

Context Management and Self-Adaptivity for Situation-Aware Smart Software Systems

Norha M. Villegas

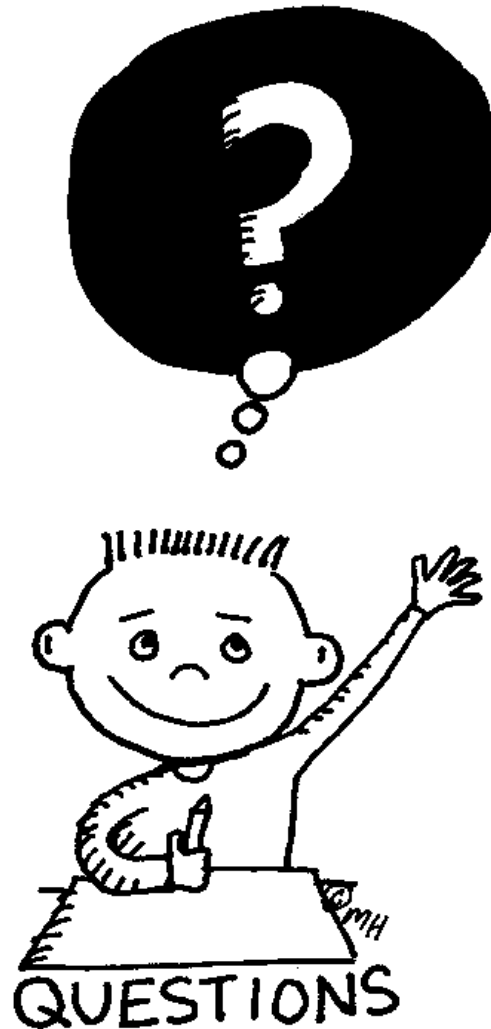
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SENG 371

February 4, 2013

Department of Computer Science, University of Victoria

Self-Adaptivity in Software Systems

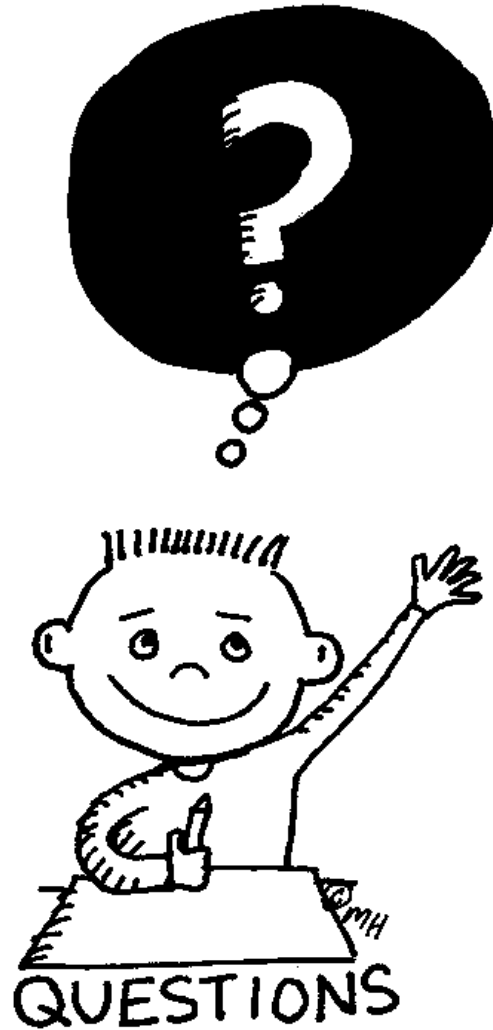


Self-Adaptive Systems

- A self-adaptive system continuously adjusts its behaviour at run-time in response to its perception of its environment and its own state in the form of fully or semiautomatic self-adaptation.

H. Giese, Y. Brun, J. Serugendo, C. Gacek, H. Kienle, H. Müller, M. Pezzè, M. Shaw.: *Engineering Self-Adaptive Systems Through Feedback Loops*, LNCS 5527, Springer, 2009.

Situation-Aware Software Systems

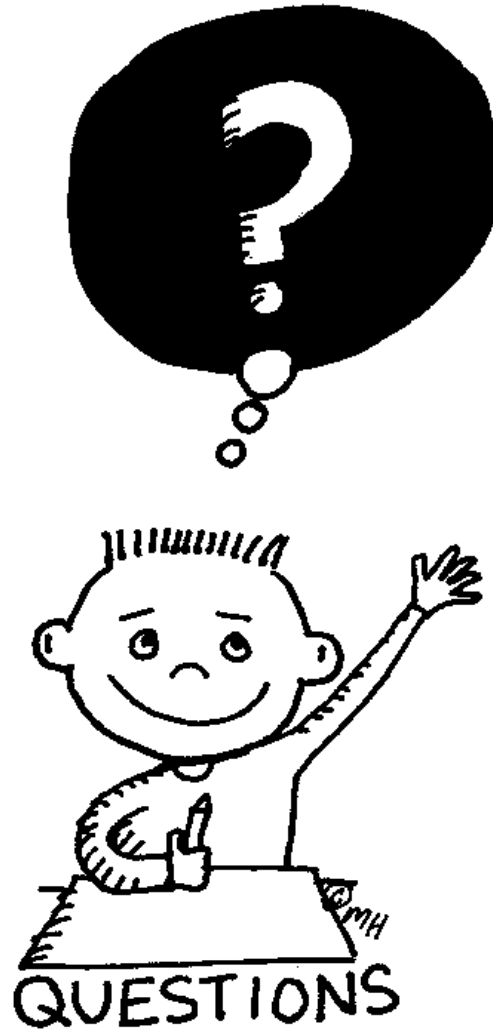


Situation-Aware Software Systems

- Situation-awareness: the perception and comprehension of elements in the environment within a volume of time and space.
- Also called context-awareness

M. R. Endsley. *Toward a Theory of Situation Awareness in Dynamic Systems*. Human Factors, 37(1):32-64, 1995.

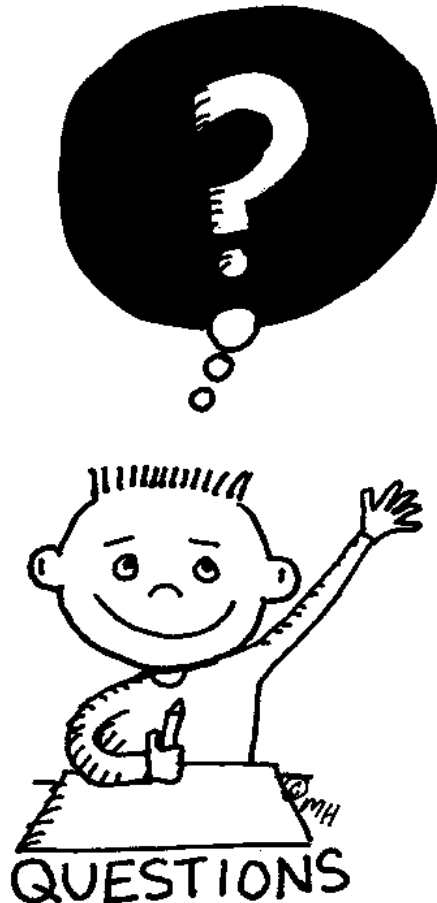
Situation-Aware Software Systems



Situation-Aware Software Systems

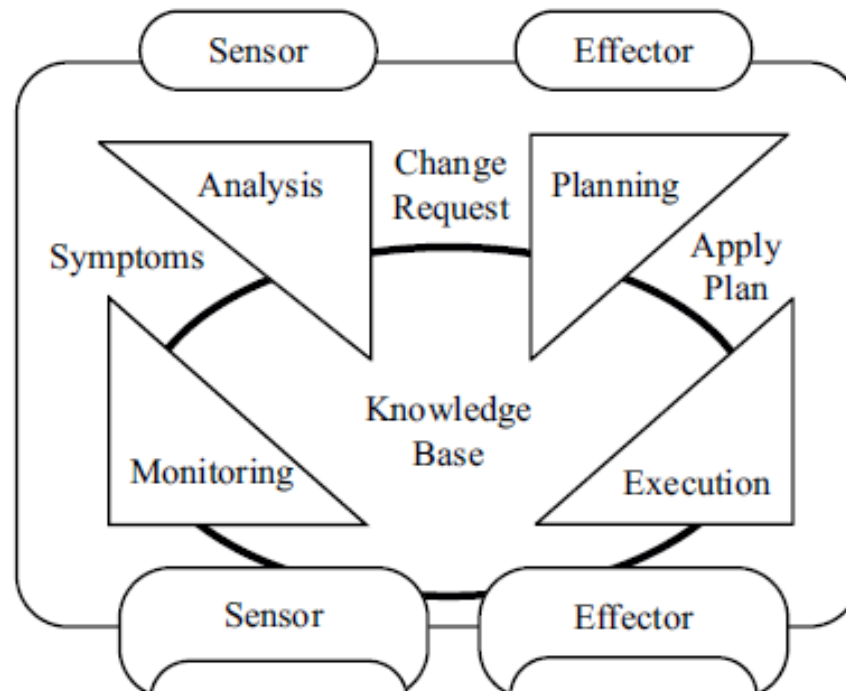
- Systems that understand themselves and their execution environment to deliver functionalities accordingly.

Situation-Aware Self-Adaptive Software Systems



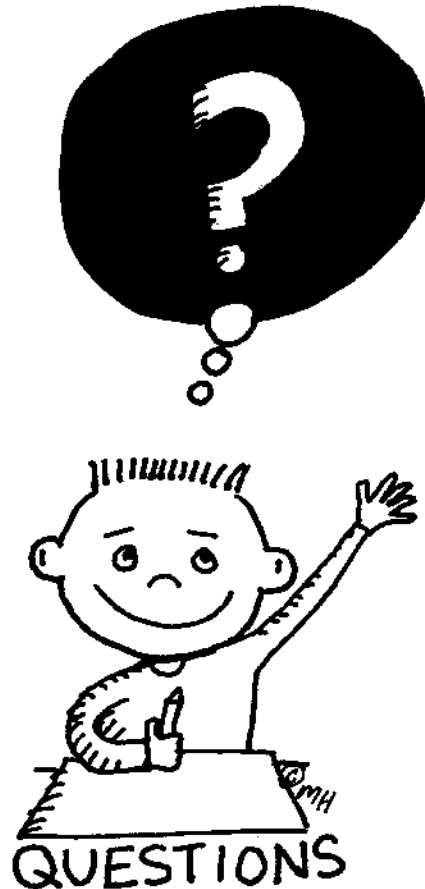
- Situation-awareness vs. self-adaptation
 - Differences?
 - How do they complement each other?

The Autonomic Manager



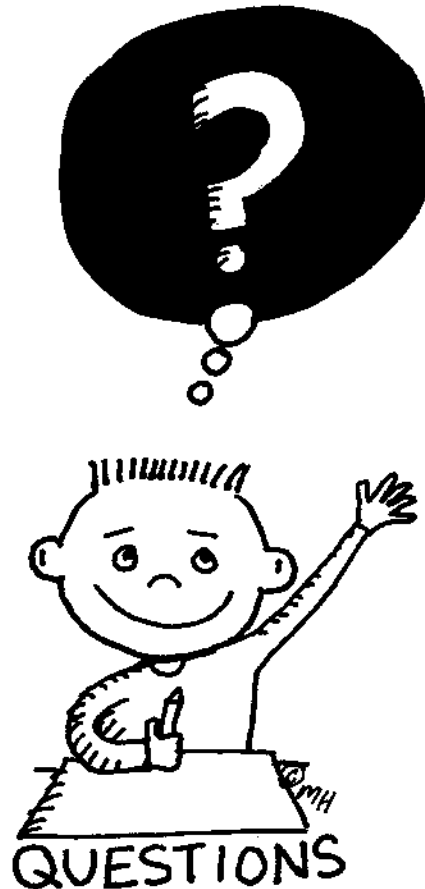
How do situation-awareness and self-adaptation cooperate each other?

Situation-Aware Self-Adaptive Software Systems: Applications



SITUATION-AWARE SMART ONLINE SHOPPING

How to exploit situation-awareness and self-adaptivity in online shopping?



User-centric Situation-aware Smart Shopping Applications

Groupon Featured Deal All Deals Getaways Goods ^{NEW} Holiday Deals Norha V.

St John's

 Get Deals By Email + Refer F

Atlas Pizza – St. John's

 One Large Four-Topping Pizza, or One Medium Four-Topping Pizza with Garlic Fingers (Up to 52% Off)

from **C\$7** **Buy!**

Value	Discount	You Save
C\$14	50%	C\$7

Buy it for a friend!

Time left to buy
5 days 8:46:18

Over 230 bought
Limited quantity available

The deal is on!

Quick Bites

In a Nutshell

Pizzas layered with savoury toppings; robustly flavoured garlic fingers

The Fine Print

Expires 180 days after purchase. Limit 1 per person, may buy 1 additional as a gift. Limit 1 per table.

"Healthy Living" Deals For You

- \$1,617 for \$2,695 at The Biggest Loser Resort Niagara Java Center, NY
- C\$29 for C\$60 at LifeSource Blood-Pressure Monitor Online Deal
- C\$59 for C\$199 at MyTrak SmartCoach Fitness Monitor Online Deal

Norha is in Markham, she is not in St. John's!

User-centric Applications: Degree of Situation-Awareness

She is not a pizza lover!

**However, Groupon
wants her to eat pizza
in St. John's**



Norha lives in Victoria

**She is in Markham, right
now!**

The Problem: Dynamic Context

You've added 4 ♥s and we found 1 deal near you. [See Deals](#)

A few basics about you. Take a few seconds to share your home, work, and other favorite places.

First name
Norha

Last name
Villegas


I prefer deals for:
Women

My birthday is:

1530 church avenue, victoria bc, canada [edit](#) [delete](#)

123 Main St, Anywhere, OH [Work](#) [Add](#)

User locations are dynamic!



What kinds of stuff do you ♥?
Click the hearts below that match your interests and we'll send matching deals your way.

♥ Home Improvement ♥ Romantic Getaway ♥ World Music ♥ Healthy Living

♥ Adrenaline ♥ All-Inclusive ♥ Always Learning ♥ Audiophile ♥ B&B ♥ Beaches

♥ Boutique Hotel ♥ BYO ♥ Casino Night ♥ Comedic ♥ Country & Bluegrass ♥ Craft Beer

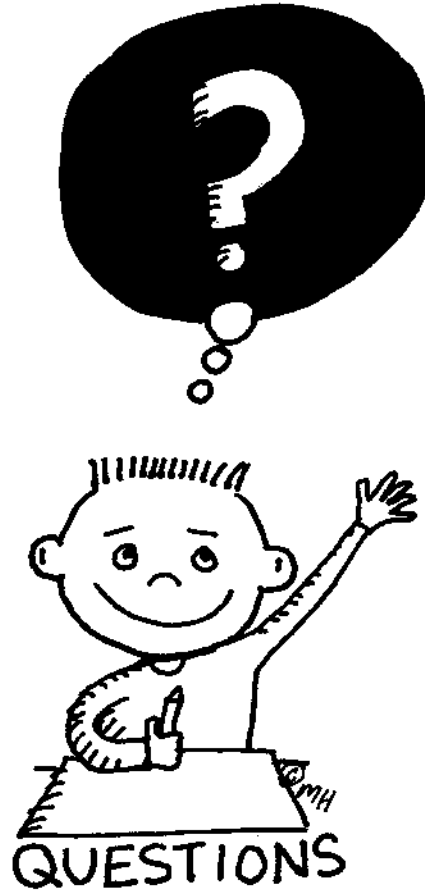
♥ Crafty ♥ Cruise ♥ Cultural Pursuits ♥ Date Night ♥ Do-Gooder ♥ Far & Away ♥ Farm-to-Table

User preferences change continuously!

Context-Awareness in E-Commerce Today



Context Information

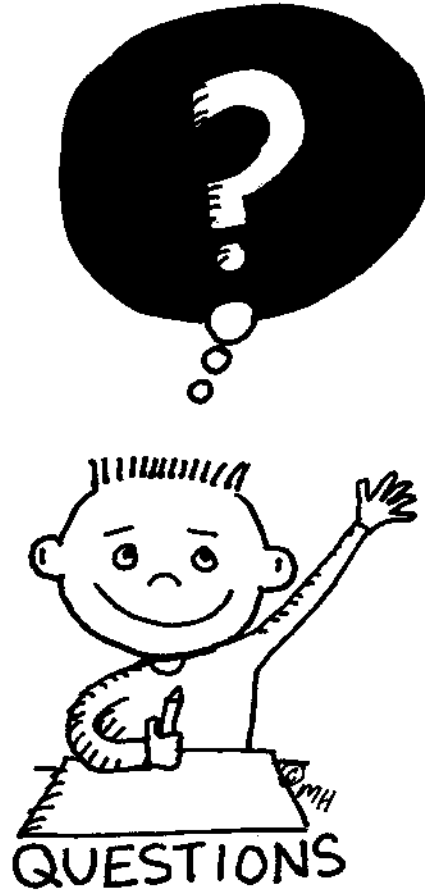


Context Information

- Any information that describes:
 - The state of entities that may affect the system operation or its interaction with the user
 - The relationship among these entities
- Must be representable at runtime
- Must be manipulable at runtime to manage its life cycle

Villegas and Müller: *Managing Dynamic Context to Optimize Smart Interactions and Services*, pages 289-318. Springer, 2010.

Static Context vs. Dynamic Context



Dynamic Context

Context is any information useful to **characterize the state** of entities that **can affect the behavior of the system and/or its interaction with the user.**

Your Social
Network

Your location

Your agenda

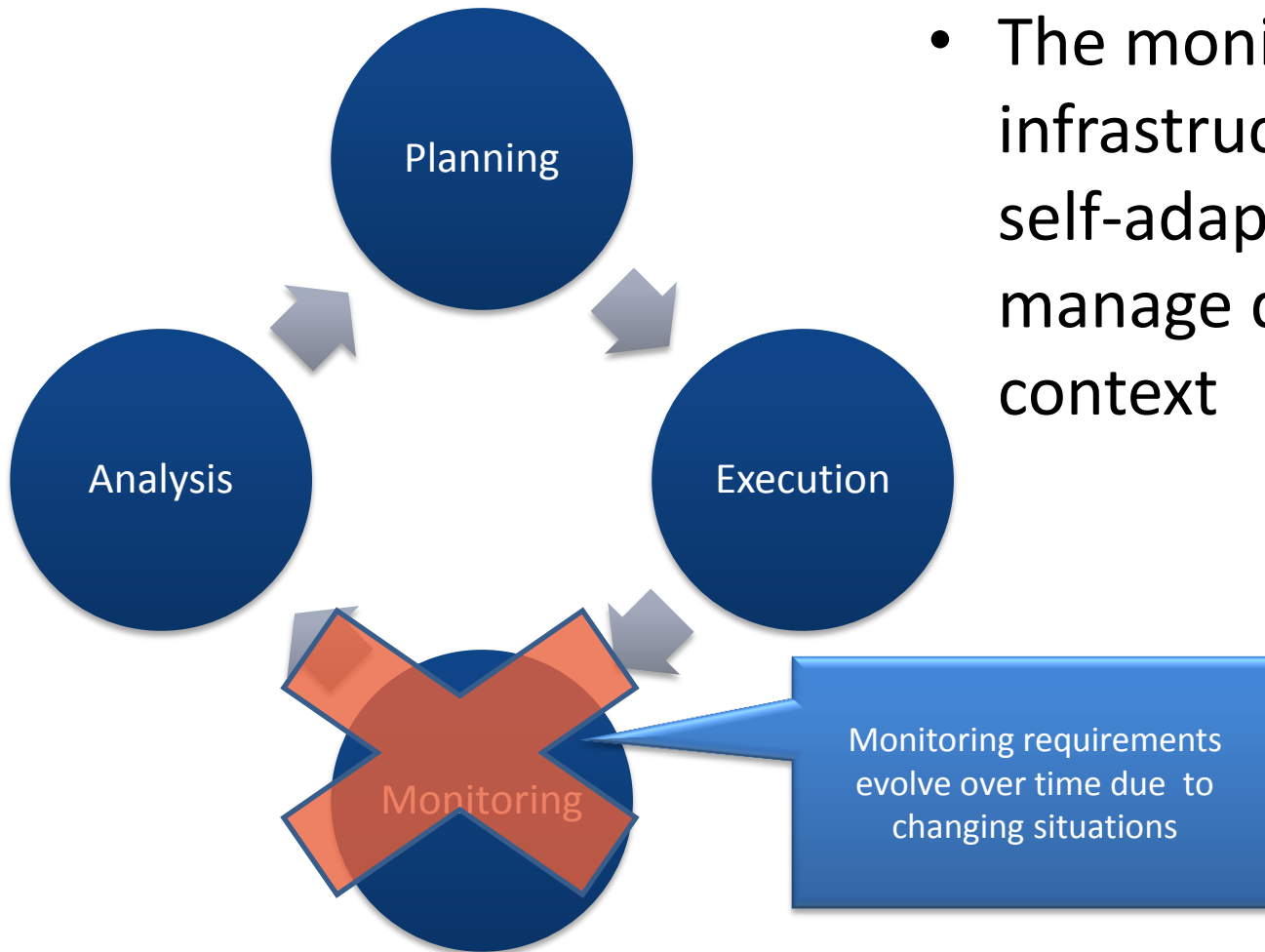
Your shopping
preferences

**Relevant context information
evolves over time!**

Villegas and Müller: *Managing Dynamic Context to Optimize Smart Interactions and Services*, pages 289-318. Springer, 2010.

Dynamic Context Management

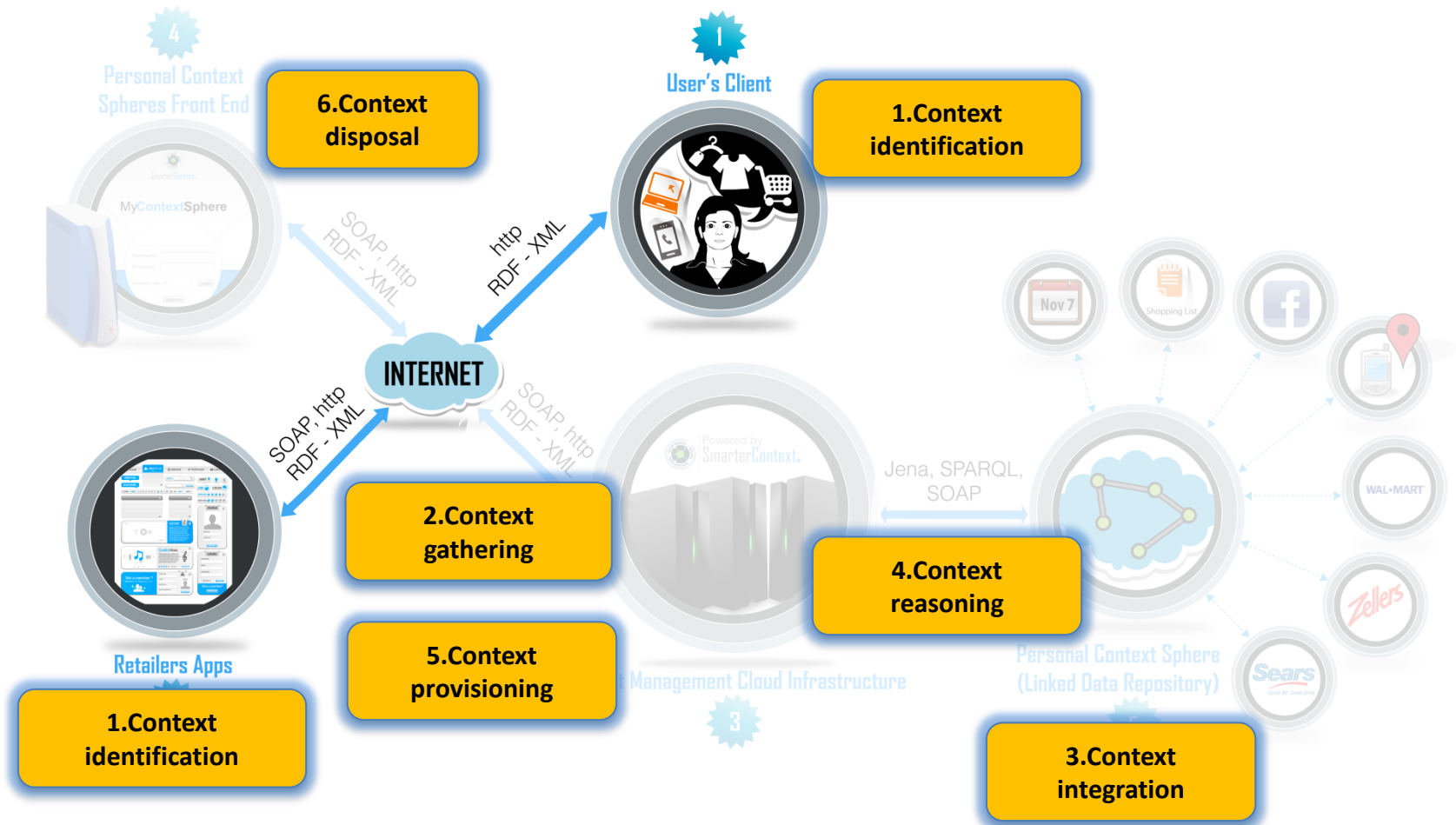
- The monitoring infrastructure must be a self-adaptive system to manage dynamic context





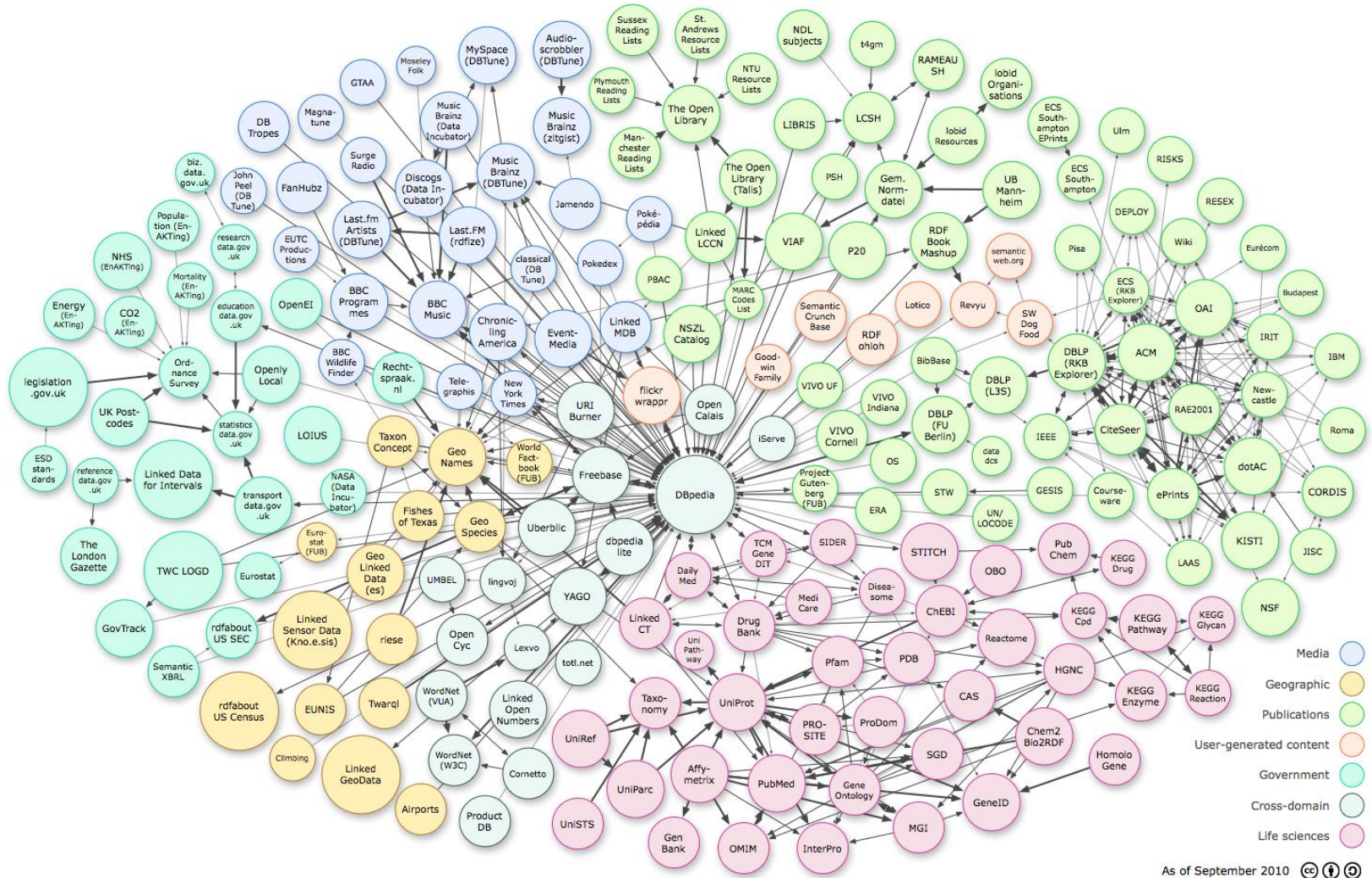


SmarterContext.



Villegas, Müller, et al.: A Dynamic Context Management Infrastructure for Supporting User-driven Web Integration in the Personal Web. CASCON 2011. ACM

Dynamic Context Representation: Linked Data





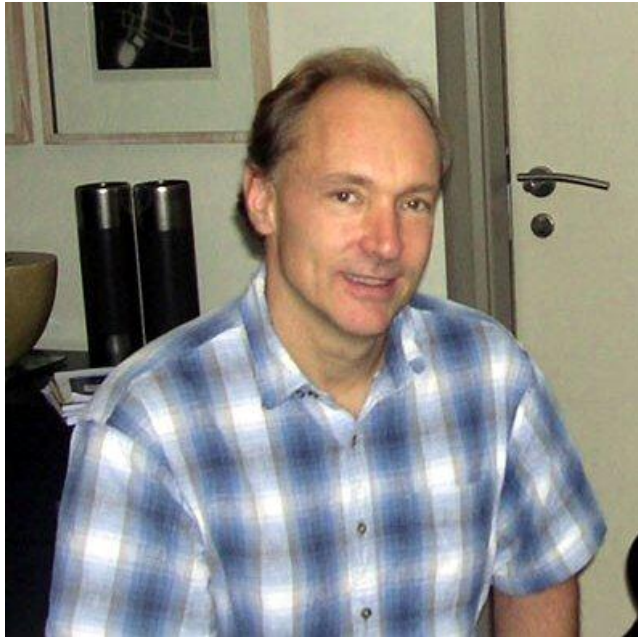
As of September 2010   

Image source: <http://rivuli-development.com/linked-data/>

Dynamic Context Reasoning: Semantic Web and Linked Data



http://en.wikipedia.org/wiki/Tim_Berners-Lee

- Tim Berners-Lee
 - The inventor of the Web
- Highly recommended inspiring readings

T. Berners-Lee. Linked Data.

<http://www.w3.org/DesignIssues/LinkedData.html>, 2006.

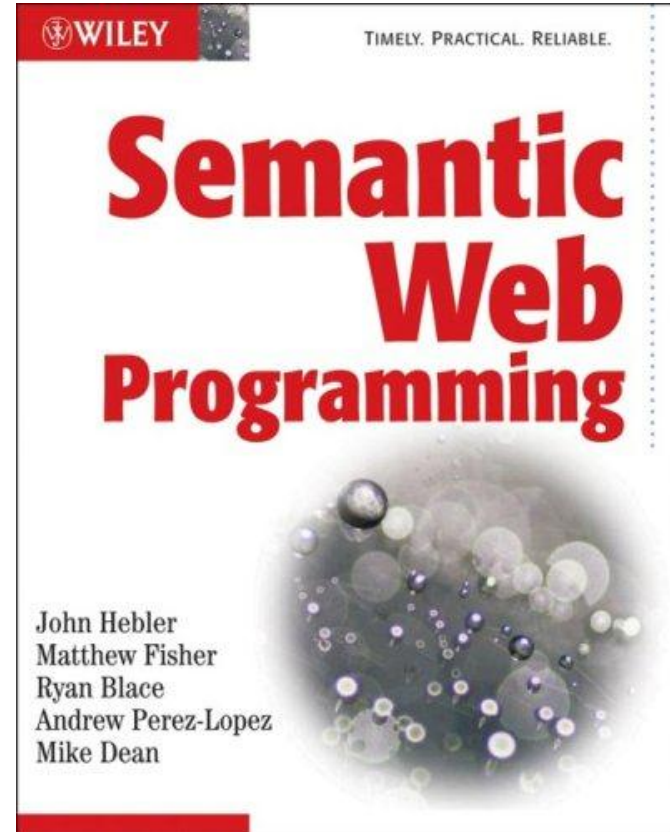
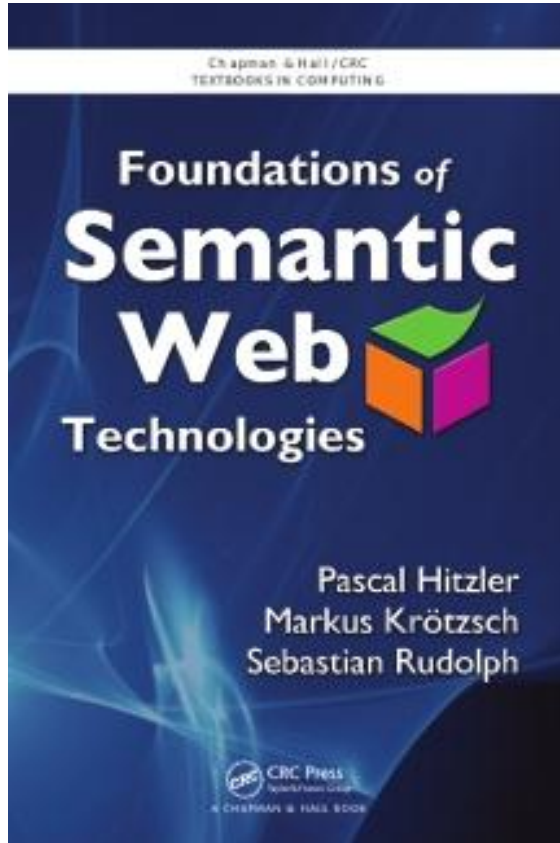
T. Berners-Lee, W. Hall, J. A. Hendler, K. O'Hara, N. Shadbolt, and D. J. Weitzner. A Framework for Web Science. Foundations and Trends in Web Science, 1(1):1-130, 2006.

Semantic Web

- Enables systems to smartly search, combine, and process web data based on the meaning that these data have to humans

P. Hitzler, M. Krötzsch, and S. Rudolph. Foundations of Semantic Web Technologies, volume 33 of Textbooks in Computing. Chapman & Hall/CRC, 1st edition, 2009

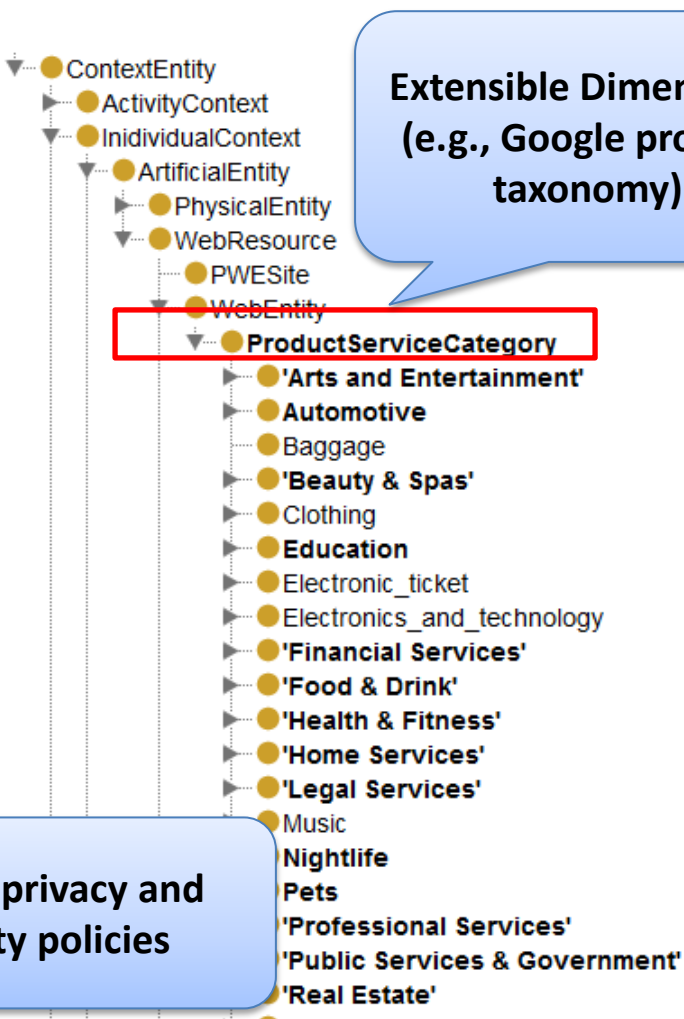
More About Semantic Web



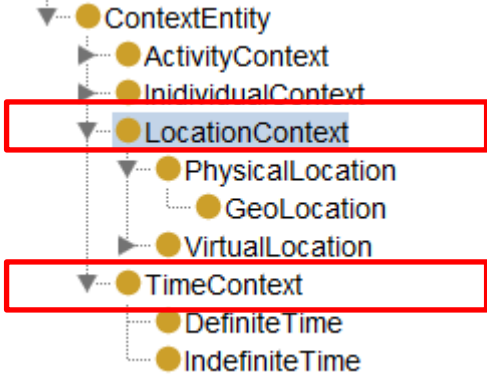
Dynamic Context Representation

**Extensible Dimensions
(e.g., Google product taxonomy)**

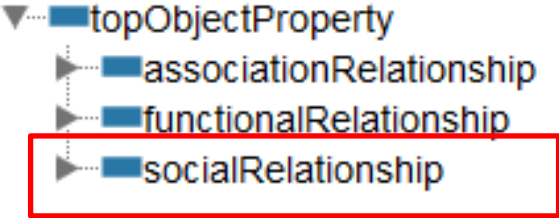
Context Entities



Context privacy and security policies



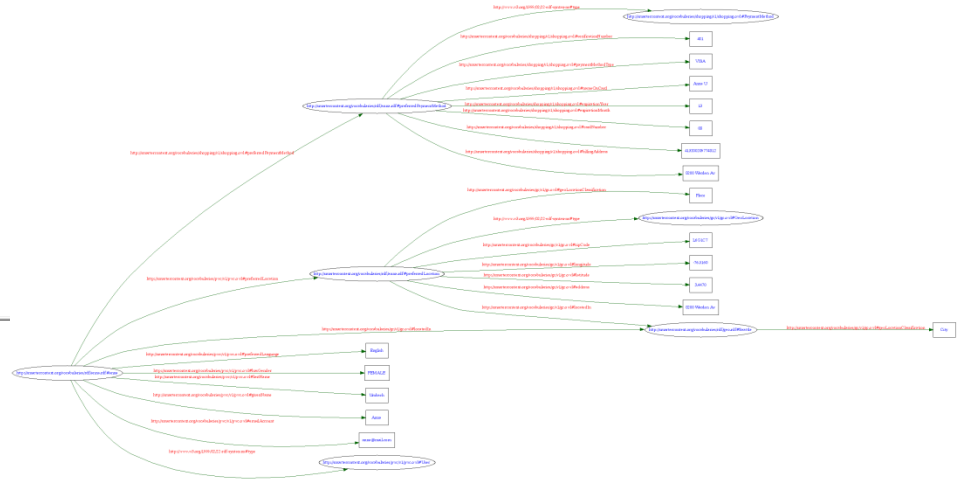
Context Relationships



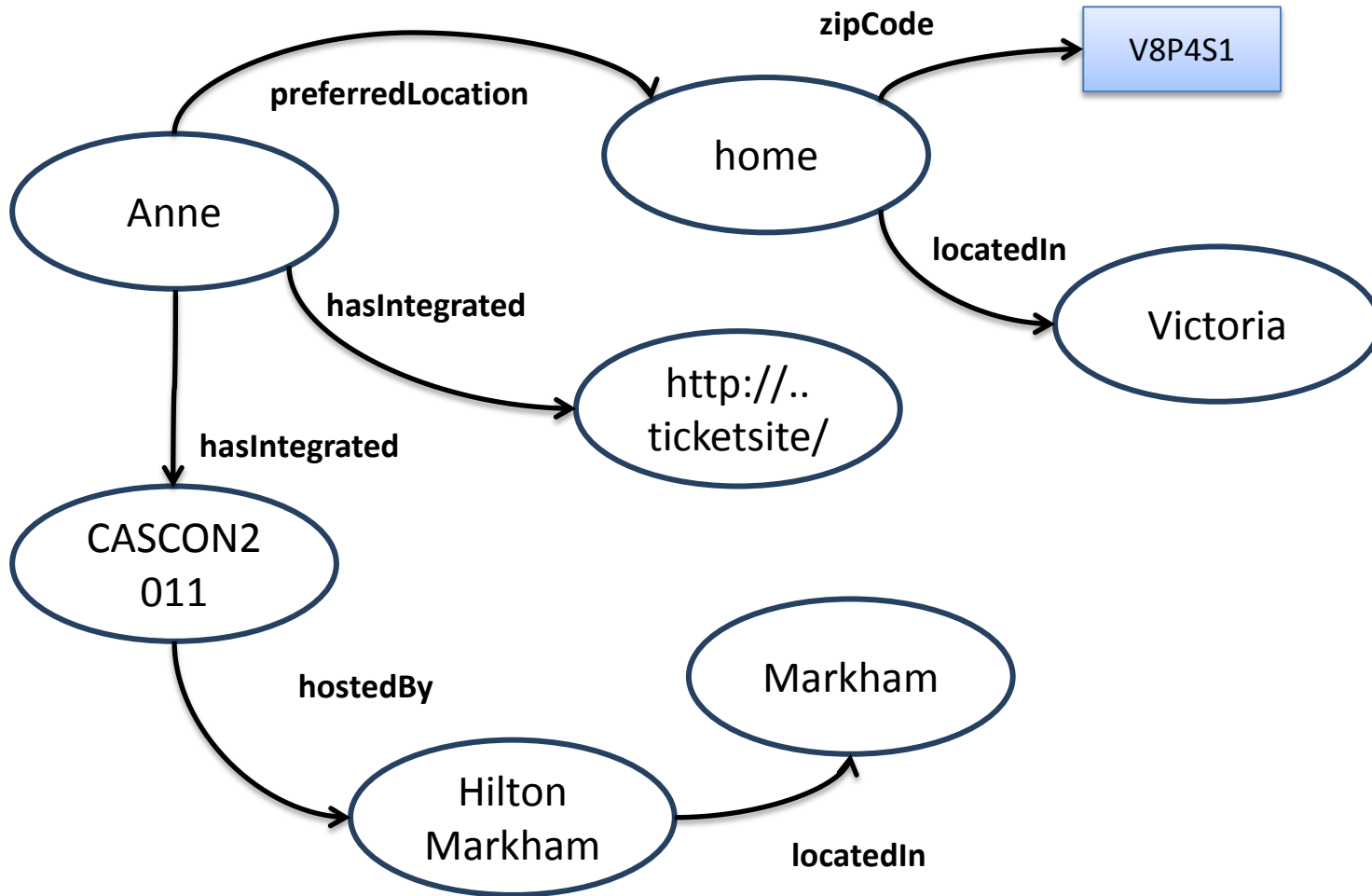
Flexible semantics according to the business needs

Dynamic Context Representation

```
1 <rdf:RDF
2   xmlns:dcterms="http://purl.org/dc/terms/"
3   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
4   xmlns:gc="http://smartercontext.org/vocabularies/gc/v1/gc.owl#"
5   xmlns:pwd="http://smartercontext.org/vocabularies/pwc/v1/pwc.owl#"
6   xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
7   xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
8   xmlns:shopping="http://smartercontext.org/vocabularies/shopping/v1/shopping.owl#"
9   xmlns:dc="http://purl.org/dc/elements/1.1/"
10  xmlns:owl="http://www.w3.org/2002/07/owl#"
11  xmlns:vcard="http://www.w3.org/2001/vcard-rdf/3.0#" >
12  <rdf:Description rdf:about="http://smartercontext.org/vocabularies/rdf/anna.rdf#preferredPaymentMethod">
13    <rdf:type rdf:resource="http://smartercontext.org/vocabularies/shopping/v1/shopping.owl#PaymentMethod"/>
14    <shopping:verificationNumber rdf:datatype="http://www.w3.org/2001/XMLSchema#string">401</shopping:verificationNumber>
15    <shopping:paymentMethodType rdf:datatype="http://www.w3.org/2001/XMLSchema#string">VISA</shopping:paymentMethodType>
16    <shopping:nameOnCard rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Anna U</shopping:nameOnCard>
17    <shopping:expirationYear rdf:datatype="http://www.w3.org/2001/XMLSchema#int">13</shopping:expirationYear>
18    <shopping:expirationMonth rdf:datatype="http://www.w3.org/2001/XMLSchema#int">08</shopping:expirationMonth>
19    <shopping:cardNumber rdf:datatype="http://www.w3.org/2001/XMLSchema#string">413200209774812</shopping:cardNumber>
20    <shopping:billingAddress rdf:datatype="http://www.w3.org/2001/XMLSchema#string">8200 Warden Av</shopping:billingAddress>
21  </rdf:Description>
22  <rdf:Description rdf:about="http://smartercontext.org/vocabularies/rdf/anna.rdf#anna">
23    <pwd:preferredLocation rdf:resource="http://smartercontext.org/vocabularies/rdf/anna.rdf#preferredLocation"/>
24    <shopping:preferredPaymentMethod rdf:resource="http://smartercontext.org/vocabularies/rdf/anna.rdf#preferredPaymentMethod"/>
25    <gc:locatedIn rdf:resource="http://smartercontext.org/vocabularies/rdf/geo.rdf#Seattle"/>
26    <pwd:preferredLanguage rdf:datatype="http://www.w3.org/2001/XMLSchema#string">English</pwd:preferredLanguage>
27    <pwd:hasGender rdf:datatype="http://www.w3.org/2001/XMLSchema#string">FEMALE</pwd:hasGender>
28    <pwd:lastName rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Umbach</pwd:lastName>
29    <pwd:givenName rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Anna</pwd:givenName>
30    <pwd:emailAccount rdf:datatype="http://www.w3.org/2001/XMLSchema#string">anna@mail.com</pwd:emailAccount>
31    <rdf:type rdf:resource="http://smartercontext.org/vocabularies/pwc/v1/pwc.owl#User"/>
32  </rdf:Description>
33  <rdf:Description rdf:about="http://smartercontext.org/vocabularies/rdf/geo.rdf#Seattle">
34    <gc:geoLocationClassification rdf:datatype="http://www.w3.org/2001/XMLSchema#string">City</gc:geoLocationClassification>
35  </rdf:Description>
36  <rdf:Description rdf:about="http://smartercontext.org/vocabularies/rdf/anna.rdf#preferredLocation">
37    <gc:locatedIn rdf:resource="http://smartercontext.org/vocabularies/rdf/geo.rdf#Seattle"/>
38    <gc:zipCode rdf:datatype="http://www.w3.org/2001/XMLSchema#string">L6G1C</gc:zipCode>
39    <gc:longitude rdf:datatype="http://www.w3.org/2001/XMLSchema#string">-76.5160</gc:longitude>
40    <gc:latitude rdf:datatype="http://www.w3.org/2001/XMLSchema#string">3.4470</gc:latitude>
41    <gc:address rdf:datatype="http://www.w3.org/2001/XMLSchema#string">8200 Warden Av</gc:address>
42    <gc:geoLocationClassification rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Place</gc:geoLocationClassification>
43    <rdf:type rdf:resource="http://smartercontext.org/vocabularies/gc/v1/gc.owl#GeoLocation"/>
44  </rdf:Description>
45 </rdf:RDF>
```

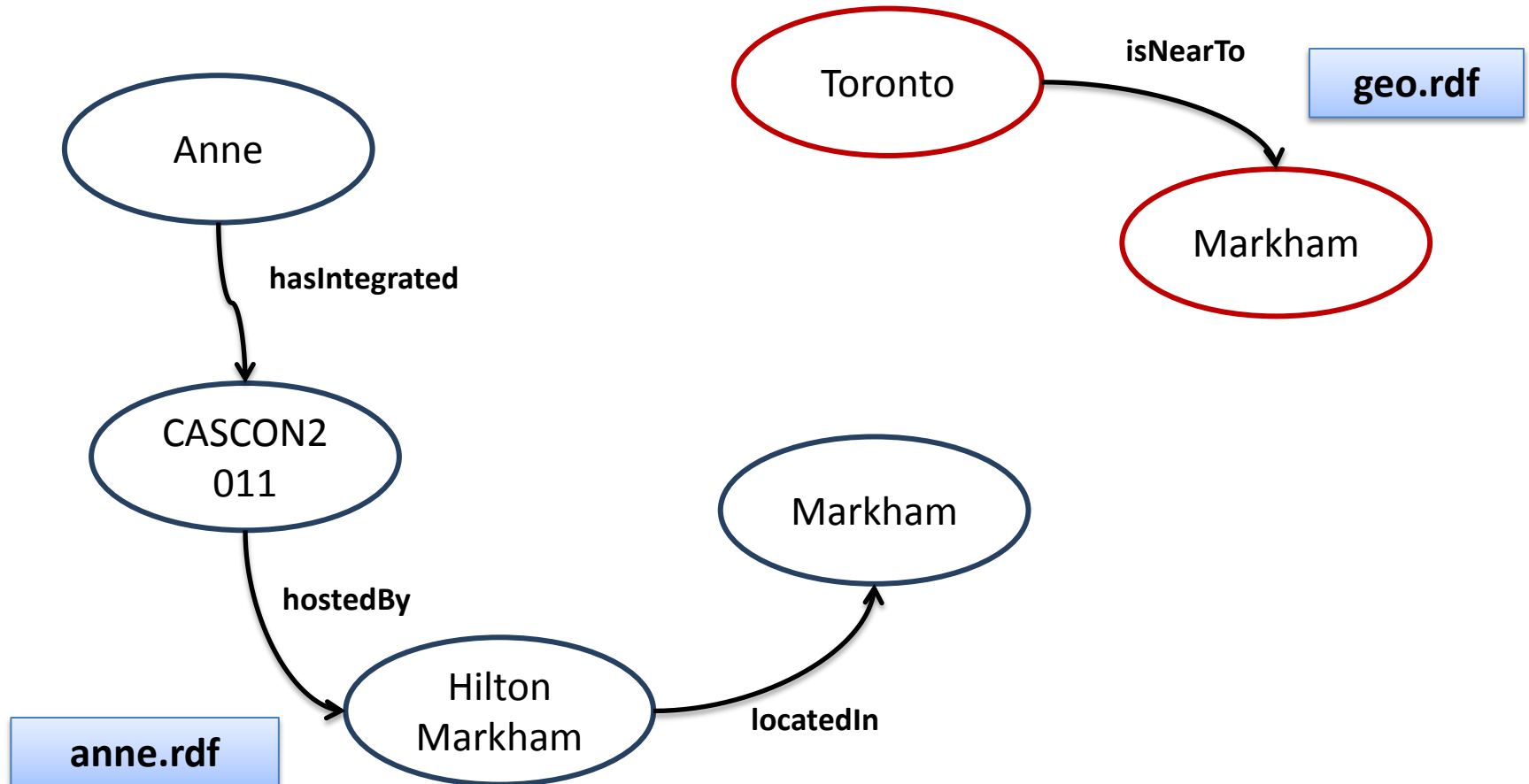


Context Integration and Reasoning

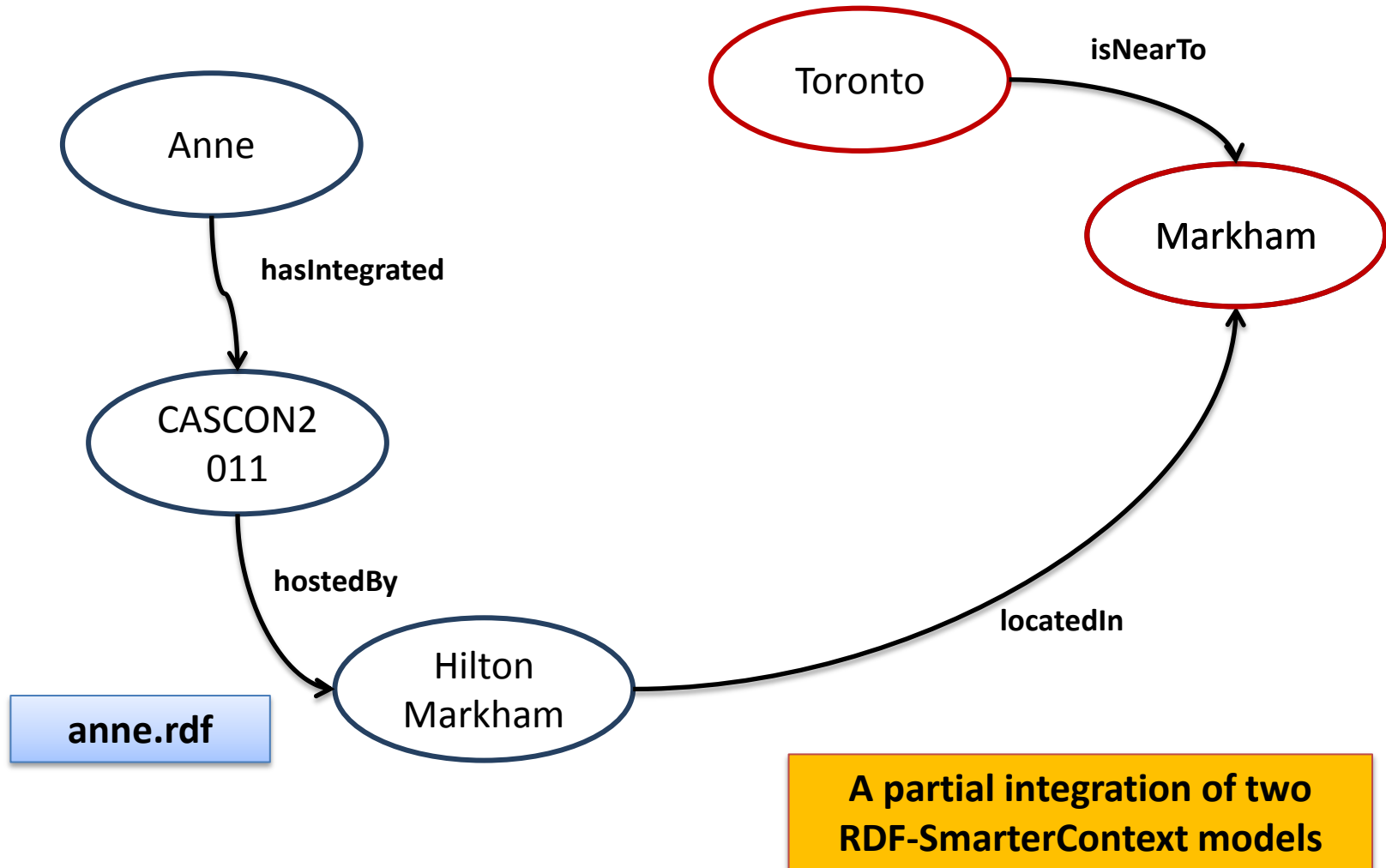


anne.rdf: Anne's initial context sphere model

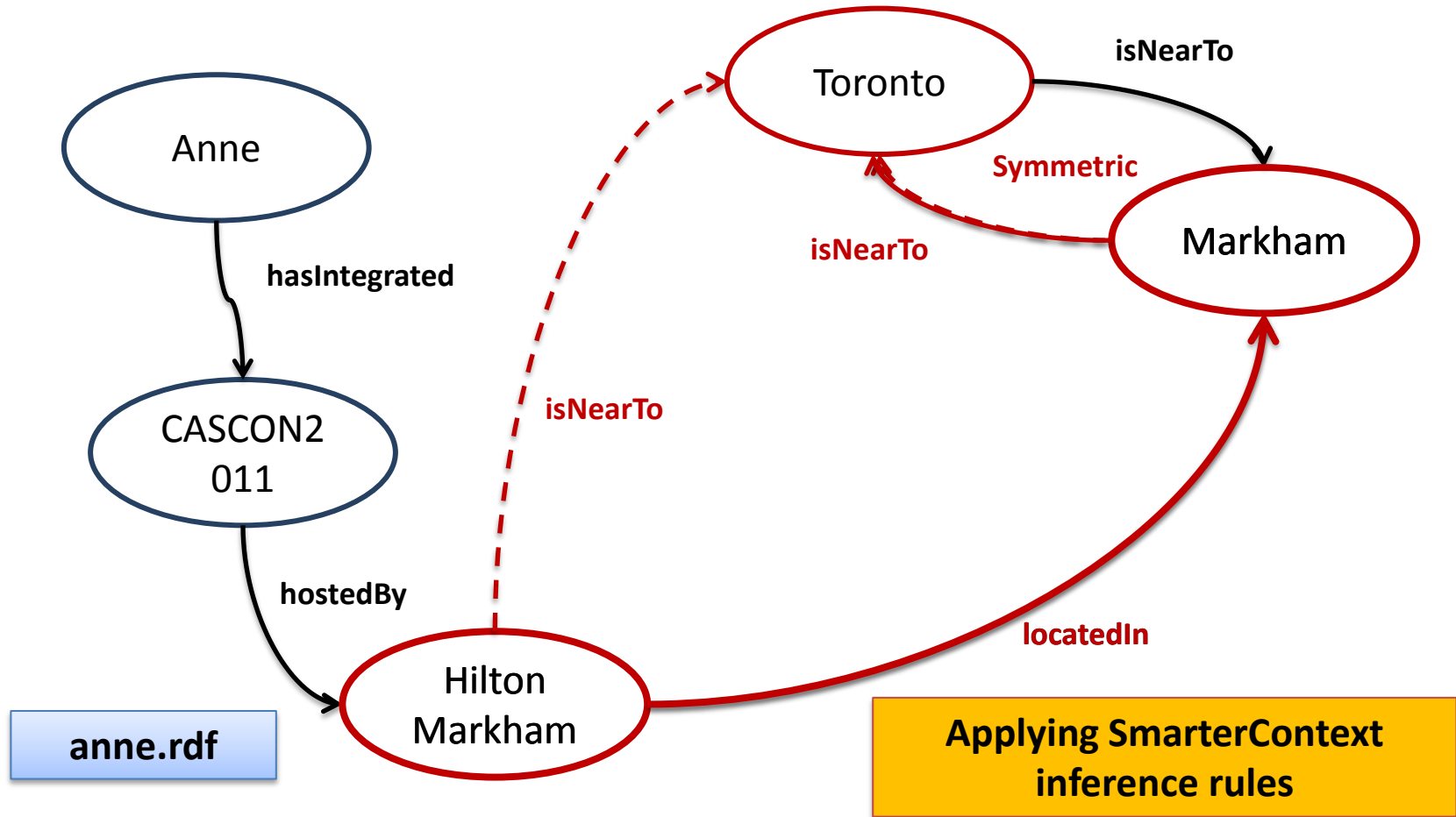
Context Integration and Reasoning



Context Integration and Reasoning

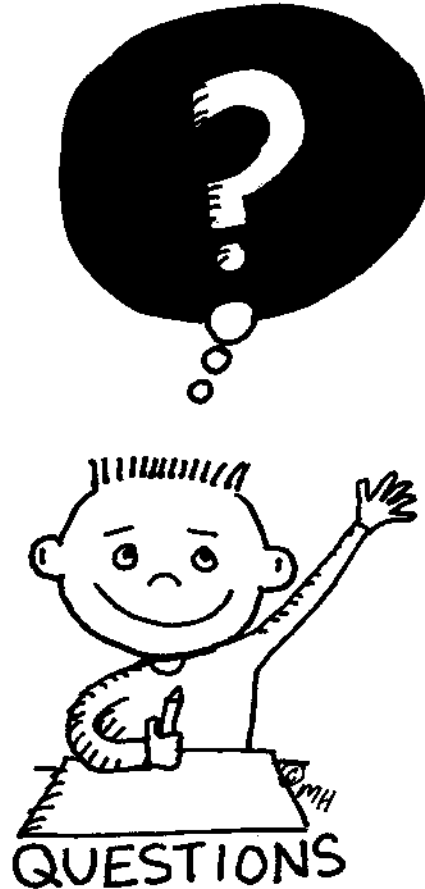


Context Integration and Reasoning

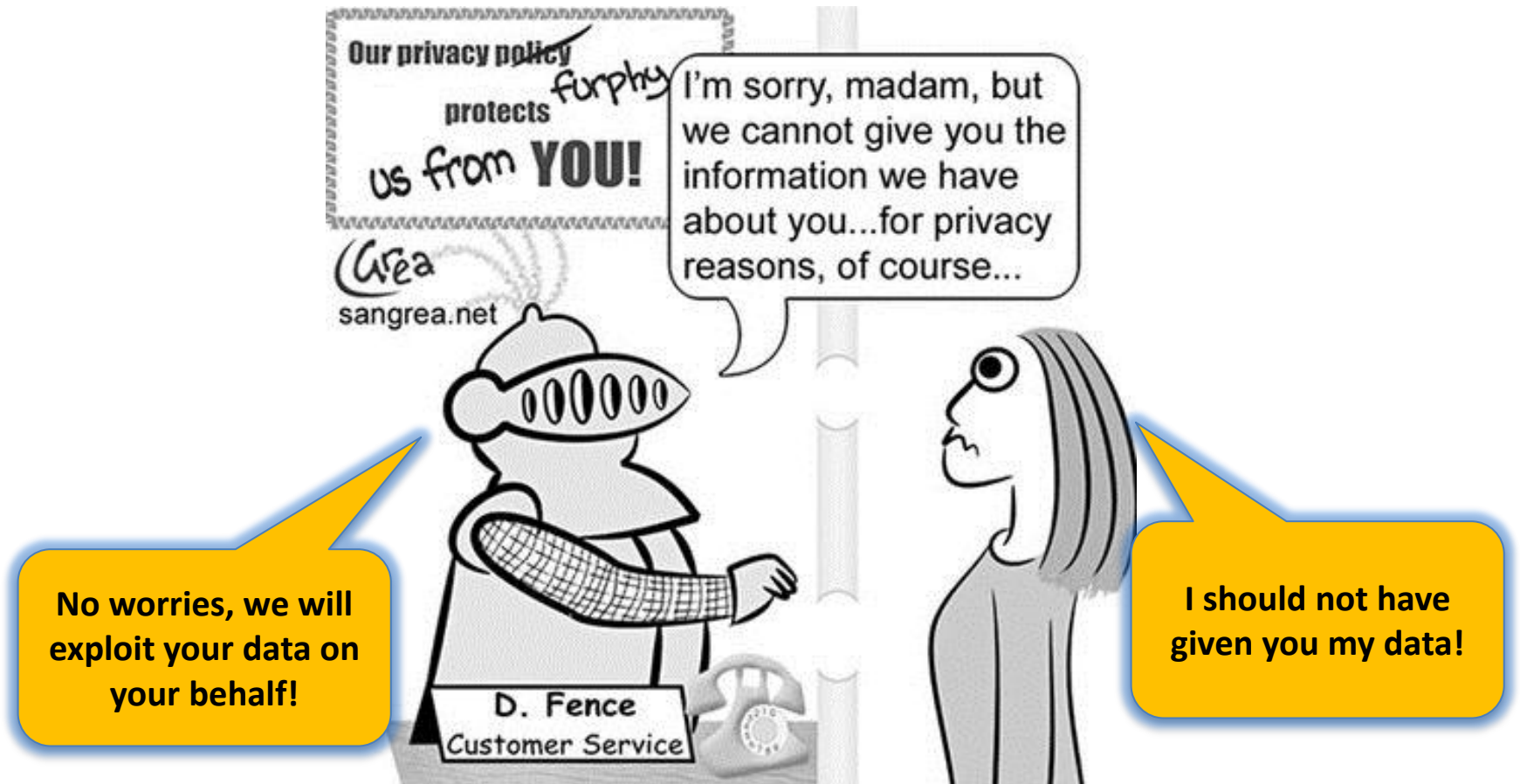


[nearTo: (?a pwc:locatedIn ?b) (?b pwc:isNearTo ?c) -> (?a pwc:isNearTo ?c)]

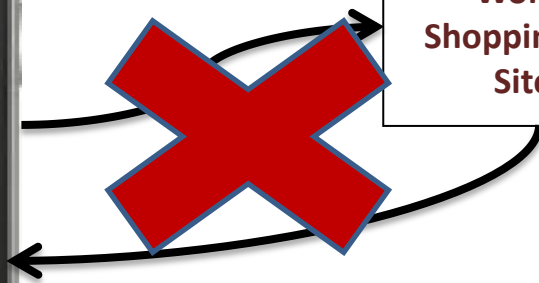
How to empower users to manage their personal context in e-shopping?



Problem: Users With No Control Over Personal Data



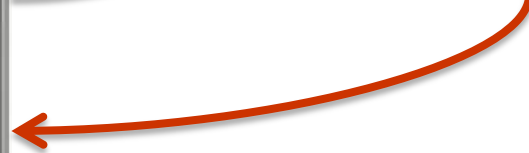
Optimizing Your Web Experience



Your user experience is limited!



Optimizing Your Web Experience

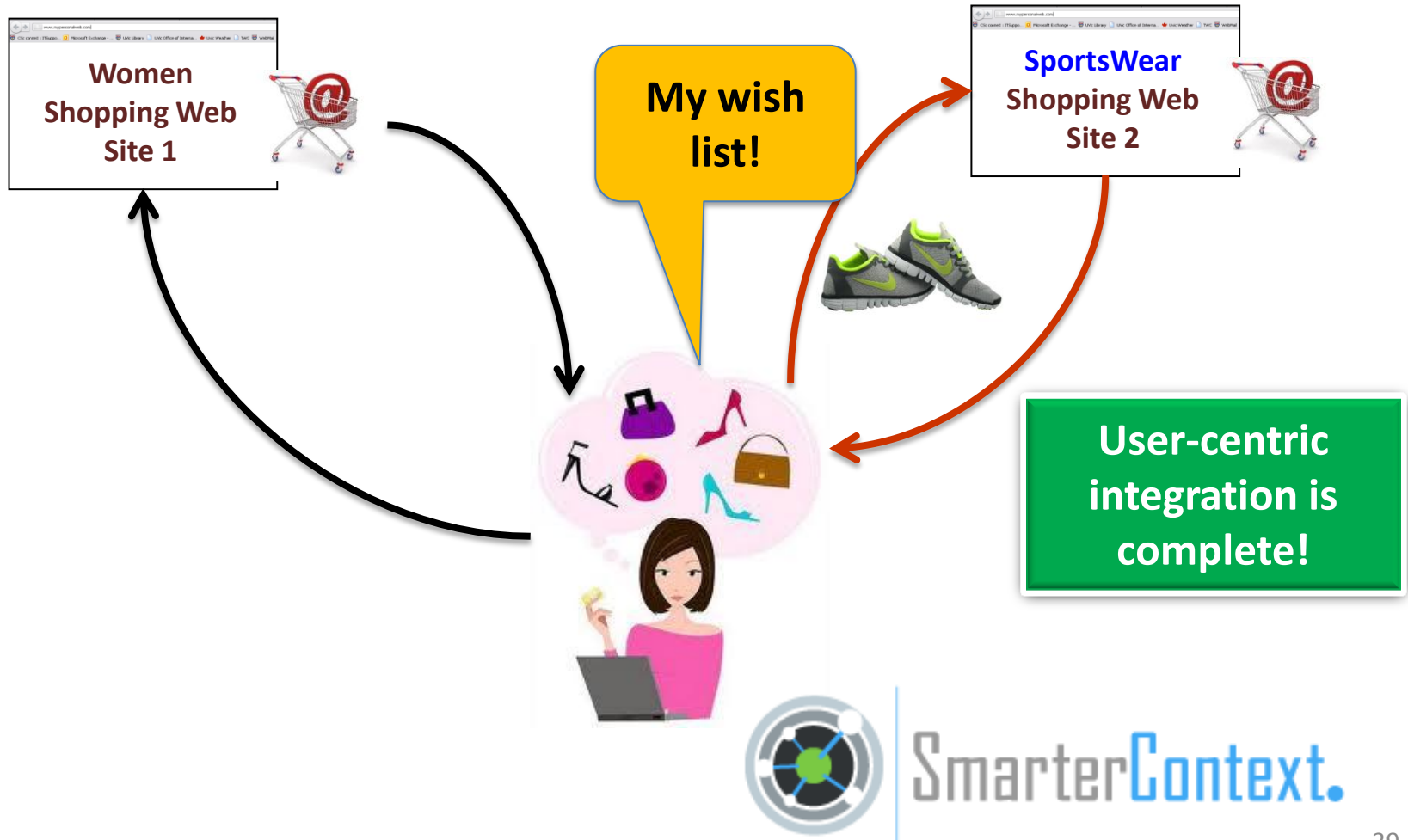


Optimizing Your Web Experience

Web interactions within the boundaries
of individual web sites



Optimizing Your Web Experience



Optimizing Your Web Experience



Your web experience is not context-aware!



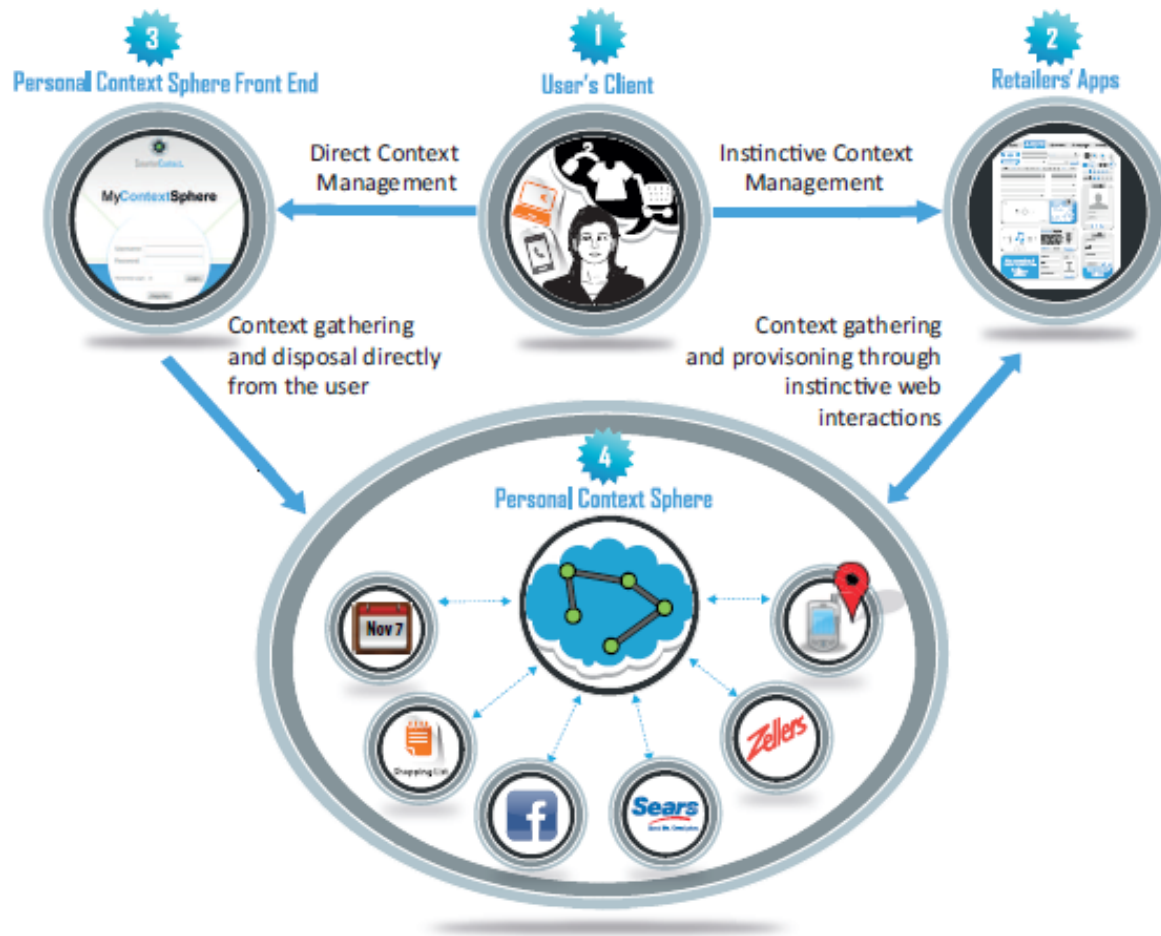
Optimizing Your Web Experience



Your web experience is context-aware!



Empowering users: The Personal Context Sphere







Value Creation with Personal Context

TOWARDS A NEW E-COMMERCE BUSINESS MODEL

The Actors

Convenience

Personalization

Norha



Customization



Shoppers

Price & Time Savings



amazon[®]

Retailers



Revenue Generation

Market Opportunity

Cloud Providers

The Infrastructure



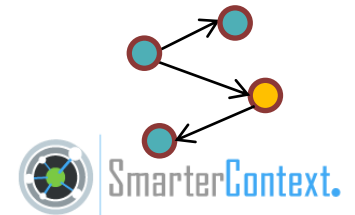
Shoppers



Retailers



Cloud Providers



Situation-Awareness and Self-Adaptation for Software Evolution



THANK YOU!