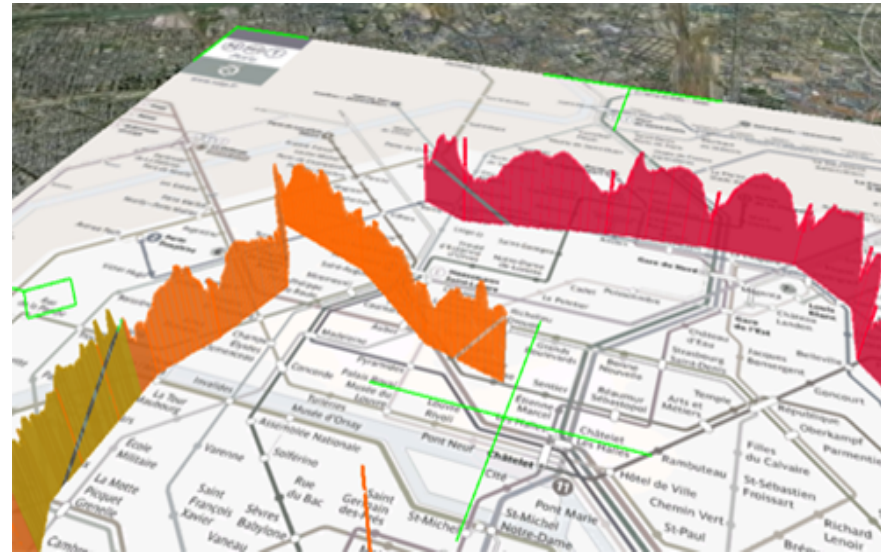
Noise Maps

Governments are using Noise-Exposure-Maps to understand the extend of the Problem.

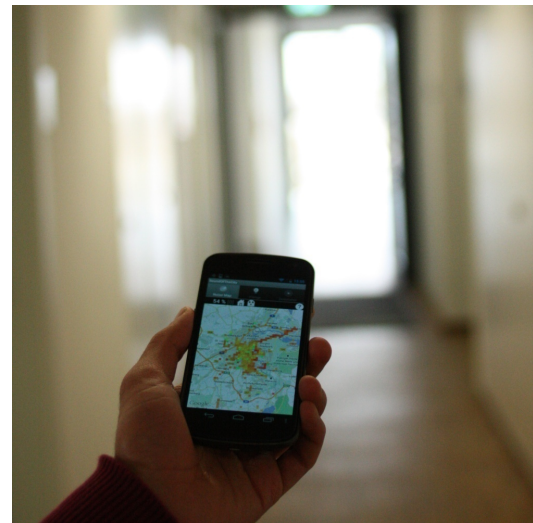
- 1 Calculated
- 2 Missing areas
- 3 Every few years
- 4 Selective sources
- 5 Expensive
- 6 Commonplace in the EU, less in the US



Case study: Exposure to noise in mass transit system



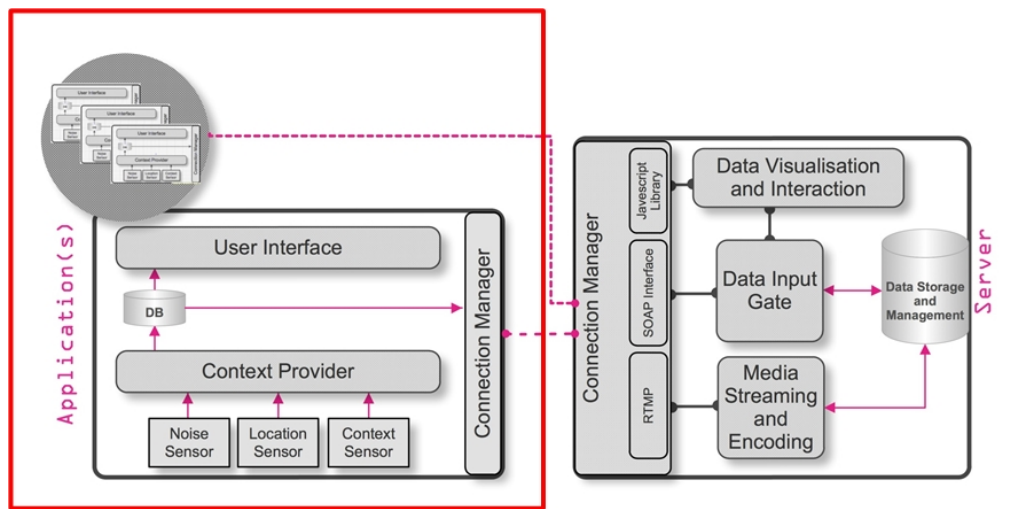
SoundOfTheCity – The Smart City Approach



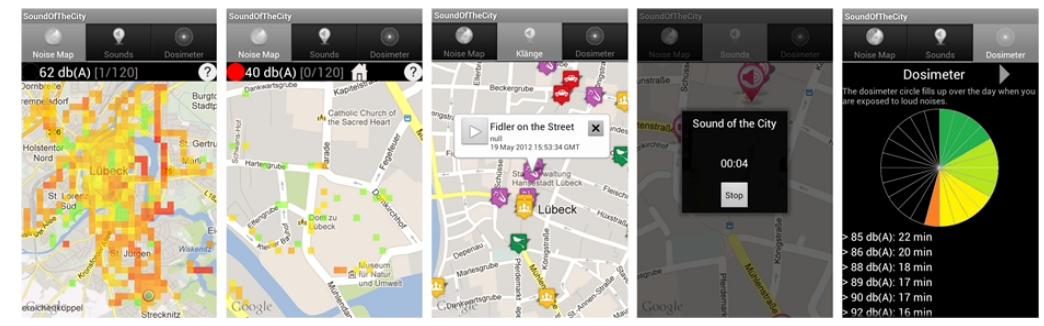
- Use available technology
- Involve citizens
- Collect and publish data
- Empower citizens



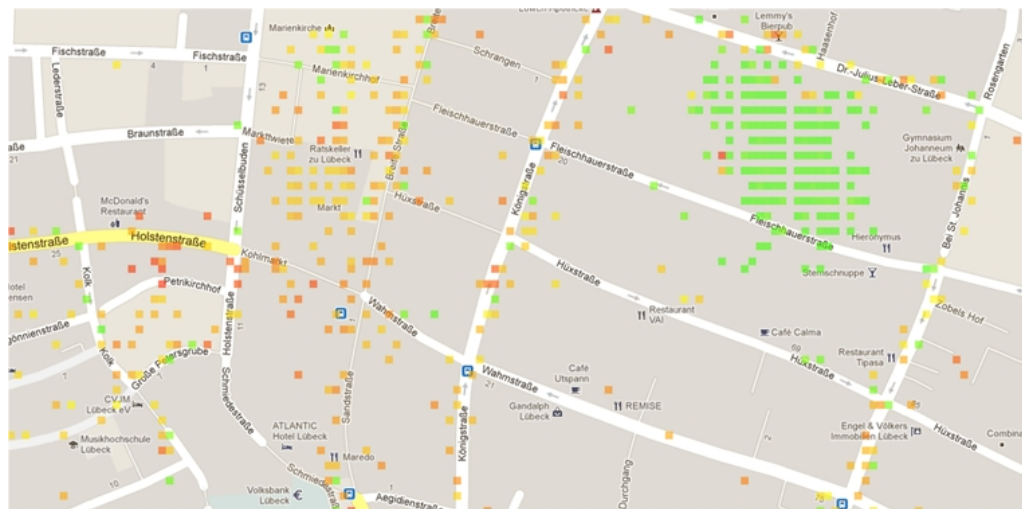
Architecture



The Mobile Application



The Noise Map

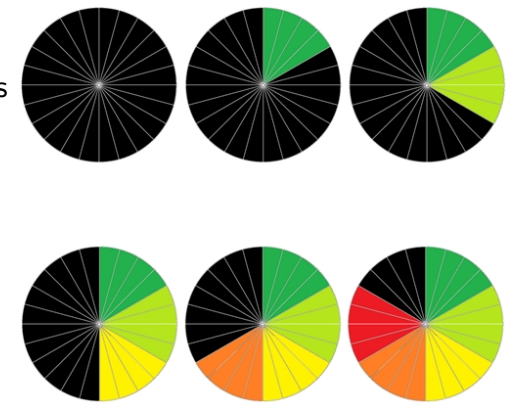


Visualizing community exposure



The Dosimeter

- Measure and visualize how a user is exposed to noise
- Generate personal benefit
- Provide an understanding of the personal exposure
- Provides risk assessment

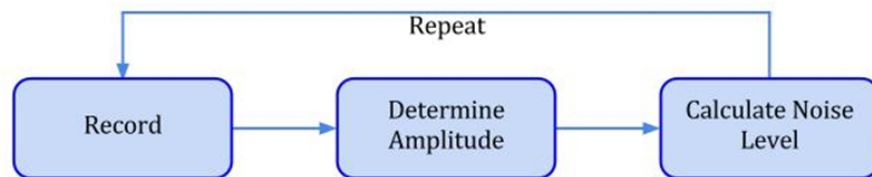


The Sound Map

- The Sound Map provides a dimension that is more easily accessible.
- It allows to capture the experience.
- Creating Records
 - Video
 - Sound
 - Picture
 - Text
- Augment the information conveyed by the sensor data



Measuring with Mobile Phones



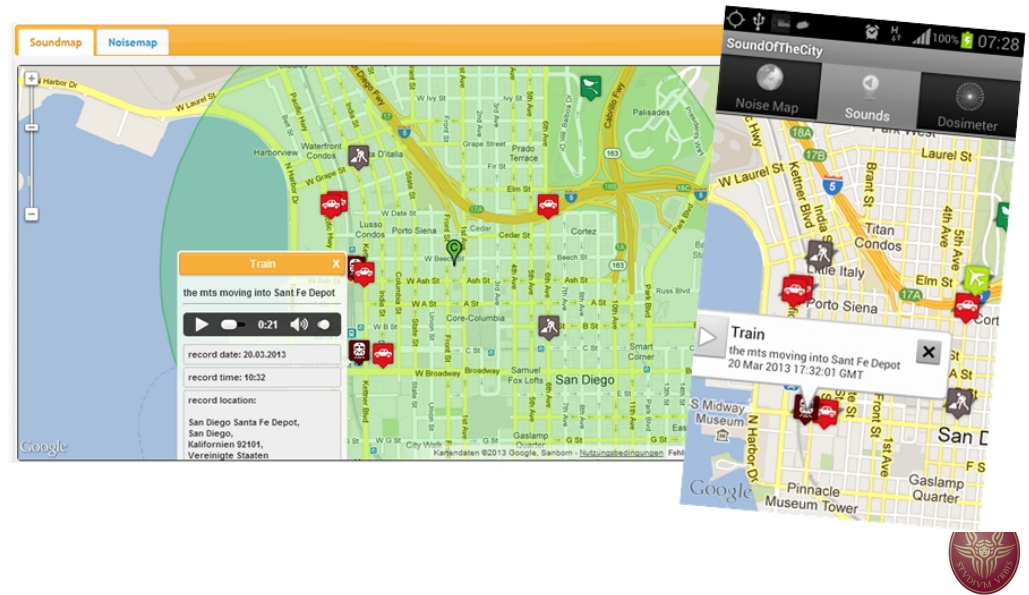
$$\times dBSPL = 20 \log_{10} \left(\frac{p}{p_0} \right) dBSPL$$

Problems:

- Handling (hands, pockets, bags)
- Protective cases
- Wind



The Sound Map



Context Awareness

- Using context can help reduce the amount of distorted measurements and reduce energy consumption
- SoundOfTheCity is supposed to visualize noise that is relevant to the community there are possibilities of exclusion
 - Phone is in the pocket
 - User is indoors
 - User is traveling at high speed
- The measurements are still used to evaluate personal exposure



Context Awareness

- Is the proximity sensor is evaluating to **true** (Pocket)
 - Turn off GPS and do not send noise levels
- Wifi is connected (Indoors)
 - Turn off GPS and do not send noise levels
- If GPS-Location has low accuracy (Indoors)
 - Do not send noise levels
- If the user is moving at high speed (cars, trains)
 - Do not send noise levels
- If the phone has not moved for several minutes
 - Do not send noise levels, reduce GPS rate



Participatory Sensing in Commerce

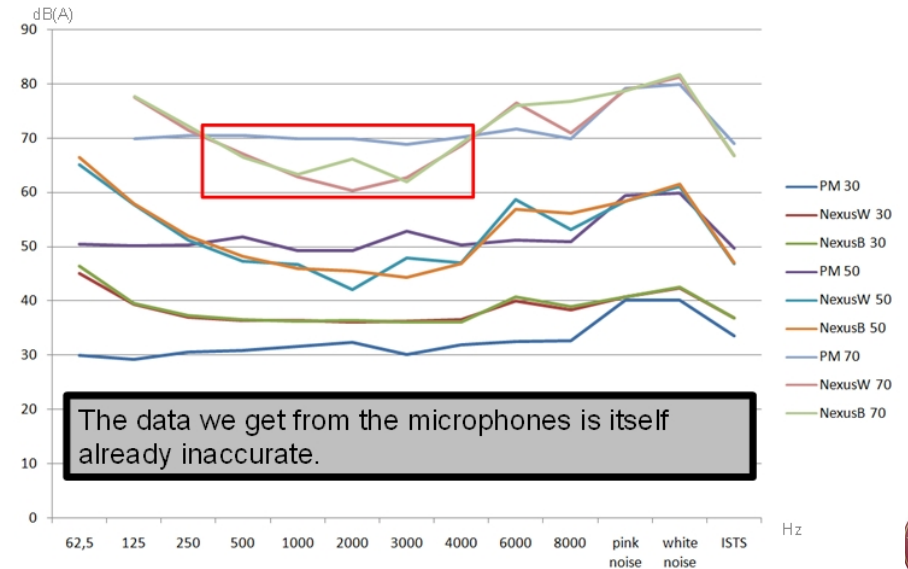
Handbook of Economics and Information Systems, 2006

“The empirical evidence for price dispersion in both online and offline markets is sizeable, pervasive and persistent”

Solution: Using Mobile Phones to Track Market Price Dispersion



Mobile Phones Microphones

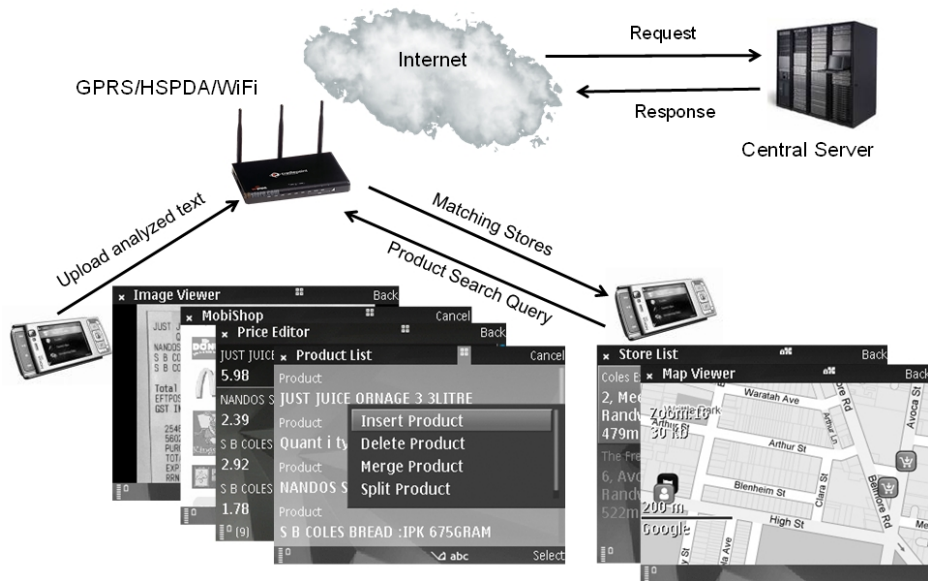


Participatory Sensing to Track Price Dispersion

- Harness power of the collective via participatory sensing
- Consumers collect and share pricing information
- Design criteria:
 - 1 As automated as possible to reduce reluctance in participation
 - 2 Use camera phones to replace human sensing, processing and communication tasks



The Architecture



Large-Scale Participatory Sensing

- Most systems are still developed/tested on a small scale.
- A number of Future Internet testbeds can be used for suitable experimentation purposes.
- Deploy systems and applications utilising large-scale infrastructure already installed.
- A few testbeds are installed in urban areas – city centers – e.g., SmartSantander.



Two Applications: MobiShip vs PetrolWatch

- Nearly identical system architectures
- PetrolWatch – camera position important
 - Special computer vision algorithms for extracting fuel price information (on server/camera phone)
 - Use of GPS and GIS to simplify image processing



SmartSantander: System Objectives

- Run “experiments” on Smartphones:
 - Virtualization of experiments on volunteers smartphones (deployment, execution, management, data exchange).
 - Transparent execution – Users can simply enable/disable if they wish no further interaction.
 - End-user customization options for privacy.
 - Integration with SmartSantander.
- Experimentation with:
 - Integrated smartphone sensors.
 - Interaction with IoT devices/networks/Web (WiFi, Bluetooth, other sensors).

Software technologies used

- OSGi, Ambient Dynamix
 - Android OS platform.
 - OSGi-based plug-and-play context sensing framework.
 - Provides a simple means for apps to request context support.
 - Download/install dynamically plug-ins on demand.
 - Mechanisms for plug-in execution management.
 - Manage access rights to smartphone resources.
- Plug-ins: Small, reusable and collaborative java components.
- Components can be composed into an application and then be automatically deployed.
- Project Plug-in repository on the Web (i.e., not a centralized market place like e.g. Google Play).



The Experimentation Process

End Users/Smartphones

- 1 End-users download participatory experimentation application
- 2 End-user customizations – e.g., which sensors to use for experimentation, when to upload results, etc.
- 3 Smartphone app registers the device to SmartSantander and downloads an experimentation plug-in
- 4 Experiment readings are stored on the device and forwarded to SmartSantander server



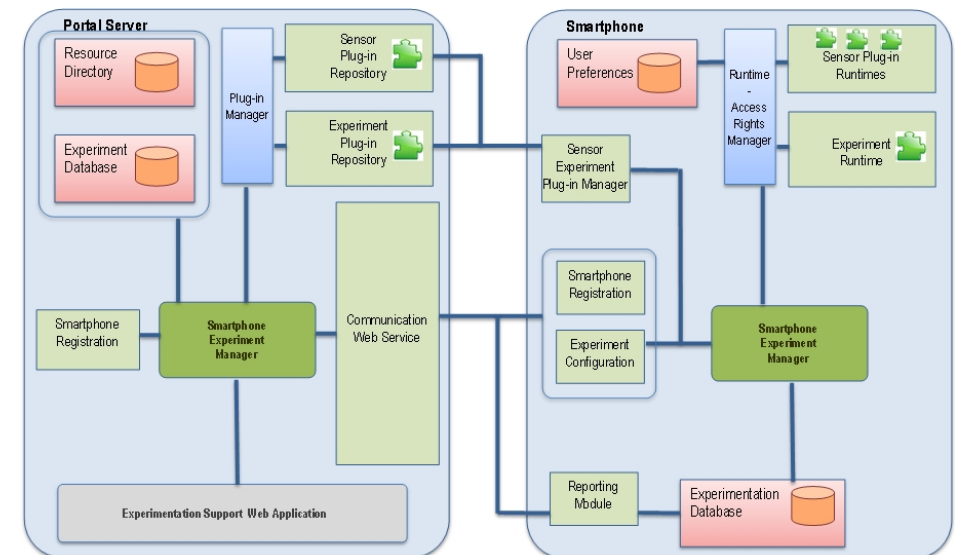
The Experimentation Process

Experimenters/Server Side

- 1 Experimenters submit code written as plugins
- 2 Code is validated locally by SmartSantander
- 3 Available as a plug-in on the projects plug-in repository
- 4 Readings are available at SmartSantander portal server

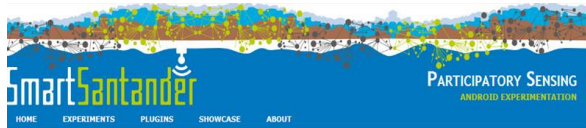


Smartphone Experimentation Components



Introduction

Web Portal



Results for Experiment:4

Draw Chart:

Device Id	Sensor	Reporting Device	Message
123	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.002944444444444444","type":"String","timestamp":1383651108914]
124	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.07891111111111111","type":"String","timestamp":138365156631]
125	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.12393644444444443","type":"String","timestamp":1383651175399]
126	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.05257448988888889","type":"String","timestamp":1383651184452]
127	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.12470894506666666","type":"String","timestamp":1383651215378]
128	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.1377246891655555","type":"String","timestamp":1383651225478]
129	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.2897595343288888","type":"String","timestamp":138365123510]
130	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.12489915026204444","type":"String","timestamp":1383651245585]
131	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.05358364049271","type":"String","timestamp":138365125549]
132	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.0989354951677084","type":"String","timestamp":1383651275544]
133	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.1025292931983095","type":"String","timestamp":1383651752089]
134	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.1152905051620914","type":"String","timestamp":1383651728978]
135	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.1223046889117281","type":"String","timestamp":1383651823741]
136	org.ambientdynamix.contextplugins.NoiseLevelPlugin	48	["context":"org.ambientdynamix.contextplugins.NoiseLevelPlugin","value":"0.137352080982458","type":"String","timestamp":1383651833649]



Introduction

Availability & Testing

- Open source, available at GitHub.
- Translated also to Spanish and Greek.
- Implementation tested with a number of different Android devices and volunteers.
- 2 different scenarios.
- 30 volunteers participated in the experiments.
- 7 days duration, 130K readings produced.
- 6.8 Km² area covered.
- Tested in 2 cities – Santander (Spain) and Patras (Greece).
- Android versions 2.x, 4.x are supported, majority > 4.0.3.



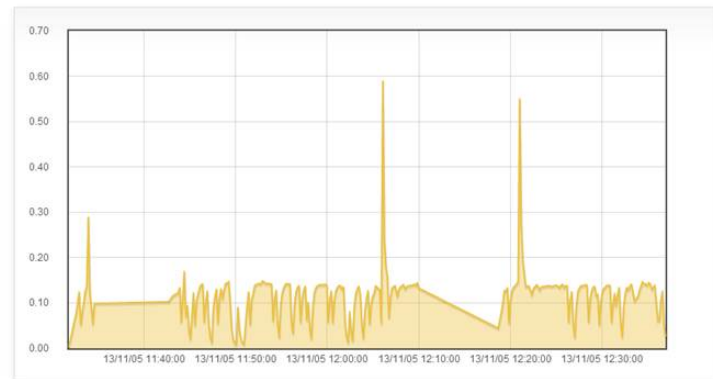
Introduction

Web Portal



Results for Experiment:4

ExperimentId	DeviceId	Sensor
4	48	org.ambientdynamix.contextplugins.NoiseLevelPlugin



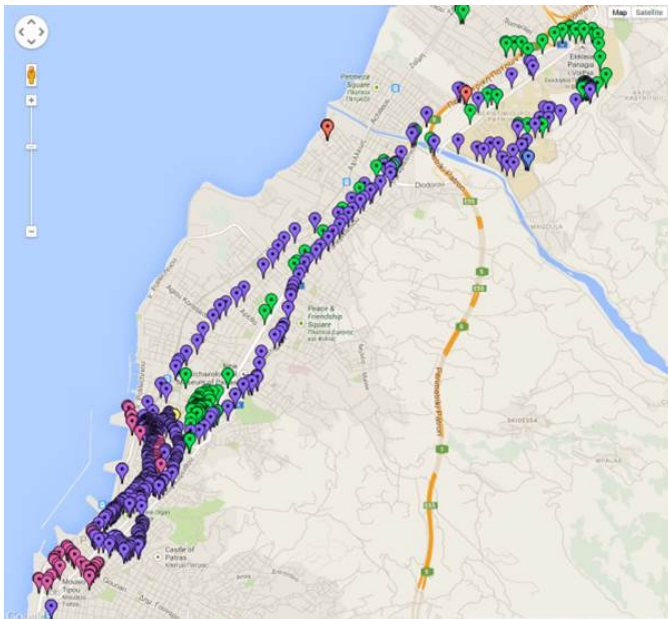
Introduction

Wardriving

- Pedestrians carry Android smartphones mapping free Wi-Fi networks along the city streets.
- Map of Wi-Fi availability over a city in just a few days.
- 8 users / 2 days, 3 Km²
- 2878 WiFi networks discovered



Wardriving



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Noise Monitoring

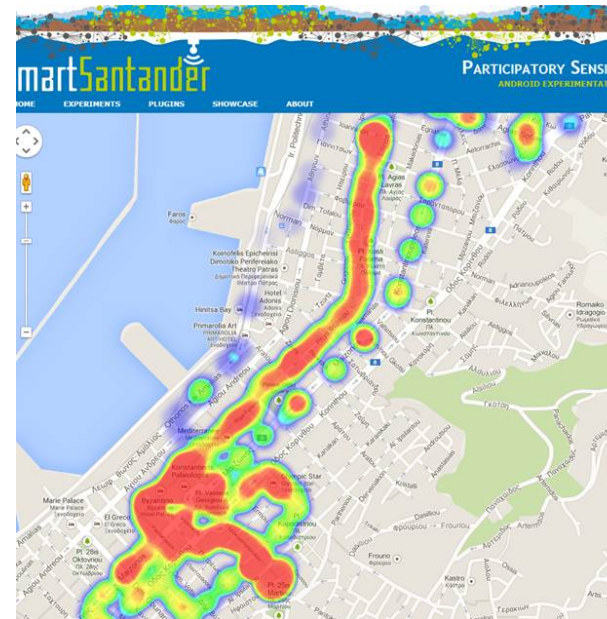
- Detect ambient noise in city centers using smartphone microphone.
- Volunteers carry smartphones monitoring the ambient noise levels the way humans perceive them in their daily lives – 27 users / 5 days, 6.8 Km²
- 45 IoT nodes equipped with microphones available in Santander - calibrated to return values between 50 and 100 dBA.
- Issues with smartphone mic accuracy, calibration profiles are required.
- Smartphone readings are close to static infrastructure readings (3-6 dBA)
- A 3dBA increase is barely noticeable to humans

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Wardriving

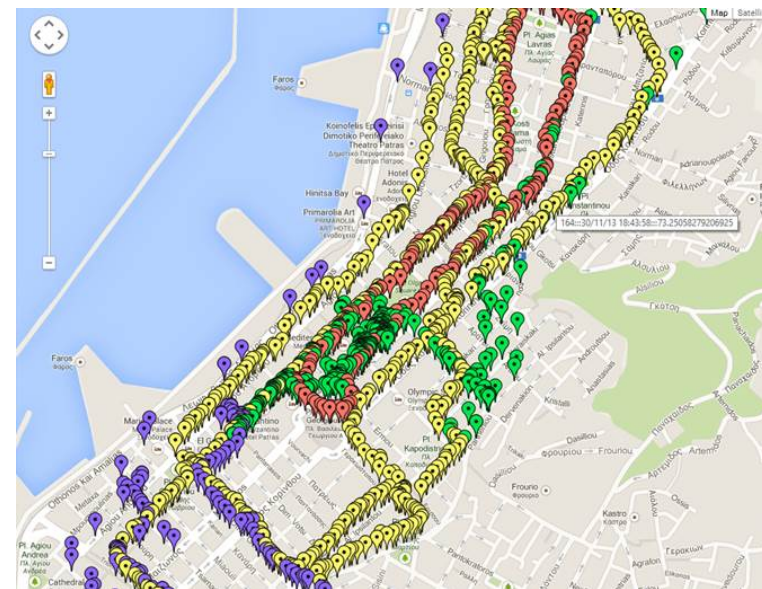


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Noise Monitoring

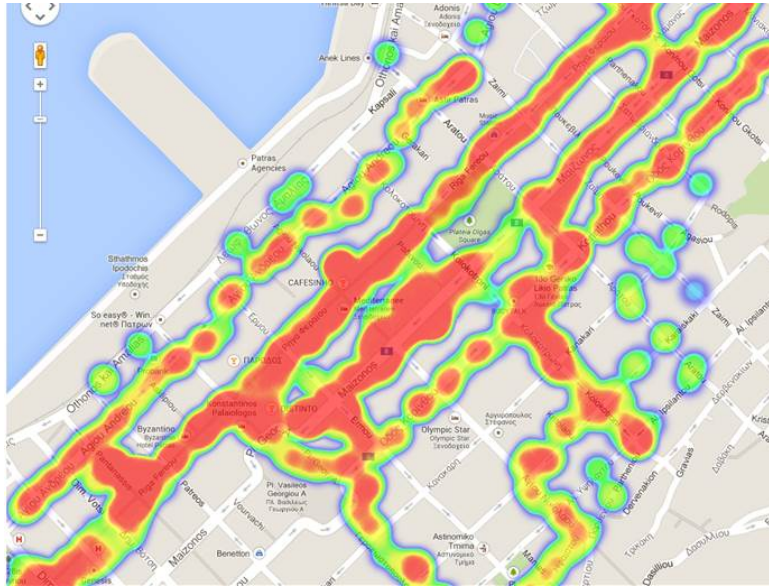


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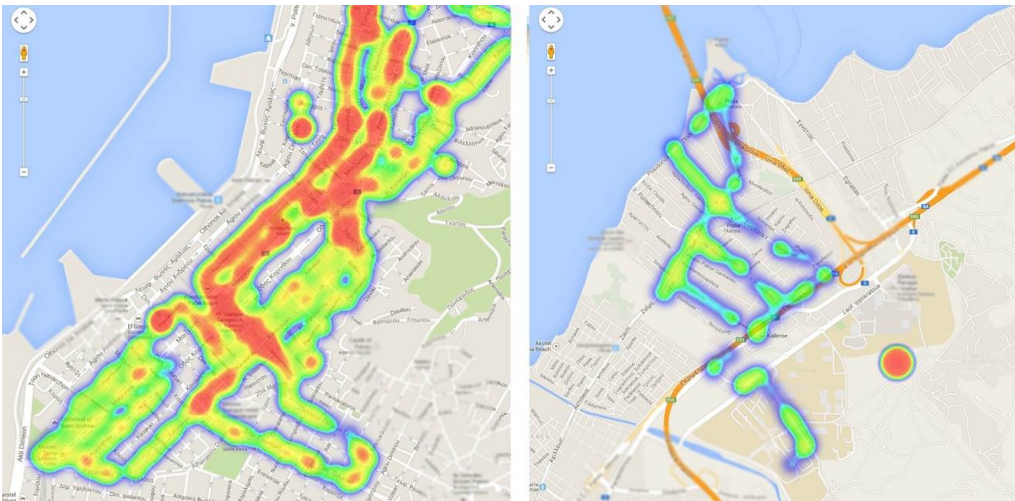
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Noise Monitoring



Noise Monitoring



City center (left) and suburb/campus (right) average noise levels between 18:00-24:00



Noise Monitoring



Stationary IoT nodes

Readings 12:00 - 18:00

Readings 18:00 - 24:00



Discussion - Limitations

- Volunteers in a smartphone experimentation platform can fill in “gaps” that are present in installation areas.
- Plugins implemented with ~400 lines of Java code.
- There are challenges in integrating smartphones within an IoT sensing infrastructure.
- Tradeoff between the number of experimentation volunteers, their commitment, time to perform the experiment, quality of the results produced.
- Researchers avoid the complexity of developing for an embedded highly specialised platform and instead use popular development tools for smartphone platforms.
- Using such experimentation procedures can lead to creating an abundance of additional data.

