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Classifying Environmental Monitoring Systems

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Outline

1. Why classification?
2. Classification method
3. Environmental monitoring systems to be classified
4. Application domain based classification results
5. Functionality based classification results
6. Architecture based classification results
7. Conclusion

1. Why classification?

- Trend:
  ever more specialized environmental monitoring systems.
- Issues with monitoring systems:
  - Should we implement yet another, or could we use some existing one?
  - Which of the existing systems fits our needs?
  - What is expected of interoperability?
  - How should we refine a system to fit a specific application domain?
  - Does some open source solution provide sufficient functionality?
  - Are there some critical, architectural differences?
  - Is there a market for a novel environmental monitoring system?
  - Why cannot we reuse existing infrastructure?

1. Why classification?

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  ever more specialized environmental monitoring systems.
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  - Are there some critical, architectural differences?
  - Is there a market for a novel environmental monitoring system?
  - Why cannot we reuse existing infrastructure?

2. Classification method (1/4)

- Three viewpoints:

1. Application domain:
   - phenomenon, interest, task, benefit

2. Functionality:
   - operation, interaction, performance, reliability, method, maintenance

3. Architecture:
   - implementation, data, capacity, connectivity

2. Classification method (2/4)

Application Domain		Interest						Task					Benefit					
		Authorities	Researchers	Rescue workers	City council	Citizens	Households	Measuring	Monitoring	Learning	Analysis	Decision-making	Understanding	Comfort	Saving costs	Improved efficiency	Improved security	Income
Phenomena	Ocean																	
	Weather																	
	Indoor air																	
	Water consumption																	
	Energy consumption																	
	Vibration																	
	Noise																	
	Chemical dispersion																	
Interest	Authorities	Redundant																
	Researchers																	
	Rescue workers																	
	City council																	
	Citizens																	
	Households																	
Task	Measuring	Redundant						Redundant										
	Monitoring																	
	Learning																	
	Analysis																	
	Decision-making																	

2. Classification method (3/4)

Functionality		Interaction			Performance							Reliability			Methods		Maintenance		
		Poll	Subscribe	Reactive	Real-time	Delayed response	Local	National	International	MB dataflow	GB dataflow	Safety-critical	Robust	Uncertainty managed	Statistical	Model-based	Calibration	Software revision	Repair
Operation	Relay																		
	Measure																		
	Store																		
	Transform																		
	Produce new																		
	Forecast																		
	Extract knowledge																		
	Presentation																		
Interaction	Poll	Redundant																	
	Subscribe																		
	Reactive																		
Performance	Real-time	Redundant			Redundant														
	Delayed response																		
	Local																		
	National																		
	International																		
	MB dataflow																		
	GB dataflow																		
Reliability	Safety-critical	Redundant			Redundant							Redundant							
	Robust																		
	Uncertainty managed																		
Methods	Statistical	Redundant			Redundant							Redundant			Redundant				
	Model-based																		

2. Classification method (4/4)

Architecture		Data							Capacity						Connectivity		
		Local	National	International	Tens of variables	Hundreds of variables	Quality controlled	External sources	GB storage	TB storage	MB processing	GB processing	Tens of sensors	Hudreds of sensors	Required extenal services	Provided external services	Open interfaces
Implementation	Loosely coupled																
	Multiple technologies																
	Use of standards																
	Multiple languages																
Data	Local	Redundant															
	National																
	International																
	Tens of variables																
	Hundreds of variables																
	Quality controlled																
	External sources																
Capacity	GB storage	Redundant							Redundant								
	TB storage																
	MB processing																
	GB processing																
	Tens of sensors																
	Hundreds of sensors																

3. Environmental monitoring systems to be classified (1/2)

1. NOAA Integrated Ocean Observing Systems:
   - High frequency radar data, ocean observations

2. INTAPMAP WU:
   - Weather data form private stations, quality control management

3. Indoor air quality and energy efficiency monitoring (AsTEKa):
   - Sensor network with heterogeneous sensors

3. Environmental monitoring systems to be classified (2/2)

4. Distributed service network for safety & security apps (TiTiMaKe):
   - Outdoor sensing with heterogeneous sensors
   - Integration of computational services

5. Icebreaker navigation and planning (IBPlott):
   - Uses satellite images, near-real time environmental data

6. Participatory sensing (EnviObserver):
   - People as sensors (with mobile devices)

4. Application doman classification results (1/4)

Application Domain		Interest							Task					Benefit						
		Authorities	Researchers	Rescue workers	Industry	City council	Citizens	Households	Measuring	Monitoring	Learning	Analysis	Decision-making	Understanding	Health and well-being	Comfort	Saving costs	Improved efficiency	Improved security	Income
Phenomena	Ocean	A, E	A	A	E	A	F		A, F	E,F	A,E,F	A,E,F	A,E,F	A, E, F	F	F	A, E	A, E	A, E	E
	Weather	A	A,B	A		A	B	B	A,B	E	A,B	A,B,E	E	A,B		B	A	A	A	
	Air quality						F		F	F	F	F	F	F	F	F				
	Indoor air		C					C	C	C	C	C	C	C	C	C	C	C		
	Water consumption		C					C	C	C		C	C				C	C		
	Energy consumption		C					C	C	C	C	C	C	C			C	C		
	Vibration		D						D	D	D	D		D					D	
	Noise		D						D	D	D	D		D					D	
	Chemical dispersion		D						D	D	D	D		D					D	
Interest	Authorities	Redundant								E, F	E	E	A,E	E			A	A,E	A, E	
	Researchers								A,B,C, D, F	D	A,B,D, F	A,B,C, D,F		A,B,C, D, F	C				D	
	Rescue workers												A				A	A	A	
	Industry									E	E	E	E	E			E	E	E	E
	City council											A	A				A	A	A	
	Citizens								B			B	B	F	F	B, F	F		F	
	Households								B,C	C	C	B,C	B,C	C	C	B,C	C	C		
Task	Measuring	Redundant							Redundant					A,C,D, F	F	B,C, F	C, F	C, F	A,D, F	
	Monitoring													E,F	F	F	C,E	C,E	D,E	E
	Learning													A,B,C, D,E,F	C,F	F	C,E	C,E	D,E	E
	Analysis													A,C,D,E ,F	C,F	B,C,F	A,C,E	A,C,E	A,D,E	E
	Decision-making													E,F	F	F	A,C,E	A,C,E	A,E	E

A=NOOA IOOS
B=INTAMAP WU
C=AsTEKa
D=TiTiMaKe
E=IBPlott
F=EnviObserver

4. Application doman classification results (2/4)

	Application Domain	Interest							Task					Benefit						
		Authorities	Researchers	Rescue workers	Industry	City council	Citizens	Households	Measuring	Monitoring	Learning	Analysis	Decision-making	Understanding	Health and well-being	Comfort	Saving costs	Improved efficiency	Improved security	Income
Phenomena	Ocean	A, E	A	A	E	A	F		A, F	E,F	A,E,F	A,E,F	A,E,F	A, E, F	F	F	A, E	A, E	A, E	E
	Weather	A	A,B	A		A	B	B	A,B	E	A,B	A,B,E	E	A,B		B	A	A	A	
	Air quality						F		F	F	F	F	F	F	F	F				
	Indoor air		C					C	C	C	C	C	C	C	C	C	C	C		
	Water consumption		C					C	C	C		C	C				C	C		
	Energy consumption		C					C	C	C	C	C	C	C			C	C		
	Vibration		D						D	D	D	D		D					D	
	Noise		D						D	D	D	D		D					D	
	Chemical dispersion		D						D	D	D	D		D					D	
Interest	Authorities	Redundant								E, F	E	E	A,E	E			A	A,E	A, E	
	Researchers								A,B,C, D, F	D	A,B,D, F	A,B,C, D,F		A,B,C, D, F	C				D	
	Rescue workers												A				A	A	A	
	Industry									E	E	E	E	E			E	E	E	E
	City council											A	A				A	A	A	
	Citizens								B			B	B	F	F	B, F	F		F	
	Households								B,C	C	C	B,C	B,C	C	C	B,C	C	C		
Task	Measuring	Redundant							Redundant					A,C,D, F	F	B,C, F	C, F	C, F	A,D, F	
	Monitoring													E,F	F	F	C,E	C,E	D,E	E
	Learning													A,B,C, D,E,F	C,F	F	C,E	C,E	D,E	E
	Analysis													A,C,D, ,F	C,F	B,C,F	A,C,E	A,C,E	A,D,E	E
	Decision-making													E,F	F	F	A,C,E	A,C,E	A,E	E

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4. Application doman classification results (3/4)

Health and Comfort

	Application Domain	Interest							Task					Benefit						
		Authorities	Rescue workers	Industry	City council	Citizens	Households	Researchers	Measuring	Monitoring	Learning	Analysis	Decision-making	Understanding	Health and well-being	Comfort	Saving costs	Improved efficiency	Improved security	Income
Phenomena	Ocean	A, E	A	E	A	F		A	A, F	E,F	A,E,F	A,E,F	A,E,F	A, E, F	F	F	A, E	A, E	A, E	E
	Weather	A	A		A	B	B	A,B	A,B	E	A,B	A,B,E	E	A,B		B	A	A	A	
	Air quality					F			F	F	F	F	F	F	F	F				
	Indoor air						C	C	C	C	C	C	C	C	C	C	C	C		
	Water consumption						C	C	C	C		C	C				C	C		
	Energy consumption						C	C	C	C	C	C	C	C			C	C		
	Vibration							D	D	D	D	D		D					D	
	Noise							D	D	D	D	D		D					D	
	Chemical dispersion							D	D	D	D	D		D					D	
Interest	Authorities									E, F	E	E	A,E	E			A	A,E	A, E	
	Rescue workers												A				A	A	A	
	Industry									E	E	E	E	E			E	E	E	E
	City council											A	A				A	A	A	
	Researchers								A,B,C, D, F	D	A,B,D, F	A,B,C, D,F		A,B,C, D, F	C				D	
	Citizens								B			B	B	F	F	B, F	F		F	
	Households								B,C	C	C	B,C	B,C	C	C	B,C	C	C		
Task	Measuring													A,C,D, F	F	B,C, F	C, F	C, F	A,D, F	
	Learning													A,B,C, D,E,F	C,F	F	C,E	C,E	D,E	E
	Analysis													A,C,D,E ,F	C,F	B,C,F	A,C,E	A,C,E	A,D,E	E
	Monitoring													E,F	F	F	C,E	C,E	D,E	E
	Decision-making													E,F	F	F	A,C,E	A,C,E	A,E	E

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4. Application domain classification results (4/4)

1. Health and comfort
   - INTAMAP WU, AsTEKa, EnviObserver
   - Emphasis on delivering personalized information.
2. Sea and water
   - NOAA IOOS, IBPlott, EnviObserver
   - Services for authors supporting monitoring and decision making
3. Improved security
   - NOAA IOOS, TiTiMaKe, IBPlott, EnviObserver
   - Share an interest for understanding underlying phenomena
4. Improved efficiency
   - NOAA IOOS, AsTEKa, IBPlott
   - Emphasis on saving costs, learning, and analysis

5. Functionality classification results

1. Local monitoring
   - AsTEKa, TiTiMaKe
   - Model based methods
2. Decision making
   - NOAA IOOS, INTAMAP WU, TiTiMaKe
   - Forecasting, knowledge extraction, delayed response
3. Robust and reliable
   - NOAA IOOS, IBPlott, EnviObserver
   - Non-cohesive, including real-time monitoring, uncertainty management, use of statistical methods

6. Architecture classification results

1. Open systems
   - INTAMAP WU, EnviObserver
   - Loosely coupled, open interfaces
2. Closed systems
   - NOAA IOOS, AsTEKa, TiTiMake
   - Use of standards, locality, specialized interfaces
3. Large data flow
   - NOAA IOOS, IBPlott
   - Same domain (ocean)!
4. Externally dependent
   - INTAMAP WU, TiTiMaKe, IBPlott, EnviObserver
   - Loosely coupled components, multiple technologies
   - Real-time aspects vs. forecasting

7. Conclusion

- We proposed a cross-tabulation method for classifying environmental monitoring systems.
- The analysis reveals interesting shared and disjoint aspects.
- Problem: detailed information is seldom available.
- Method is good for mapping competition, strengths and weaknesses.

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