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Facilitate Open Science Training for European Research

Geo-information infrastructures for aggregation, visualization and analysis of heterogeneous geo-spatial Open Data

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INTRODUCTION

Introduction, recent works

- V.Vescoukis, C.Bratsas, Open Data in Natural Hazards Management, topic report N.2014/01, EPSI platform EU

- V.Vescoukis, Architectures for distributed mission-critical geospatial applications: challenges and opportunities, talk in Geomatik seminars (2014), ETH Zurich

- V.Vescoukis, Distributed Web-GIS, Linked Open Data, Lectures in MSc Geomatics (2014), Dept. of Civil, Environmental and Geomatics Engineering, ETH Zurich

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Introduction, recent works

- V.Vescoukis, Geo-information applications development, Course in MSc in Computing Science (2015), University of Groningen, the Netherlands
- V.Vescoukis et al., Geo-information infrastructures for inter-disciplinary risk analysis research, European Security and Reliability Conference (2015), September 2015, ETH Zurich
- V.Vescoukis, Integration of inter-disciplinary approaches in hazard management: a Geo-Information Engineering perspective, ETH Risk Center Fall 2015 Seminars, Oct 13, 2015, ETH Zurich

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THE BIG PICTURE

What is this about?

- Information systems
  - An application idea makes sense if there is a need and the intended functionality can be implemented
  - Data will be input to the system by its users, depending on the application specifics

- Geo-Information systems
  - An application idea makes sense if there is a need and the intended functionality can be implemented AND the spatial data needed can be made available
  - The availability of data drives new application ideas
  - Need to access data from literally ANY source, in any format:
    No data -> No application

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Need to share data

- Why NOT share data?
  - Data is expensive to acquire and maintain
  - Proprietary formats mean more 'loyal' customers
  - Data is power

- Why share data?
  - Data enables new services
  - Data creates new knowledge
  - Data does not belong to those who collect it
  - Data is power

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Open Data

- Questions
  - What is Open Data?
  - Who creates Open Data?
  - Who needs Open Data?
  - Who provides Open Data?
  - How open is "Open Data"?
  - Quality of Open Data?

- What's the big deal?

- Facts
  - Every human activity (almost!) produces digital data that is stored and processed
  - This data does not "belong" to specific entities: it is "just there"
  - Huge opportunities arise

- Cases
  - Social networking, sharing
  - Daily activities, transportation
  - Sensors, Internet of things
  - VGI, crowdsourcing, ...

Open Data

- Why is Open Data important
  - Decision making
  - Public awareness
  - Transparency
  - New government ethics
- Who supports Open Data
  - Citizens, of course
  - Governments (some!), NGOs
  - Public and even some private entities of any size
- Who benefits?
  - Everybody: individuals and societies alike
- Who is threatened?
  - Those who want to keep the power of knowledge for their own

Geo-spatial apps and Open Data

- Geo-spatial applications
  - Technologies, standards:
    SF, GML, WMS, WFS, WPS and many others
  - Data:
    Images, rasters, vectors
- Data, however
  - Are critical (not as in a "personal address manager" app)
  - Are expensive, hard to maintain up-to-date, non-standard, ...
- Geo-spatial apps rely heavily on data!

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What is special about spatial?

- Geo-information systems are about managing geographical information (data)

- What distinguishes geographical data from any other kind of data processed today?

- Are there any unique attributes of software applications that process geographical data?

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What is special about spatial?

- Data vs. spatial data
  - Spatial data is data used to describe spatial entities: roads, blocks, buildings, etc.
  - Spatial data is also data about the location of events (purchases, transactions, any activity)
  - Spatial data may also involve time (tracks)

- Spatial data…
  - Is BIG data (and keeps getting bigger)
  - Can be complex (coordinate systems and more)
  - Is computationally intensive to process and organize

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GIS and spatial data

- GIS is (used to be) about managing spatial data for applications such as
  - Mapping
  - Geo-statistics
  - Environmental, planning, etc.
- Early GIS software was desktop-based and offered a wide range of geo-spatial analysis tools for targeted application domains
- However, traditional desktop-based GIS applications cannot deal with the quantity and complexity of spatial data produced today

Distributed Web-GIS

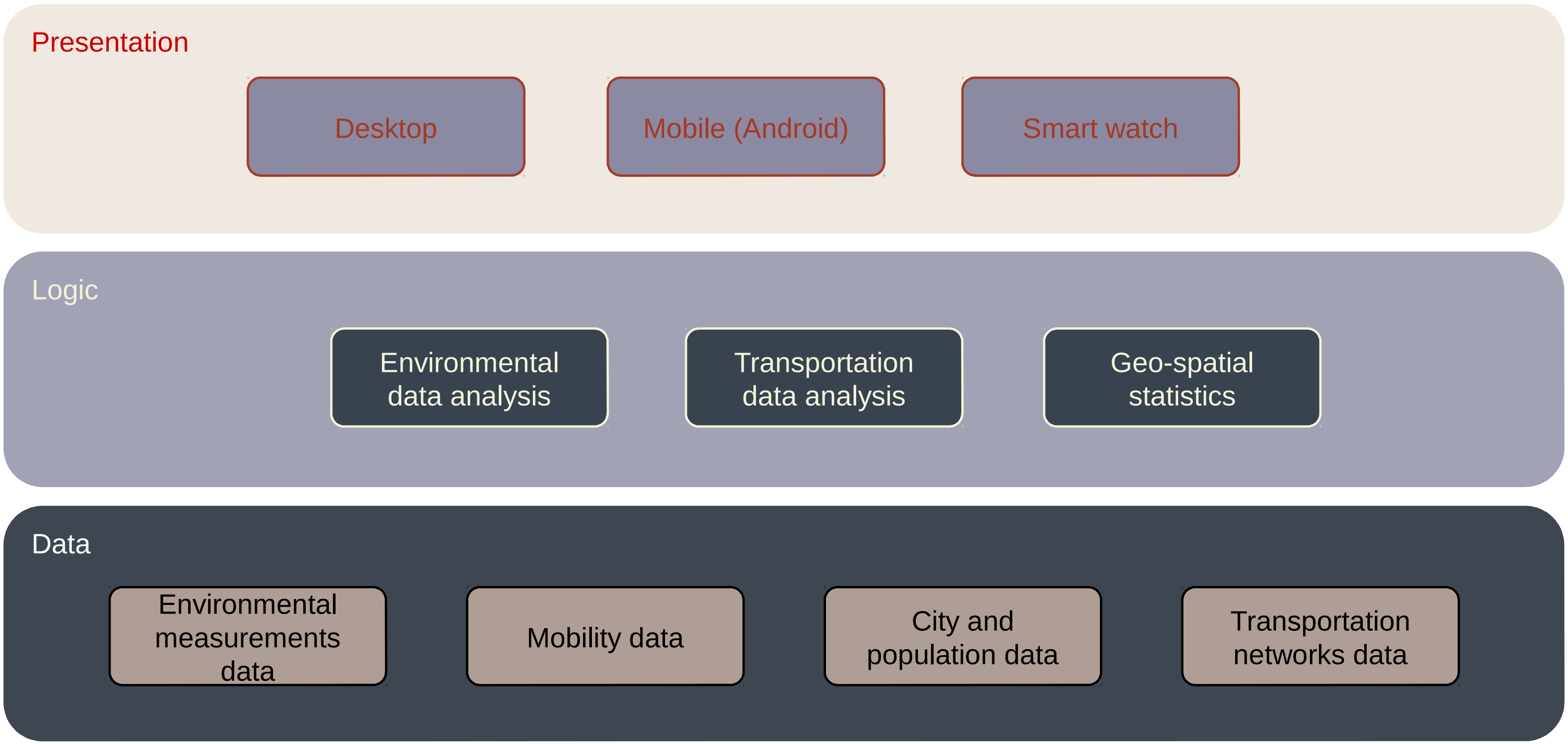
- Spatial data
  - Base maps, surface models, imagery
  - Thematic layers, roads, cities, PoIs
  - Events with spatial reference and timestamp: measurements, tracks, tweets, check-ins, etc.
- Services
  - Queries and analytics on data
  - Mapping, geo-statistics, computations etc.
- Presentation
  - Web-based mapping platforms (autonomous, embedded)
  - Handheld devices, infographics, wearables.

Distributed Web-GIS

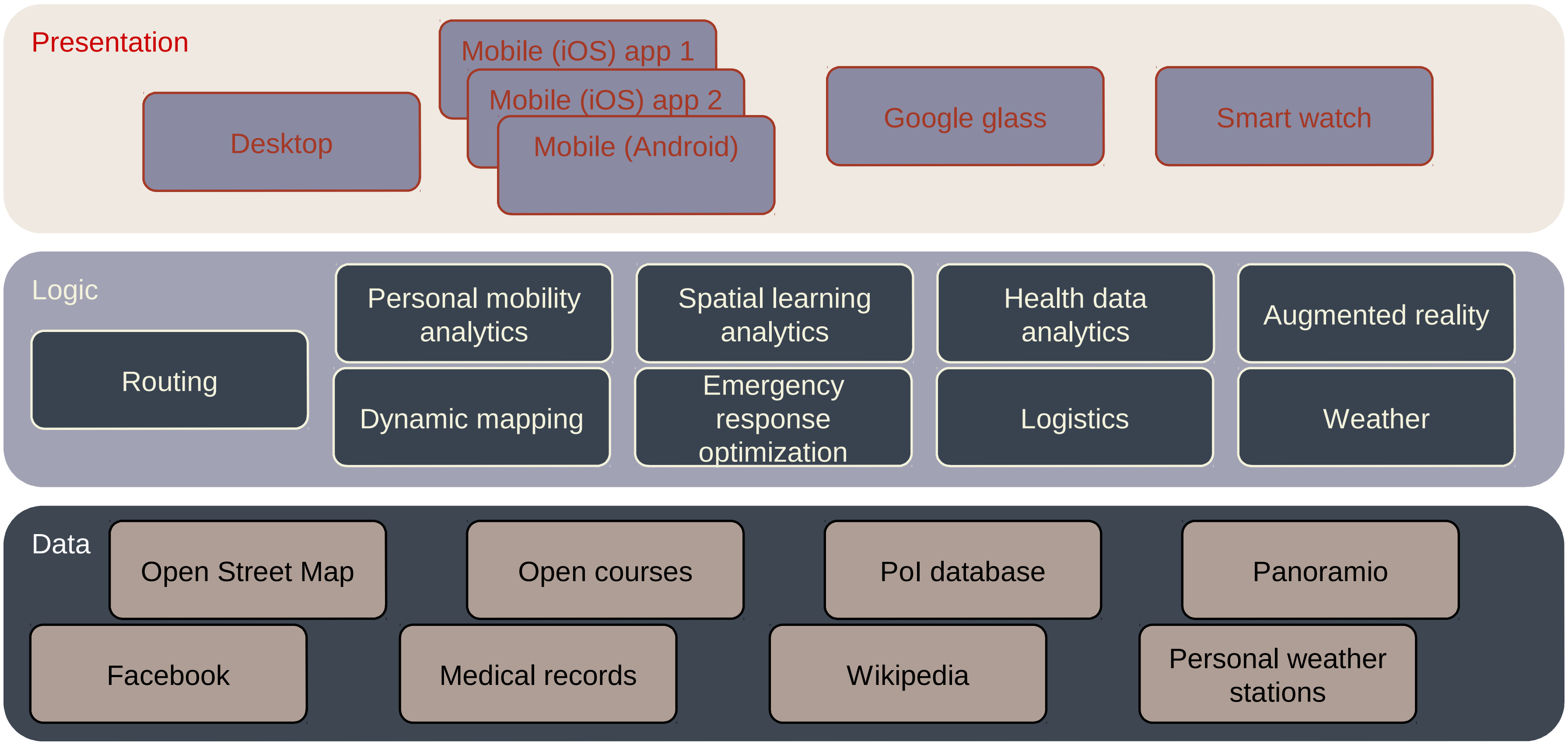
- Why “distributed”?
  - Data comes from many different sources
  - Possible services are restricted only by imagination
  - Services and computations may be offered independently of data
  - Pluralism and heterogeneity of user interfaces: classic, mobile, wearables (what’s next?)

- What makes it interesting?
  - Unlimited possibilities and business cases
  - Technical challenges raised by diversity

Distributed Web-GIS - example



Distributed Web-GIS - example



Geo-information applications, today

- It is not about "software development" anymore!
- Even multi-tier applications seem "so early 2000s"...
- How to deal with heterogeneity of spatial data, both semantic and structural?
- Answer: Accept it, go with Open Data and make good use of Open Data technologies

- To do useful things with Open geo-spatial Data, we need infrastructures, not single information systems : aggregation, visualization and analysis, even mission-critical applications!

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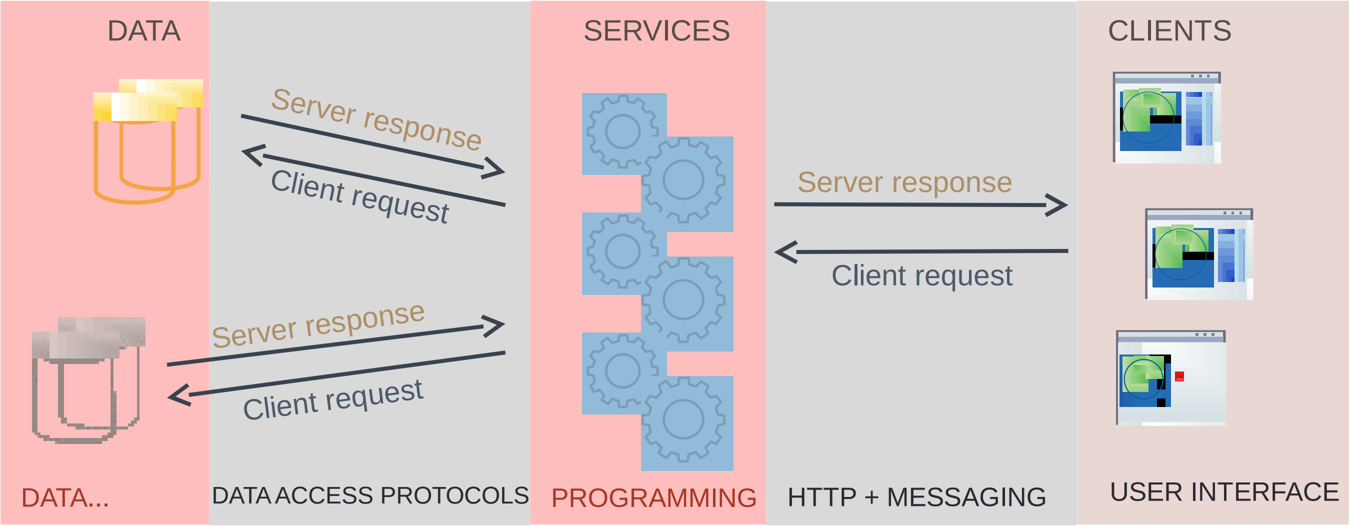
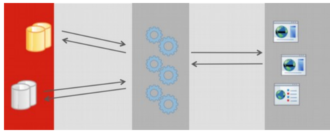
FUNDAMENTALS: ARCHITECTURES AND TECHNOLOGIES

A common reference architecture



Key technologies: Data tier



- Relational databases + SQL
  - ACID: Atomicity, Consistency, Isolation, Durability
  - Heavy processing requirements
  - Relational schemas, data management fundamentals
  - Examples: MySQL, Oracle, SQL Server, Postgres

- Non-relational databases
  - BASE: Basically Available, Soft-state, Eventually consistent
  - Useful for big data manipulation
  - Used by Google, Amazon, Facebook, 4-square, …
  - Examples: NoSQL, MongoDB, SPARQL

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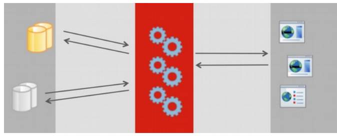
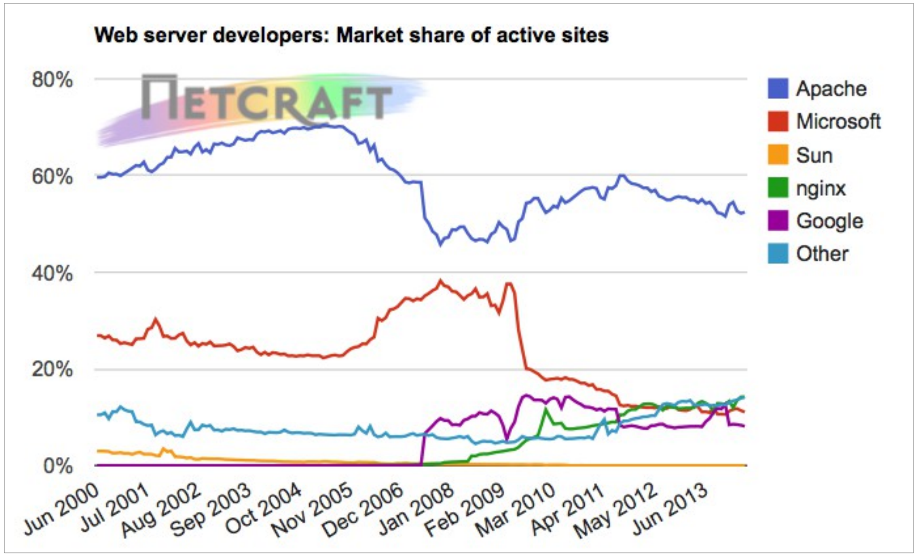
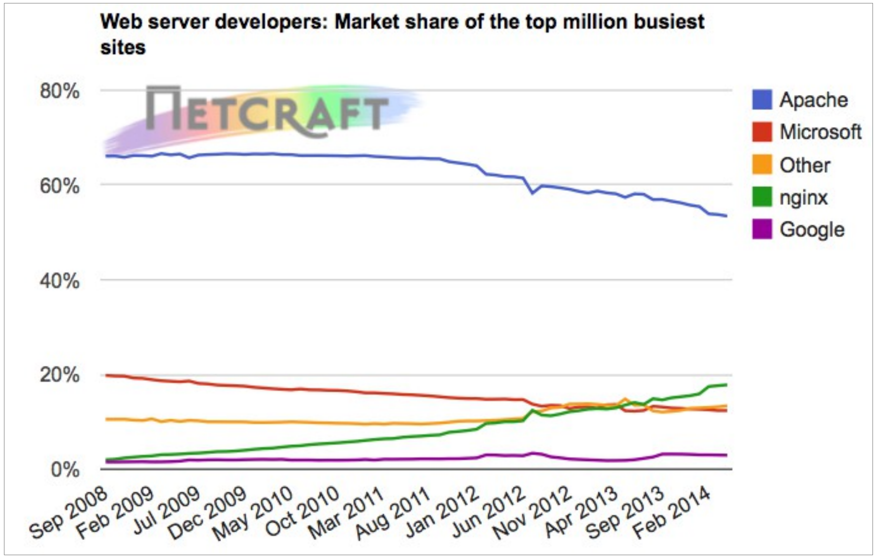
Key technologies: Service tier



- Web servers: HTTP only
  - Apache: ~60%, Open source, multi-platform
  - IIS: ~15%, Proprietary, Windows-only





Source: netcraft.com

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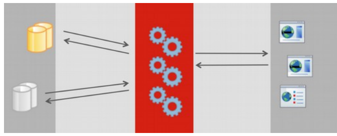
Key technologies: Service tier



- Application servers
  - Support more protocols than HTTP to implement also business logic into the server
  - Lately they lose ground from web service architectures
  - Examples: GeoServer, Tomcat, IBM Websphere, etc.

- Programming
  - Server-side scripting (PHP, Python, …)
  - Service-specific descriptions (example: SLD for WMS)
  - Java Enterprise Edition, Java Server Pages
  - Microsoft ASP.NET, C#, Visual Studio tools

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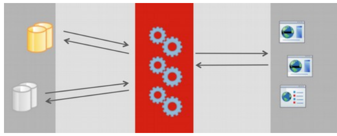
Server-side scripting



- How server-side scripting works
  - Request received by the client
  - Server runs locally a program (script)
  - The output of the program is HTML or any other text
  - The resulting text is sent to the client using HTTP
  - The client does not know if the received data comes from a script or is static text (stored as text file on the server)

- Scripts have local privileges on the server as needed for connecting to databases or other services

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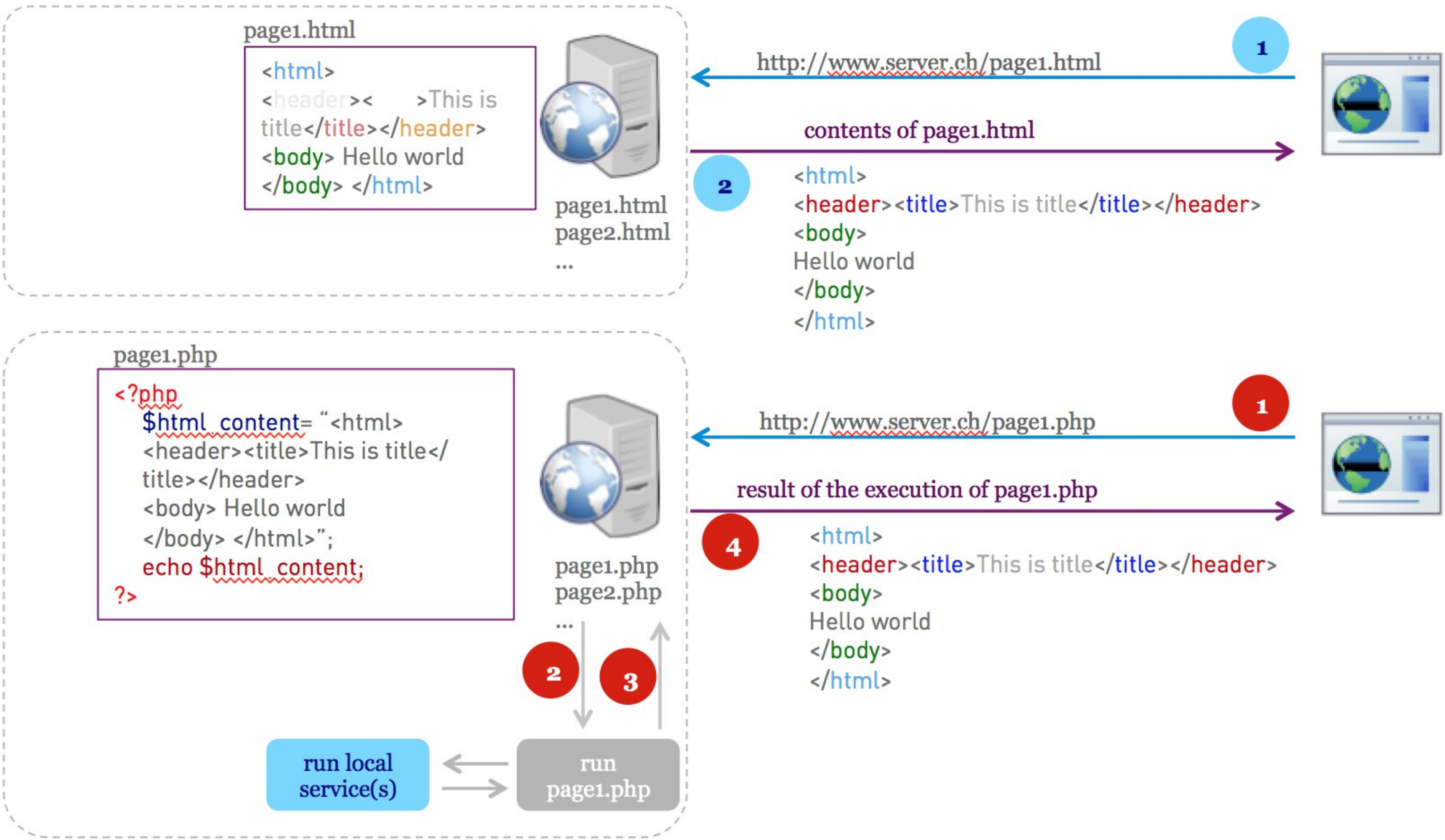
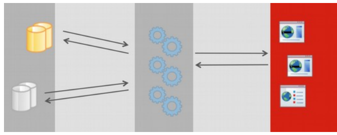
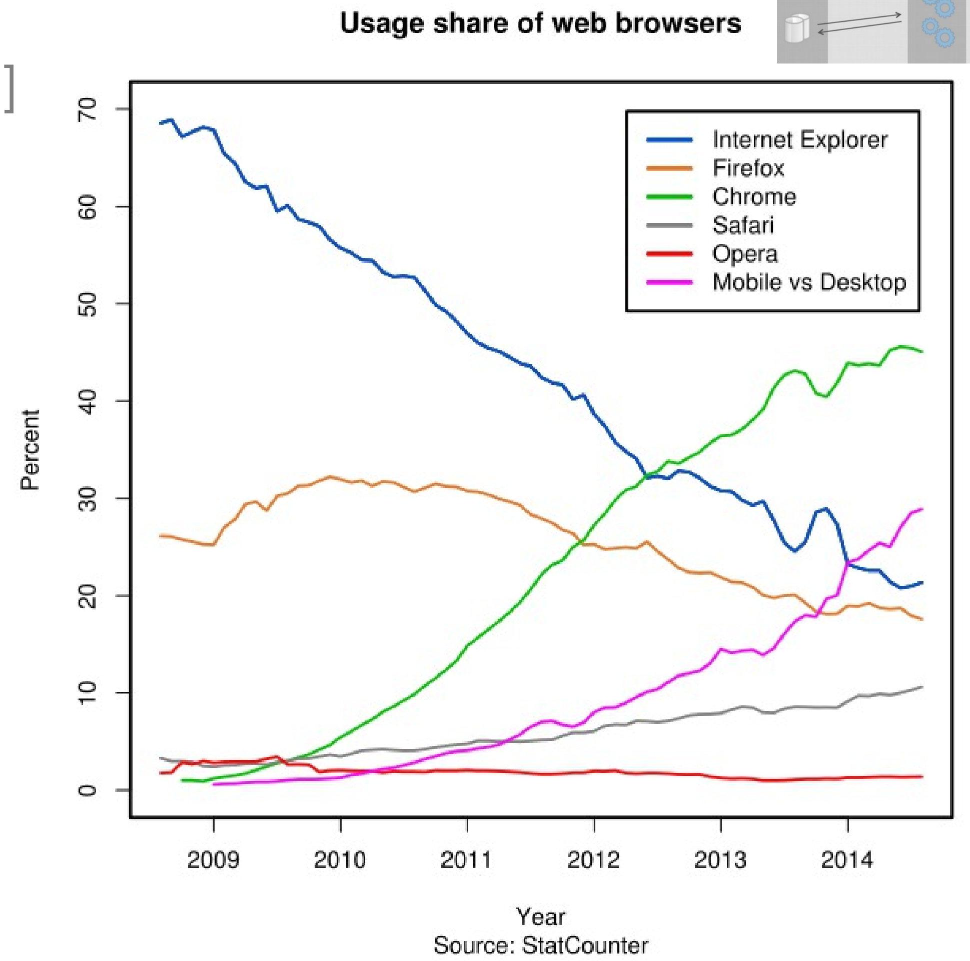
Server-side scripting



Key technologies: Presentation tier

- Layout engines
  - Webkit, Mozzila Gecl
- Browser languages
  - HTML/CSS
  - Javascript, AJAX
  - Flash, Silverlight
  - …
- Client-side scripting





Client-side scripting

- How client-side scripting works
  - Response received by the server contains a recognizable script
  - The browser decides where to execute it (browser or operating system of the client machine)
  - The execution of the script may modify the client machine!
  - The output of the script is rendered as any other HTML content
- Security warning: scripts actually run on the client machine (yours!)

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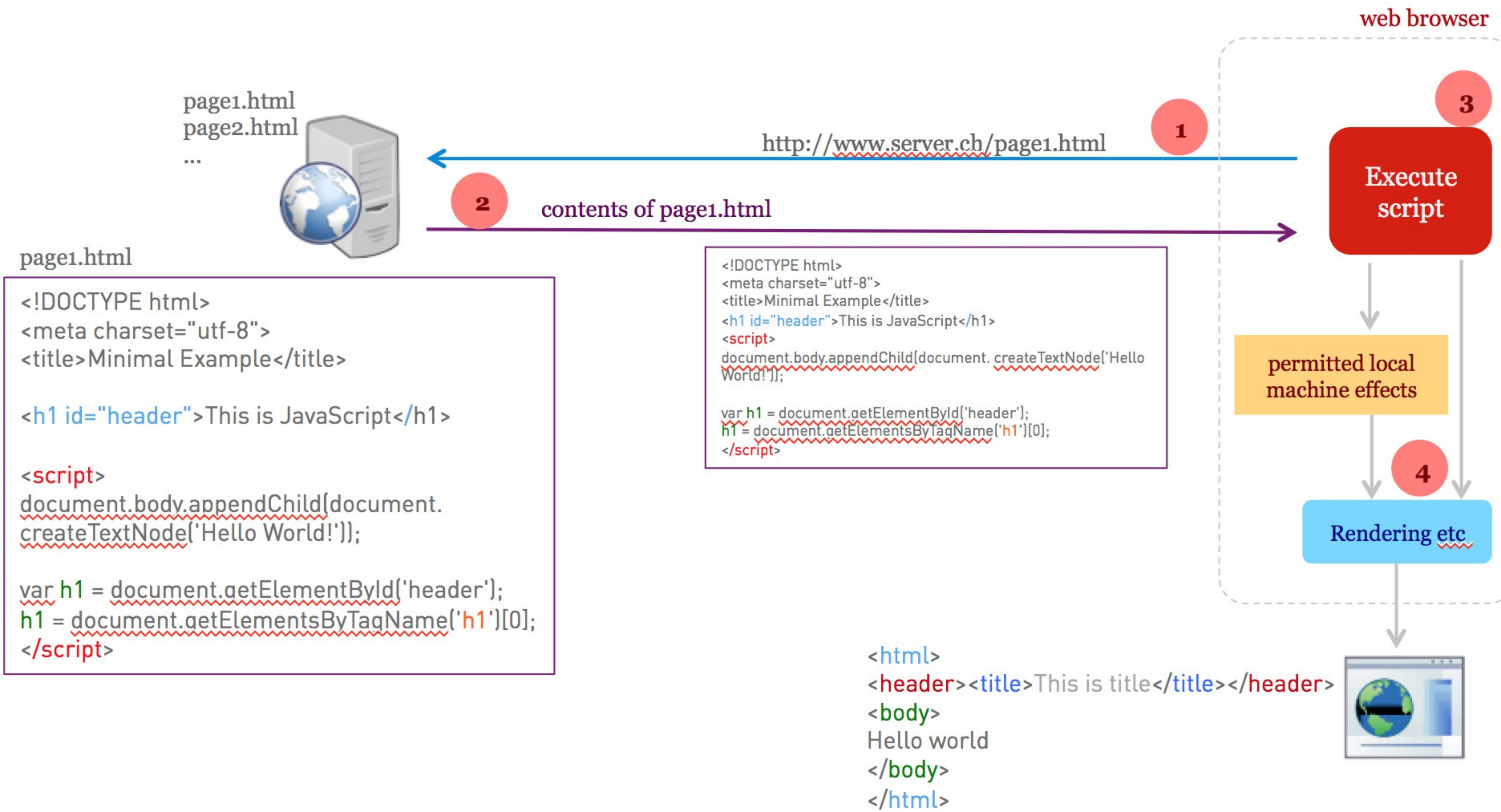
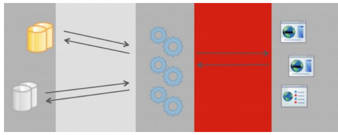
Client-side scripting (simplified)



Key technologies: XML



- XML is for Extensible Markup Language
- From HTML to XML
  - HTML is used to mark up text to be displayed to users
  - XML is used to mark up data to be processed by computers
  - HTML describes both structure and appearance
  - XML describes only content, or “meaning”
  - HTML uses a fixed, unchangeable set of tags
  - In XML you make up your own tags

- Both XML and HTML come from SGML (Standard Generalized Markup Language)

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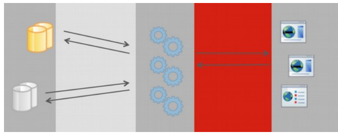
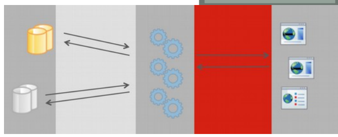
XML



- XML- Related
  - DTD (Document Type Definition) and XML Schemas are used to define legal XML tags and their attributes for particular purposes
  - CSS (Cascading Style Sheets) describe how to display HTML or XML in a browser
  - XSLT (eXtensible Stylesheet Language Transformations) and XPath are used to translate from one form of XML to another
  - DOM (Document Object Model), SAX (Simple API for XML), and JAXP (Java API for XML Processing) are all APIs for XML parsing

Key technologies: JSON



- JSON stands for JavaScript Object Notation
  - Very simple to write and parse using Javascript (it follows a subset of Javascript's syntax, anyway)
  - Efficient and simple structured data communication
  - Data types: Numbers, Strings, Booleans, Arrays, Objects, Nulls

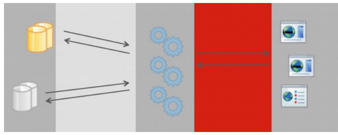
- GeoJSON
  - Simple JSON format for geographical features
  - Objects supported: geometry (position, point, multipoint, etc), features, collections, coordinates

JSON

```
{
  "type": "FeatureCollection",
  "features": [
    {
      "type": "Feature",
      "geometry": {
        "type": "Point",
        "coordinates": [102.0, 0.6]
      },
      "properties": {
        "prop0": "value0"
      }
    },
    {
      "type": "Feature",
      "geometry": {
        "type": "LineString",
        "coordinates": [
          [102.0, 0.0], [103.0, 1.0], [104.0,
0.0], [105.0, 1.0]
        ]
      },
```

```
      "properties": {
        "prop1": 0.0,
        "prop0": "value0"
      }
    },
    {
      "type": "Feature",
      "geometry": {
        "type": "Polygon",
        "coordinates": [
          [
            [100.0, 0.0], [101.0, 0.0], [101.0, 1.0],
[100.0, 1.0],
            [100.0, 0.0]
          ]
        ]
      },
      "properties": {
        "prop1": {
          "this": "that"
        },
        "prop0": "value0"
      }
    }
  ]
}
```

Key technologies: XML-RPC



- Concept
  - Mechanism for calling functions across a network (RPC is for Remote Procedure Call)
  - XML for messaging, HTTP for communication between computers

- XML-RPC structure
  - Data types for requests and responses
  - Basic and complex data types (arrays, structs)
  - Request: HTTP post with method name and parameters
  - Response: HTTP response with return values

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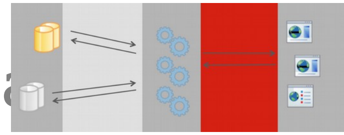
XML-RPC



- Use an XML-RPC library to make function ca
  - Any programming language
  - Apache XML-RPC supports Java

- Generic workflow
  - Develop the function(s) to be called
  - Create the server
  - Register the function(s) to the server (RPC handler(s))
  - Start the server

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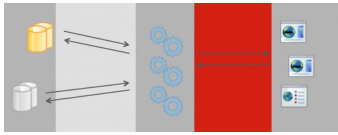
Key technologies: SOAP



- Simple Object Access Protocol
  - Yet another protocol specification for remote execution of methods over XML and HTTP (other protocols possible)
  - Platform- and language- independent
  - Developed by Microsoft and others (IBM, too)
- SOAP message structure
  - Envelope
  - Header (optional)
  - Body
  - No DTD or processing instructions

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SPATIAL DATA: WHAT THIS IS ALL ABOUT…

Spatial data management

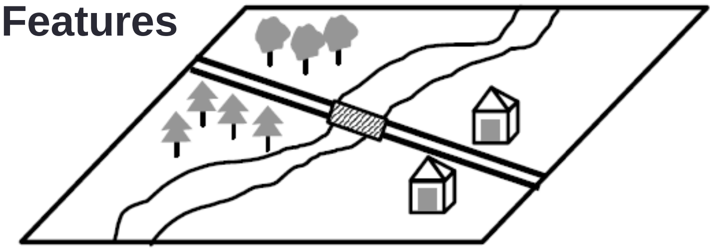
- Representation of spatial data:
  All forms of spatial data must be storable in the system
  - Boundaries, roads, blocks, buildings, paths, points, …

- Spatial queries:
  Queries with spatial reference or context
  - Which properties lie next to a main road?

- Integration with thematic data:
  Combine thematic and spatial data in an adequate form
  - Which properties in corporate ownership lie next to rivers?
  - What types of vegetation exist in country X?

Representation of spatial data

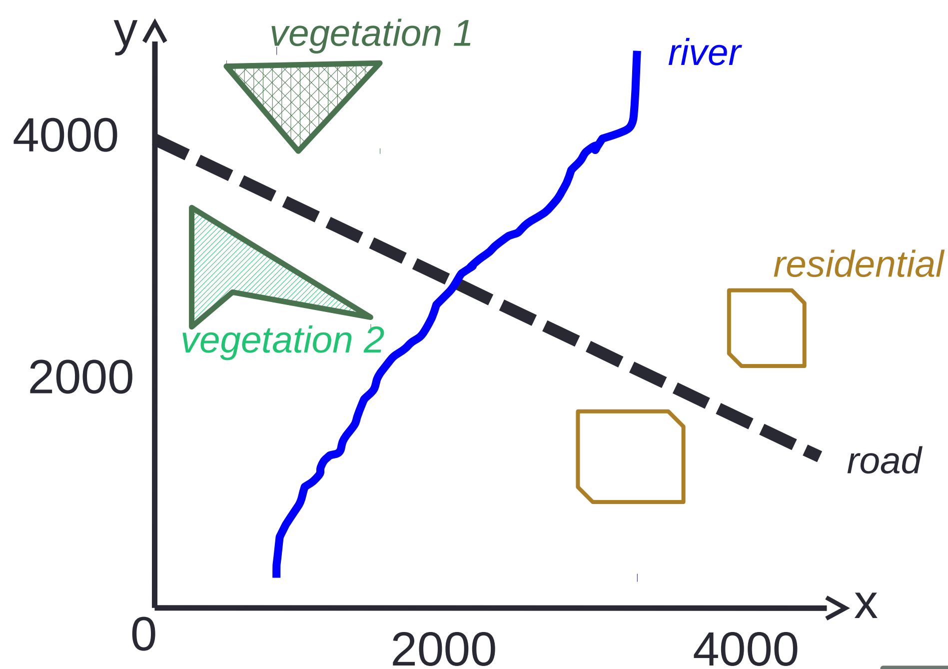
Features



Raster

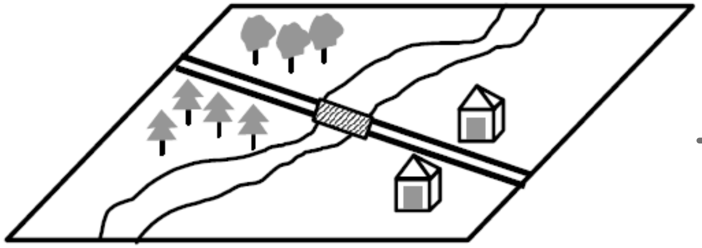
t1		t1		rv		
R	t1			rv		
t2	R		rv			
t2	t2	R	rv			
		rv	R			
		rv		R	h	
	rv				R	
	rv				h	R
	rv					

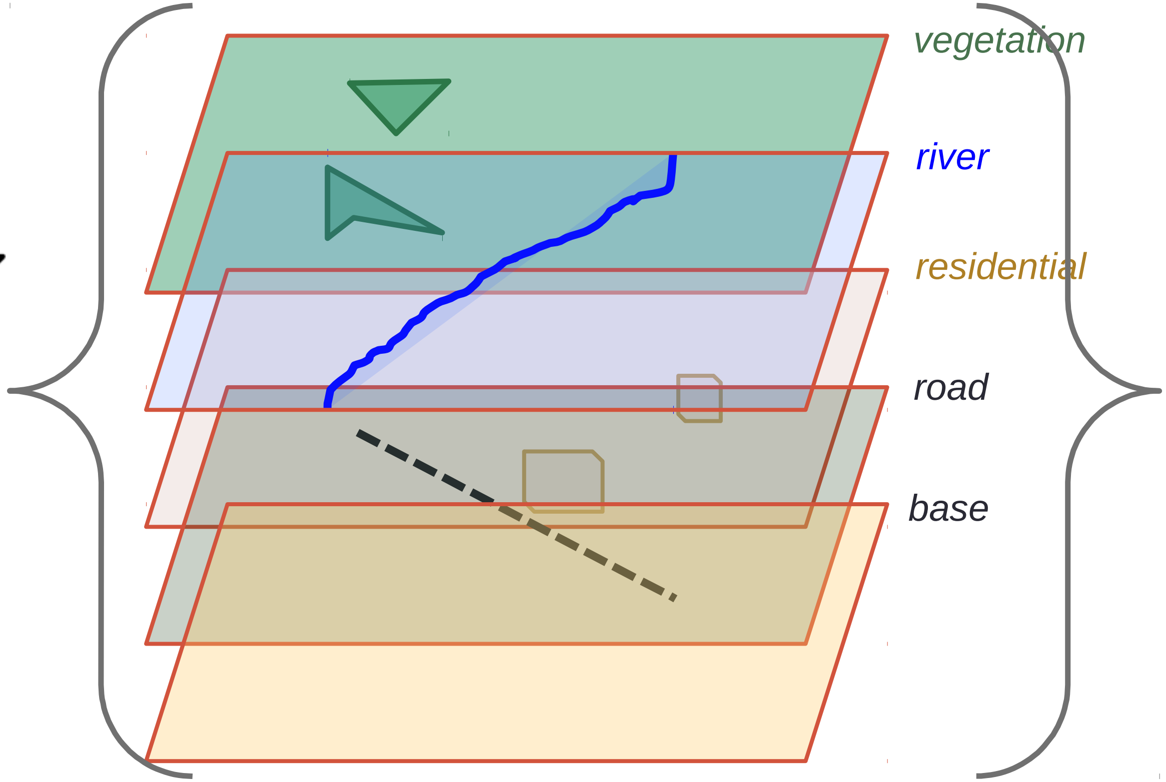
Vector



Representation of spatial data

- Layers
  - a layer contains spatial data under a thematic abstraction
  - thematic abstractions are usually application-dependent





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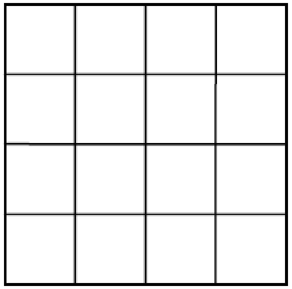
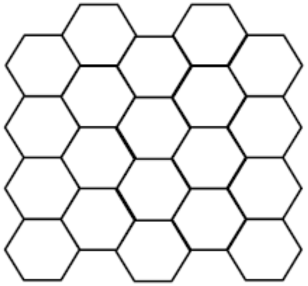
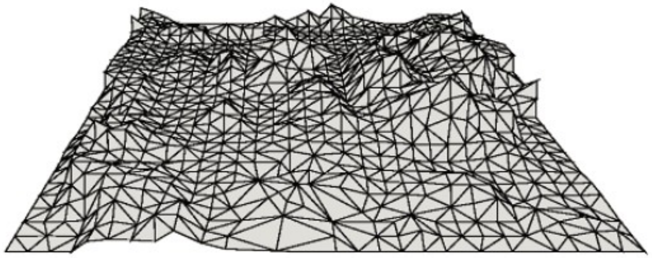
Rasters

- Space is represented as a mosaic
  - Non-overlapping cells
  - Each cell contains information about some attribute
  - Multiple-dimensions are possible
  - An image is a raster with optical information
- Cells' shape may be
  - Canonical (grid)
  - TIN







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Spatial data management

- Thematic data can be managed on the basis of existing data models (e.g. relational model).

- Spatial data may be integrated in different ways:
  - by employing a DBMS data model
  - by extending a given DBMS data model
  - by separate management in a specialized storage system

Spatial data management

- Geographical Information Systems (GIS): Visualize and analyze spatial data
  - Search (location, address, ...)
  - Analyze (buffer, overlay, ...)
  - Terrain attributes (slope, features, ...)
  - Measurements (distance, area, perimeter, ...)
  - Can use data from a SDBMS
- Spatial Databases (SDBMS)
  - Efficiently manage large volumes of spatial data
  - Spatial indexing and search (query) optimization
  - No mapping tools

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Spatial data management

- Create new spatial data types, which are implemented as abstract data types (ADT) within the DBMS.
  - Usage in analogy to primitive SQL data types
  - Spatial index structures can be used within the query process
  - Spatial operators and predicates may be evaluated using special algorithms within the DBMS
- Optimize indexing and query processing for efficiency and speed due to the geometric nature of data

OGC

- The Open Geospatial Consortium (OGC)
  - non-commercial organization, consisting of authorities, companies and universities.
  - OGC offers standards for spatial data and services

OGC Simple Features

- The OGC Simple Feature Specification for SQL:
  - Describes a set of geometry data types for SQL based on the
    OGC geometry model
  - Describes a set of SQL operations on these types

- Characteristics:
  - A "feature" is an abstraction of a phenomenon of the real world ("geo-object"), stored as a dataset in a feature table
  - Modeling of the geometry of spatial objects:
    - Only 0-2 dimensional objects
    - Only linear interpolation between points
    - No explicit representation of topology

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Geo-spatial data sharing practices

- Today there are a number of approaches, sometimes called design patterns, for accomplishing geospatial data exchange between dissimilar systems
  - File based approach: geographic data is encoded in a structured file format, for batch transfer or download
  - Application programming interface (API) approach: geographic data is exchanged as needed between software applications running locally (not on a network)
  - Web services approach: geographic data is accessed and exchanged over networks and the Internet between software components, using HTTP and other web-based protocols

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Standards and interoperability

- Standards (in general)
  - Are needed to achieve interoperability
  - Specify interfaces that different vendors should use
  - Need to be agreed upon (not easy!)
- Data standards
  - Specify a conception of the spatial world (vocabularies, hierarchies, attributes, …)
- Web service standards:
  - specify format of HTTP requests and responses: what parameters, names of parameters, type of value for parameters, type of results, security, …

Main standards bodies

- OGC (Open Geospatial Consortium)
- ISO/TC 211 (International Organization for Standardization, Technical Committee 211)
  - Covering digital geographic information and geomatics.
- W3C (World Wide Web Consortium)
  - Address issues of incompatibility in Web technology by different vendors

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Geography Markup Language

- Geography Markup Language (GML) has its roots in decades-old geo-data exchange standards in the US, developed to solve the problem of packaging geospatial data in a file format independent of any GIS vendor's software
- XML-based encoding standard for geographic information
- Defines an XML schema for geographic entities
- GML objects can represent features, geometries, topologies, coordinates, observations, styles, values and more

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GML and XML

- Because GML is based on XML, it leverages a wealth of standards, tools and practices for data exchange being developed by several consortia around the world
- Standard XML technologies exist…
  - for encoding and data modeling (DTD, RDF and XSD)
  - for linking and associating resources (Xlink)
  - for selecting and pointing (XPath, Xpointer)
  - for transforming content (XSLT)
  - for graphical rendering (SVG, VML, X3D)

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GML vs Simple Features

- GML is an XML representation of geometrical entities ("features", collections)
  - It is about communicating data over the web
  - Also, about communicating meta-data

- Simple Features is a standard for adding geometrical data types in databases
  - Definition, Constraints
  - Operations on geometries, topological relationships, spatial operations

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SERVICE LAYER OPEN STANDARDS

OGC Web Services

- Geospatial Web Services from OGC
  - Map Service: Map= f(semantics, map extent, scale, …)
    -> OGC Web Map Service (WMS)
  - Data Access- / Download- / Feature- / Coverage- Service:
    Geospatial Data = f(filter criteria)
    -> OGC Web Feature Service (WFS) for vector data (Features)
    -> OGC Web Coverage Service (WCS) for fields
  - Geocoding Service: Point = f (postal address)
    -> OGC OpenLS
  - Catalogue Service: Metadata= f(filter criteria)
    -> OGC Catalog Service Web (CSW)

- More at www.opengeospatial.org/standards

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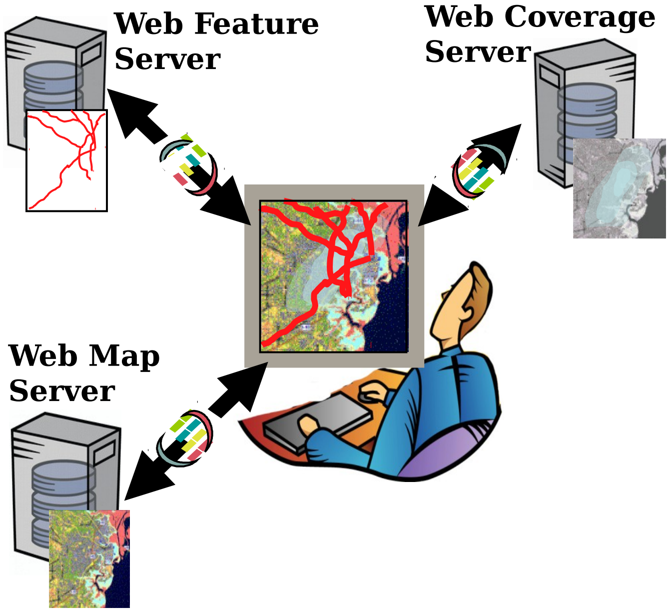
OGC Web Standards

- Enable the geo-spatial web
  - Web Map Service (WMS)
  - Web Map Tile Service (WMTS)
  - Web Feature Service (WFS)
  - Web Processing Service (WPS)
  - Web Coverage Service (WCS)
  - Catalogue (CSW)
  - Geography Markup Language (GML)
  - KML
  - Others…



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OGC Web services

- Map services (WMS, WMTS, WCS)
  - Offer maps for use in your application
- Feature services (WFS, CSW)
  - Offer spatial data
- Processing services (WPS)
  - Provide a framework for spatial data processing over the web

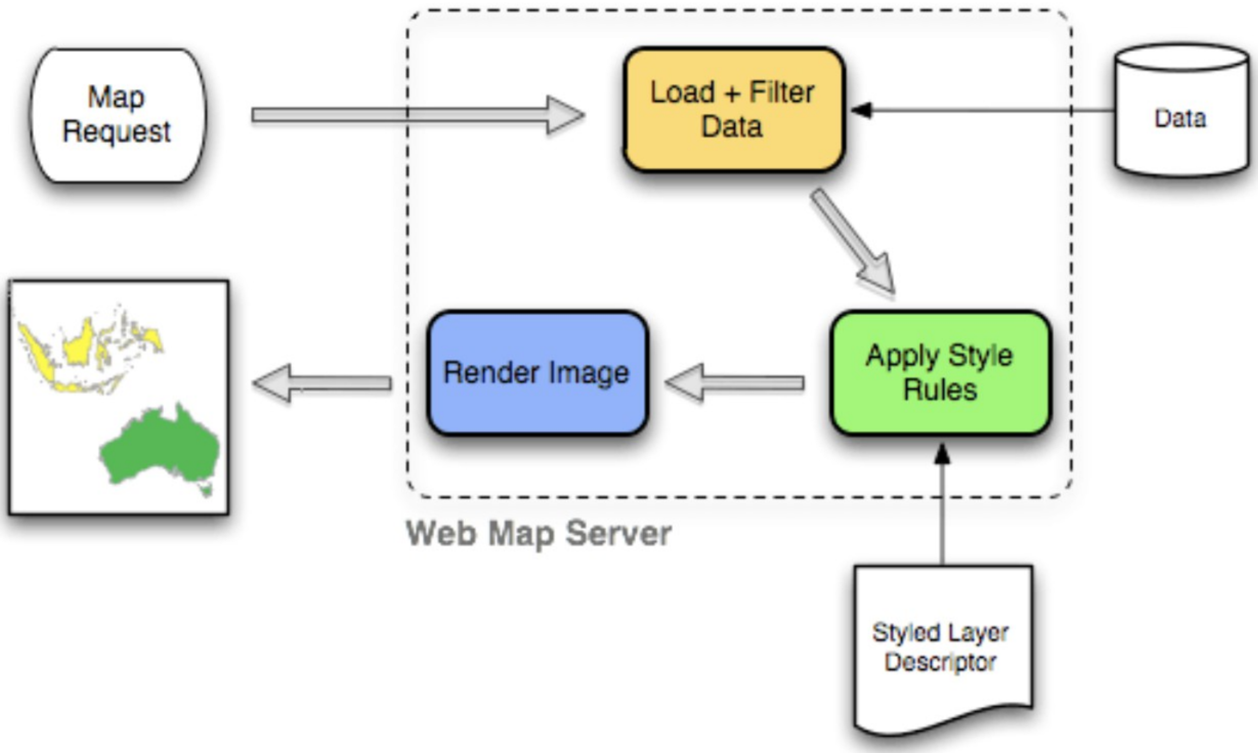
- Enabling technologies for mash-ups and new value-added services

OGC Web Services

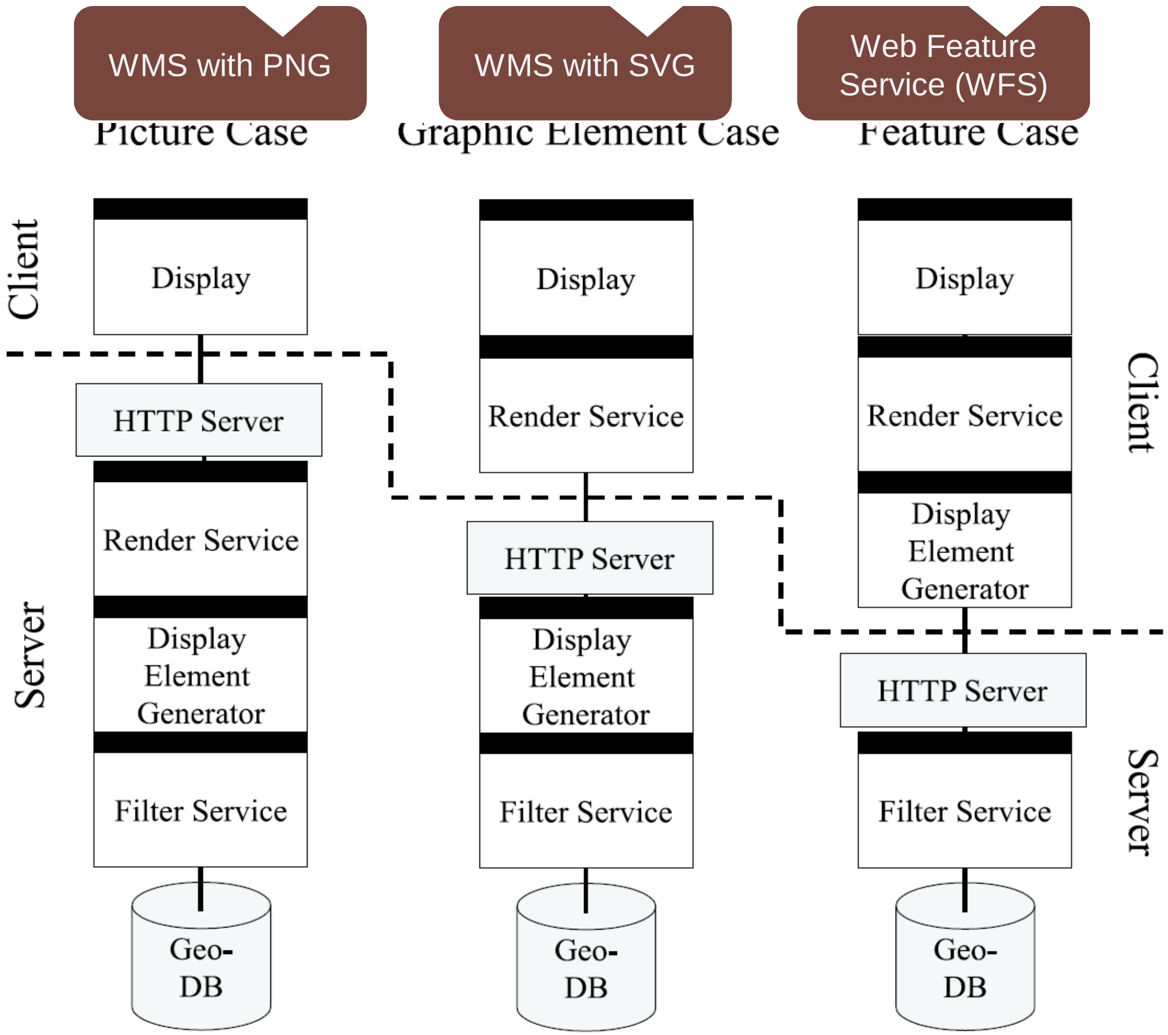
- Interface concept
  - Get the capabilities of the service:
    returns information about what a specific implementation of the service can do
  - Get info on some entity/property:
    returns the attributes of entities offered by the service
  - Run the service:
    accepts parameters and returns the result of the service

OGC WMS – Web Map Service

- OGC & ISO standard for requesting & serving maps over the Internet in pictorial format (PNG, GIF, JPEG).



WMS System Architecture



[Image source: OGC 2000 modified by A. Donaubauer]

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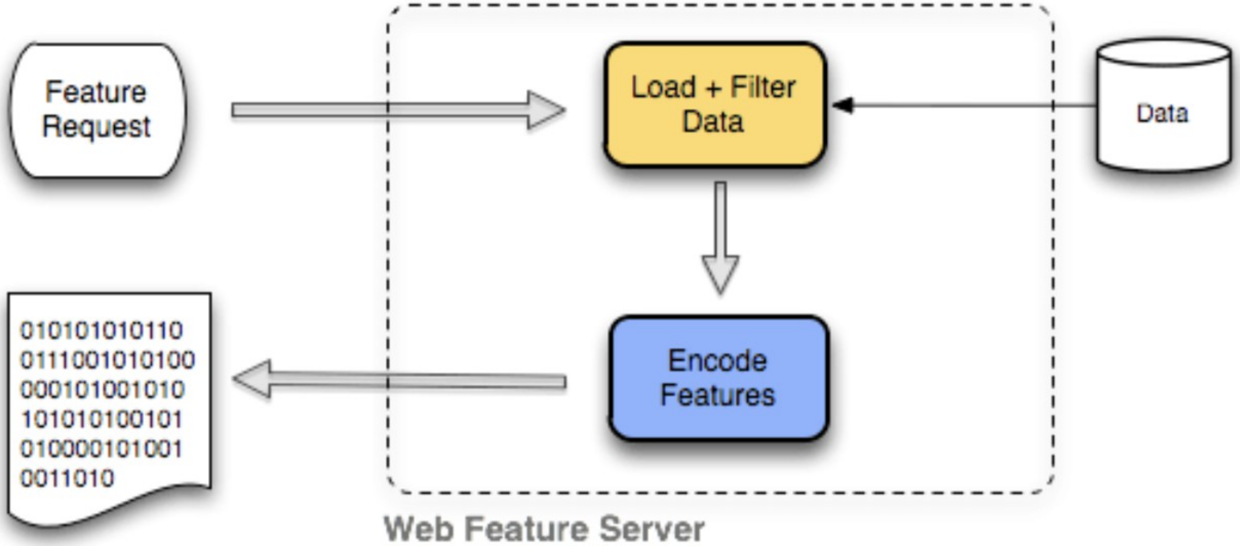
OGC WFS – Web Feature Service

- OGC Web service standard for reading & writing geographic features in vector format.



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Other web services

- WPS – Web Processing Service
  - Provides rules for standardizing inputs & outputs for geospatial processing services.
  - GetCapabilities, DescribeProcess, Execute
- SWE – Sensor Web Enablement
  - Standards enable users to discover & access sensor data of a sensor Web or sensor network
  - Sensor Observation Service (SOS), Sensor Alert Service (SAS), etc.

WPS – Web Processing Service

- Standardized interface
- Facilitates the publishing of geospatial processes
- Discovery of and binding to those processes by clients

- Process:
  Any algorithm, calculation or model that operates on spatially referenced data and gives any data type, including spatial data, as a result

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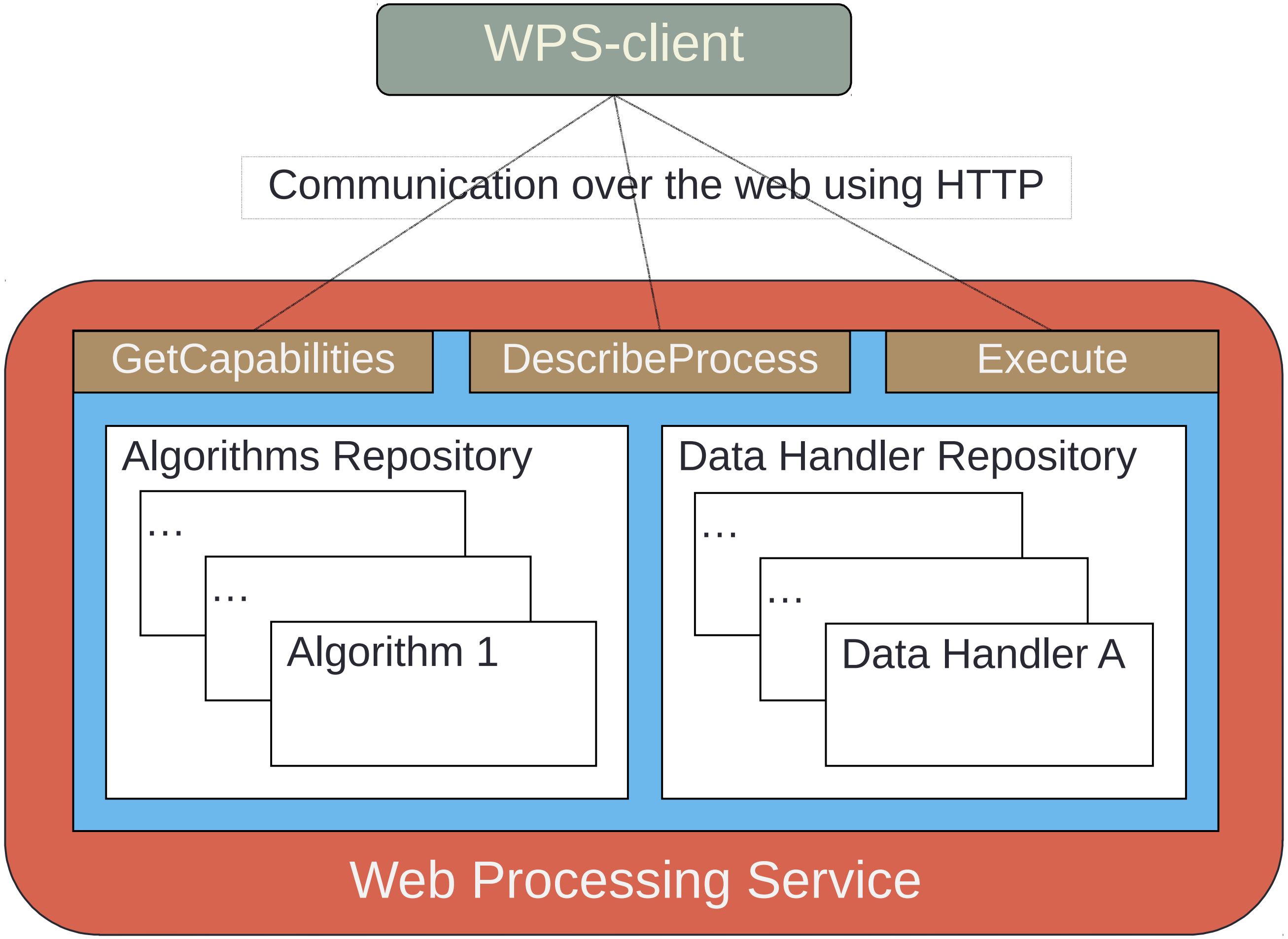
Web Processing Service



Credit: Open Geospatial Consortium

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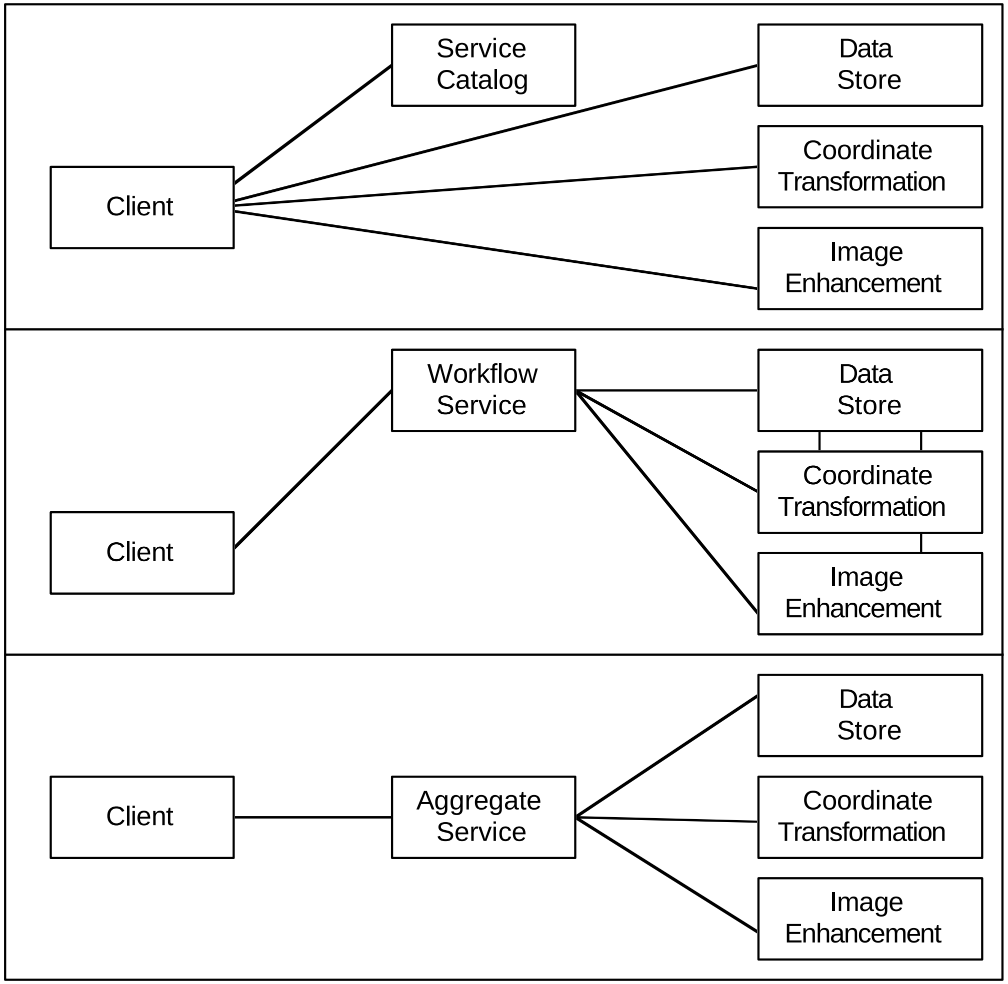
Design patterns for Service Chaining



Credit: Open Geospatial Consortium

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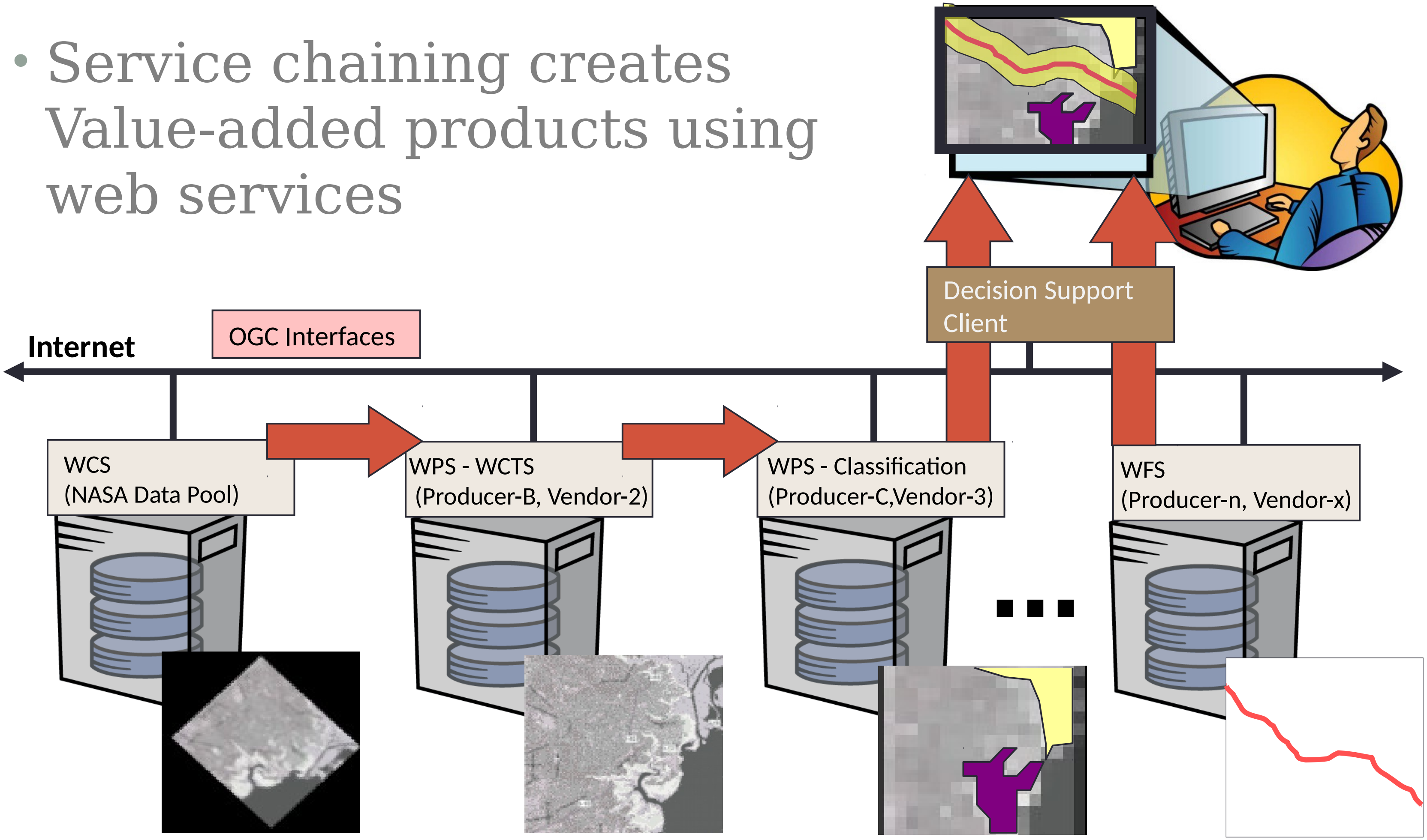
Workflow example

- Service chaining creates Value-added products using web services



Credit: Open Geospatial Consortium

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Value added and considerations

- Unlimited applications are possible
- Spatial data and service sharing
- Democracy, redefined

- However…
  - It takes some (initial only?) data therapy
  - Quality and validation considerations
  - Privacy issues
  - Mission-critical applications

  - A shift of mentality is required

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STANDARDS-BASED TOOLS FOR GEOSPATIAL APP DEVELOPMENT: GEOSERVER

What is GeoServer

- "*GeoServer is a powerful map and feature server for sharing, analyzing, and editing geospatial data from spatial data sources using open standards*"
  - Support for many back-end data formats (ArcSDE, Oracle Spatial, DB2, MS SQL Server, Shapefile, GeoTIFF, etc.)
  - Multiple output formats (Esri Shapefiles, KML, GML, GeoJSON, PNG, JPEG, TIFF, SVG, PDF, GeoRSS)
  - Fully-featured web administration interface and REST API for easy configuration
  - Configurable role-based security subsystem Java J2EE application works with Jetty, Tomcat, JBoss, and others

Source: boundlessgeo.com

What is GeoServer

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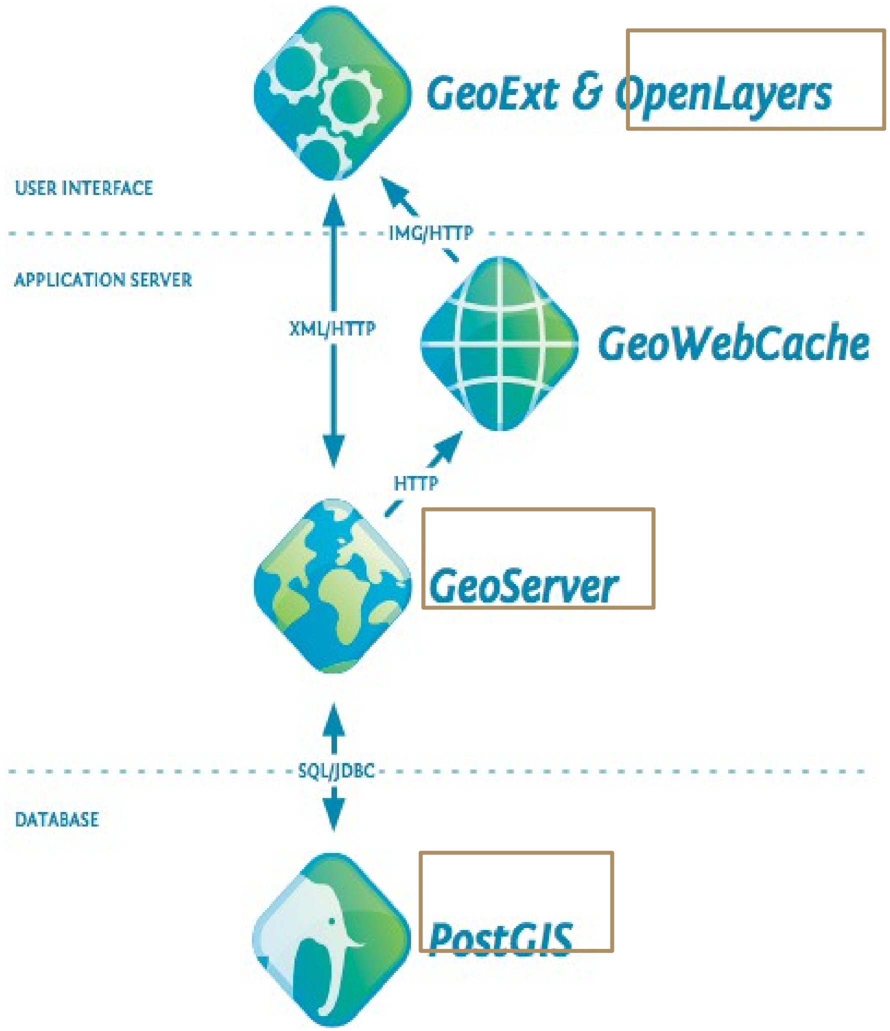
Part of OpenGeo Suite



APPLICATION FAMILY: GEO-MASHUPS

What is a 'mashup'?

- Mashup: a Web page or application that dynamically combines contents or functions from multiple Web sites.
  - Live linkage to its sources!
- Geomashup: a mashup where at least one of the contents/functions is georeferenced.
  - Integrating multiple data sources based on common geographic location.
  - Topological (e.g., flood boudaries with city boundaries) & graphic overlays.

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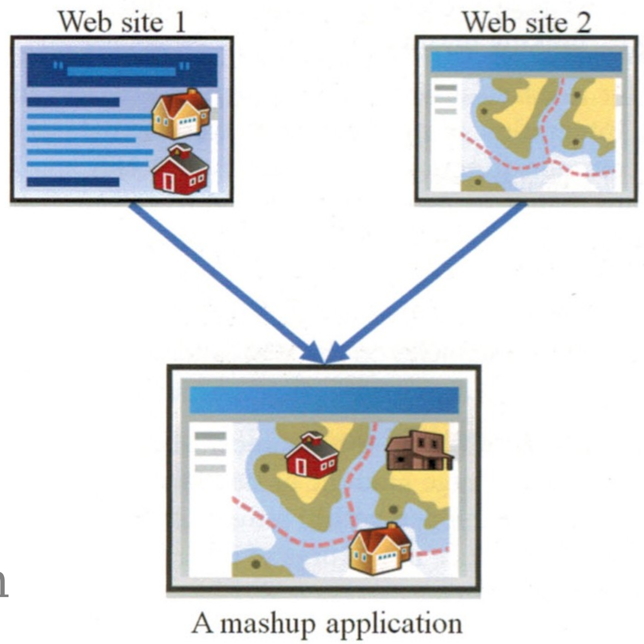
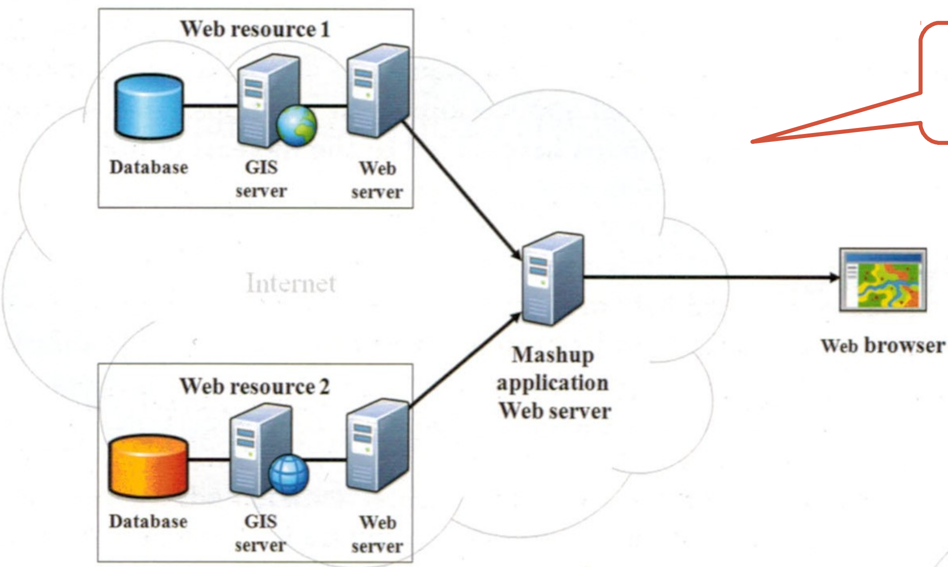
What can be 'remixed'?

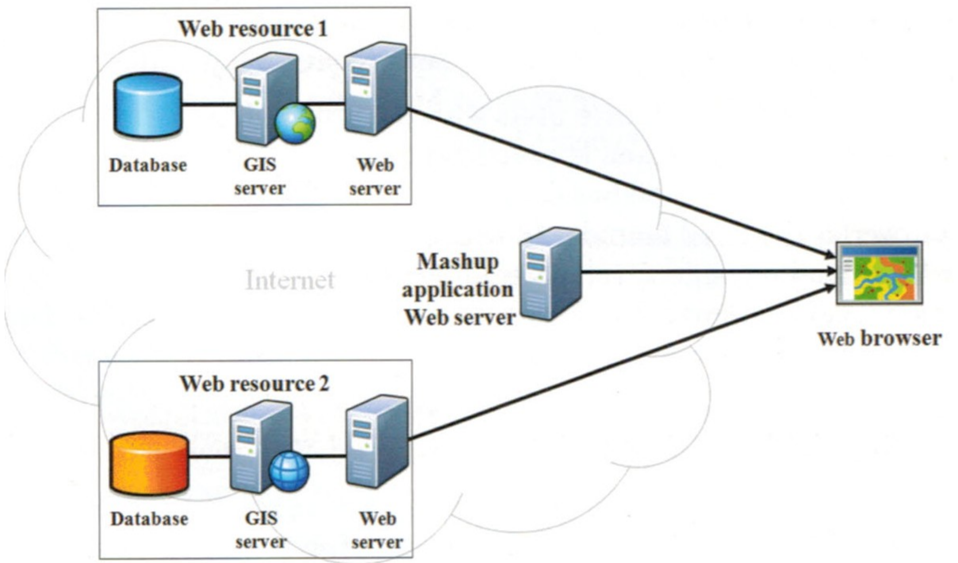
- Maps, web services, web pages, blogs, photos, videos.
  - Housing Maps
    - www.housingmaps.com
    - Craigslist & Google Maps
  - Crime Mapping
    - www.crimemapping.com
    - Crime activity by neighborhood
  - Transportation services
    - Real-time traffic+weather information
    - Road network
    - Routing service



Design patterns for mashups



Server-side architecture



Mashups: browser-side architecture

- Maps provided via JavaScript
- Users can view sources
- Google, etc. officially released their mapping capabilities via a JS API.

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Geo-mashup application design

- We need to integrate
  - Basemaps, data
    setup (and license?) maps + data from some provider
  - Operational layers
    develop software to implement the user experience and respond to user actions, e.g., mouse click on a map, a form, etc.
  - Tools
    develop (or interface to) software to implement business logic, analytical functions, etc.

WMS, WFS

WPS

- Mashups promote development of public participation GIS

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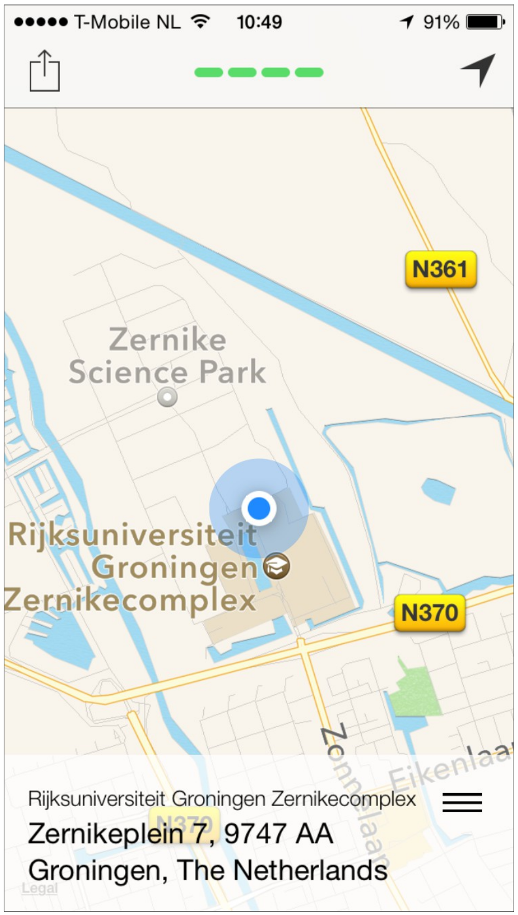
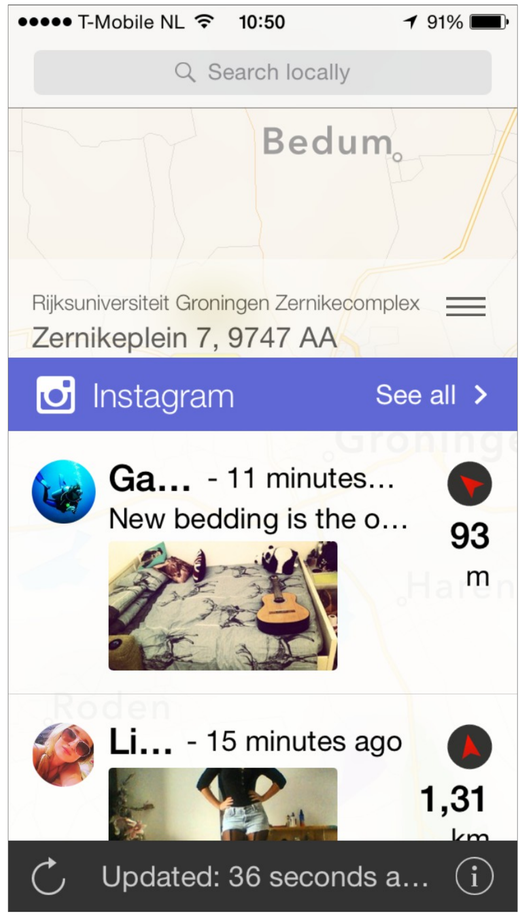
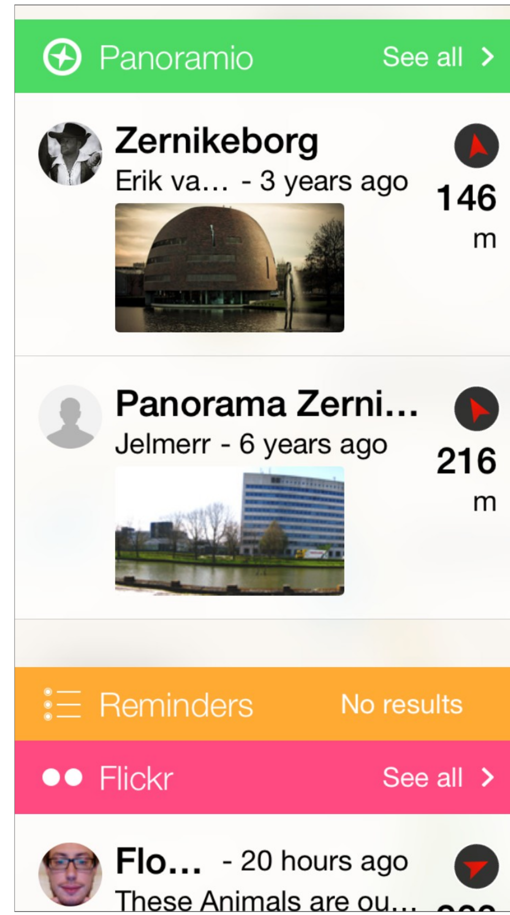
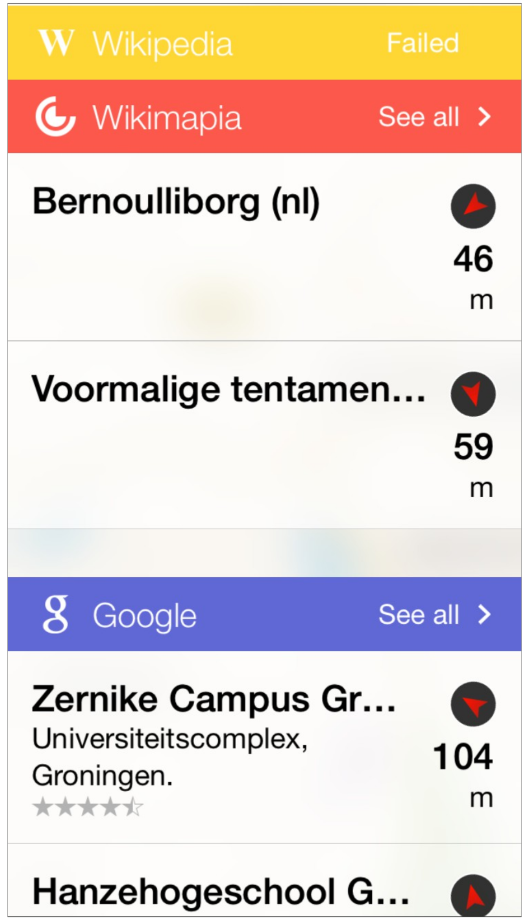
Geo-mashup example: localscope

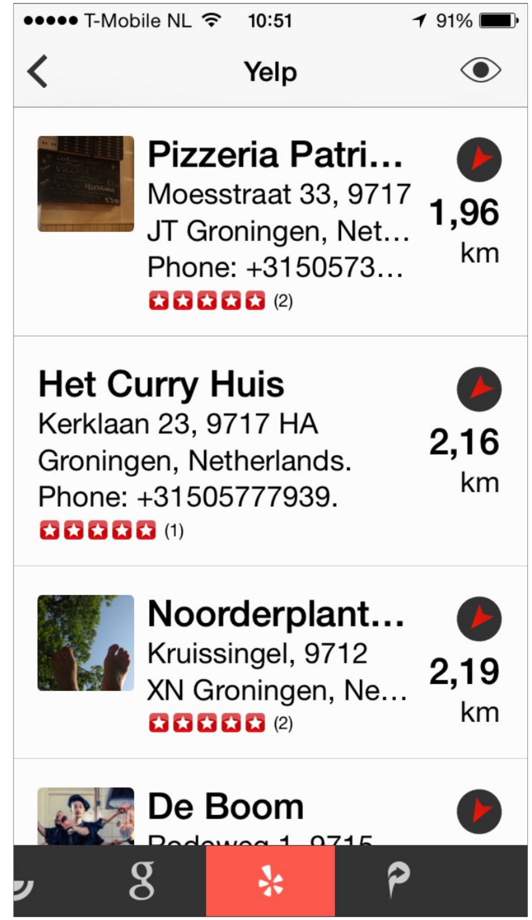






Geo-mashup example: localscope





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SENSOR WEB ENABLEMENT: GEO-INFORMATION APPS EVERYWHERE

What is SWE?

- Sensor Web Enablement (SWE) is a set of OGC standards that enable developers to make all types of sensors, transducers and sensor data repositories discoverable, accessible and useable via the Web

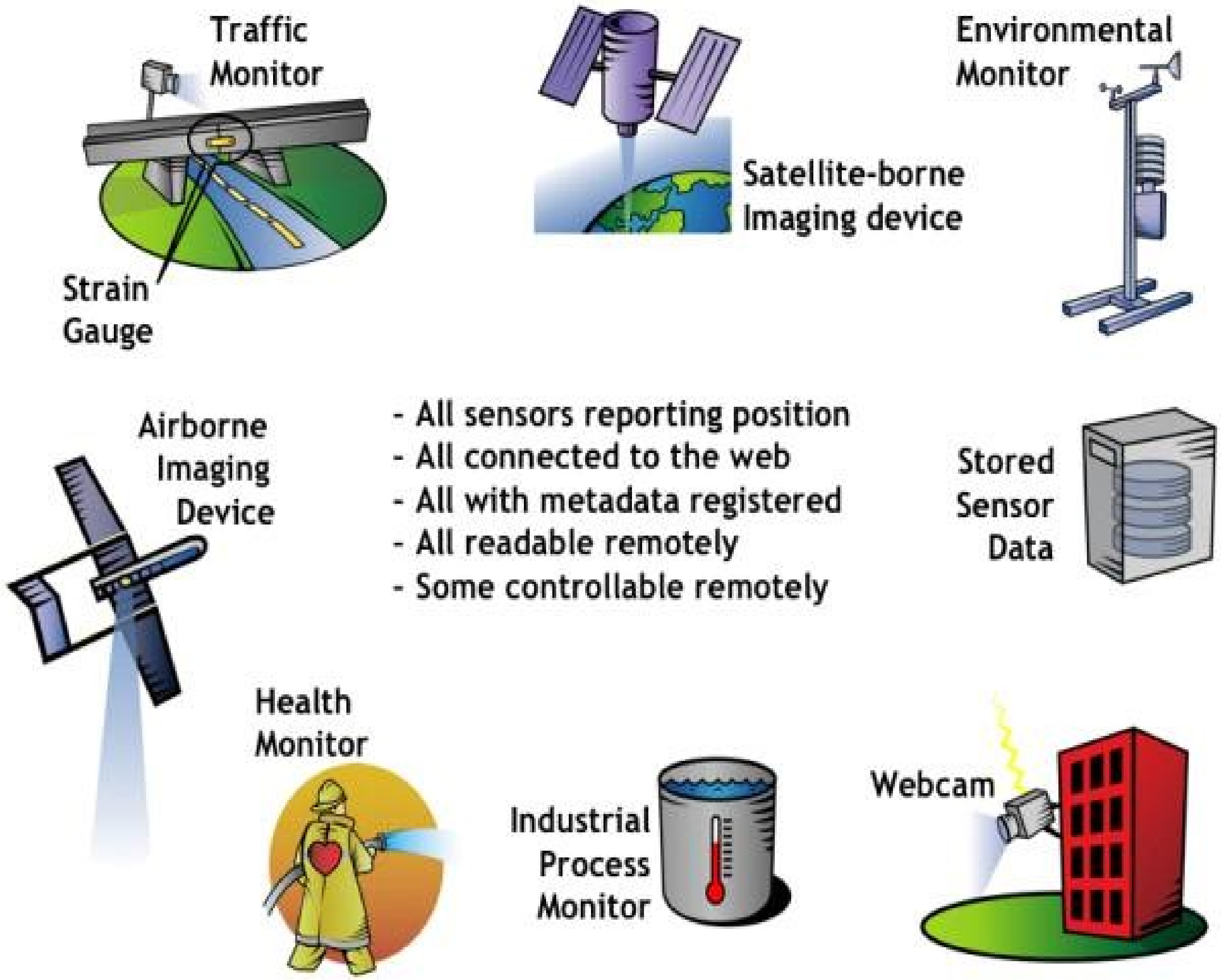
(source: opengeospatial.org)

- A sensor Web is a Web-accessible network of sensors and archived sensor data that can be discovered and accessed using standard protocols and APIs.'

(Botts et al. 2006)

- SWE is about monitoring and controlling Objects, Phenomena and Processes through Web-enabled Sensors

What is SWE?



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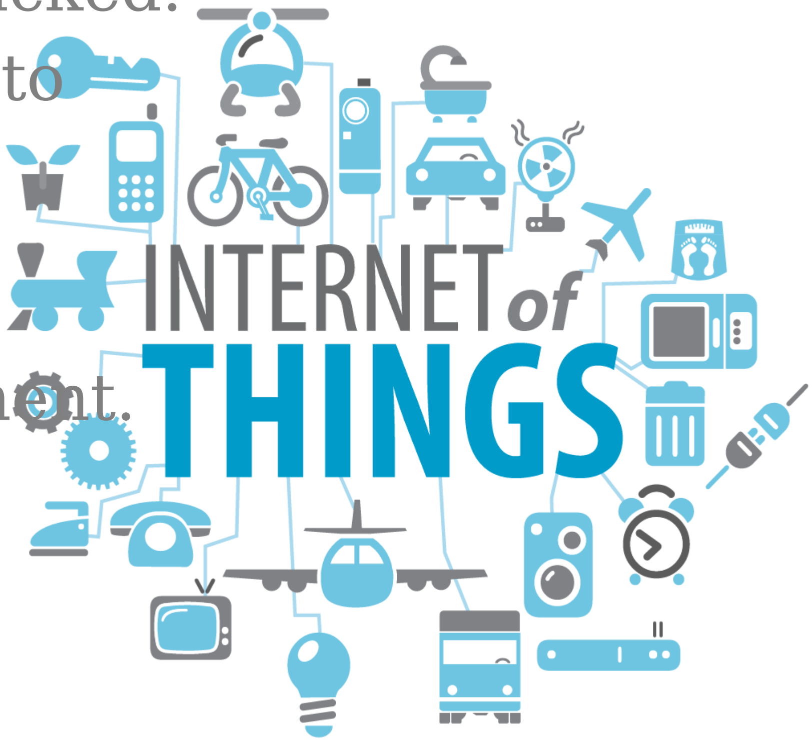
Internet of Things

- Real-world objects (lights, cars, packages, etc.) are **interlinked & connected** to the Internet.
- Location & status can be tracked.
- Network **intelligent** enough to self-organize information.
- **Automatically respond** to context, circumstances, or events from the environment.



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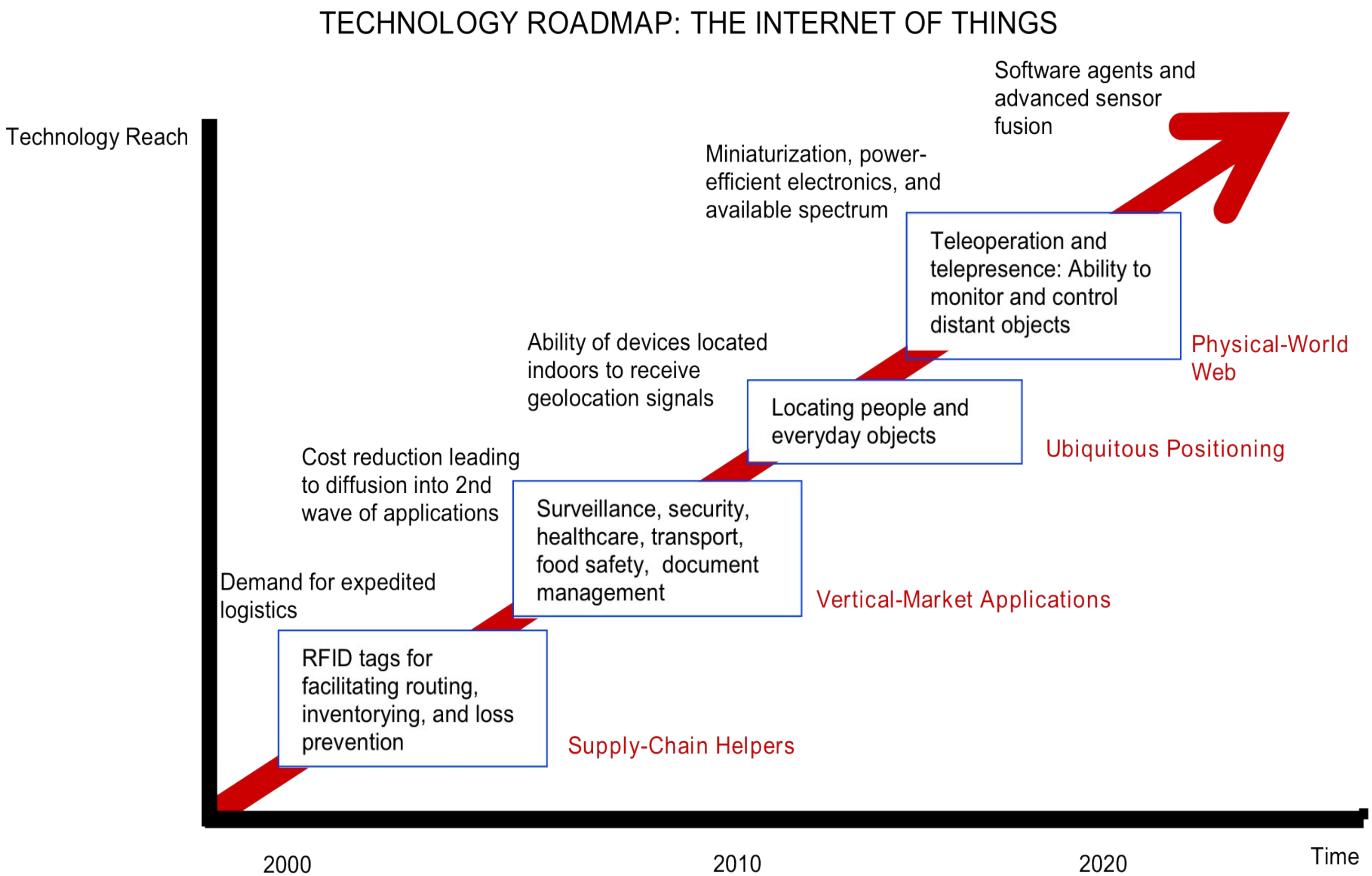
Internet of things



Source: SRI Consulting Business Intelligence

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The vision behind SWE

- Quickly discover sensors and sensor data (secure or public) based on location, observables, quality, ability to task, etc.
- Obtain sensor information in a standard encoding that is understandable by my software and enables assessment and processing without a-priori knowledge.
- Readily access sensor observations in a common manner, and in a form specific to my needs.
- Task sensors, when possible, to meet my specific needs.
- Subscribe to and receive alerts when a sensor measures a particular phenomenon.

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Why SWE?

- Enable interoperability not only within communities but between traditionally disparate communities.
  - different sensor types: in-situ vs. remote sensors, video, models
  - different disciplines: science, defense, intelligence, emergency management, utilities, etc.
  - different sciences: ocean, atmosphere, land, bio, signal processing, etc.
  - different agencies: government, commercial, private, Joe Public

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What are the benefits of SWE?

- Sensor system agnostic => virtually any sensor or modeling system can be supported
- Net-Centric, SOA-based
  - Distributed architecture allows independent development of services but enables on-the-fly connectivity between resources
- Semantically tied
  - Relies on online dictionaries and ontologies for semantics
  - Key to interoperability

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Benefits of SWE cont'd

- Traceability
  - observation lineage
  - quality of measurement support
- Implementation flexibility
  - wrap existing capabilities and sensors
  - implement services and processing where it makes sense (e.g., near sensors, closer to user, or in-between)
  - scalable from single, simple sensor to large sensor collections

SWE related standards

- There are several adopted or working OGC standards
  - Observations & Measurements (O&M) –The general models and XML encodings for observations and measurements.
  - Sensor Observation Service (SOS) – Open interface for a web service to obtain observations and sensor and platform descriptions from one or more sensors.
  - Sensor Model Language (SensorML) – Standard models and XML Schema for describing the processes within sensor and observation processing systems.
  - Sensor Planning Service (SPS) – An open interface for a web service by which a client can 1) determine the feasibility of collecting data from sensors and 2) submit collection requests.

SWE related standards (cont'd)

- PUCK Protocol Standard – Defines a protocol to retrieve a SensorML description, sensor "driver" code, and other information from the device itself, thus enabling automatic sensor installation, configuration and operation.
- SWE Common Data Model – Defines low-level data models for exchanging sensor related data between nodes of the OGC® Sensor Web Enablement (SWE) framework.
- SWE Service Model – Defines data types for common use across OGC Sensor Web Enablement (SWE) services.

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