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The Cyber Sensor Network

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Abstract—Access to information has never been easier thanks to the WWW; though not as well developed, sensor web technologies are, nonetheless, increasingly making data concerning a wide range of physical phenomena available to all. Potential opportunities for research in many application domains abound. Translating this potential into meaningful research is problematic as information sources, including but not limited to those on the WWW, are characterized by diversity and heterogeneity in a multiplicity of dimensions, resulting in an unwieldy and complex data capture process. To address this problem, the concept of a Cyber Sensor Network is proposed as a construct for providing a domain-agnostic interface to diverse cyber and physical information sources. A methodology to implement such a network is described.

Keywords-Cyber-Physical-Social Computing; middleware;

I. INTRODUCTION

Diversity and disparity characterise information sources in a multiplicity of dimensions in both cyber and physical space. Though intrinsic, solutions are promised. The Semantic Web [1], a World Wide Web Consortium (W3C) initiative, seeks to ascribe meaning to data thereby enabling unprecedented data sharing. Sensor Web Enablement [2], an Open Geospatial Consortium (OGC) initiative, seeks to enable seamless access to physical sensors of varying degrees of complexity. Such information diversity on the WWW may constitute a paradox. Information variety and sheer volume are testimony to the strength of the WWW; nonetheless, its heterogeneity exacerbates the complexities of knowledge discovery. The genesis of this problem may be at least partially attributed to the needs of radically different communities. The Social Web [3], a latter day phenomenon, enables unprecedented levels of information sharing between disparate communities; the Sensor Web [4] seeks to enable dissemination of information from a physical world that is itself characterized by heterogeneity. A particular challenge is how to construct a systematic, domain-agnostic methodology for gathering information from these diverse Webs, as well as from legacy systems, so as to enable subsequent processing as per the needs of an arbitrary domain. This paper develops the construct of a Cyber Sensor Network as a means of managing heterogeneity and illustrates how the predominant paradigm for managing heterogeneity in

physical sensor networks, namely that of middleware, may be extended to realize such a network in practice.

II. DEFINING THE CYBER SENSOR

A classic view of sensors is that of physical devices which detect or measure some physical phenomena. A more encompassing definition of the term sensor can be derived. In essence, the notion of a sensor can be applied to any information-producing entity, be it in the physical world as is the prevailing view, or, more intriguingly, contained within the WWW. Such a definition encapsulates the conventional view of sensors whilst extending it to include a wide range of data-producing entities beyond the confines of the physical realm, resulting in the more encompassing concept of a *Cyber Sensor*.

From a physical perspective, a Cyber Sensor may encompass:

- physical/bio sensors, or networks of such sensors,
- software/virtual sensors where the data is derived from conventional sensors, but is augmented or conflated on the physical device,
- Internet of Things.

From a cyber perspective, a Cyber Sensor encompasses any dynamic data-producing entity on the WWW, including:

- social networks,
- dynamic data feeds,
- sensor portals, as typified by, for example, Sensorpedia [5].

III. THE CYBER SENSOR NETWORK

A Cyber Sensor Network (CSN) is thus constituted as a suite of Cyber Sensors that encapsulate dynamic data-sources across both physical and cyberspace, providing for their subsequent integration, fusion, analysis and visualisation (Fig. 1). Analogies exist; these range from inherently distributed sensor networks to overlay networks that harness existing network infrastructures. A CSN is realized solely in software although physical devices could manifestly form nodes within the network. Its primary task is to provide for the capture and initial processing of the diverse data streams

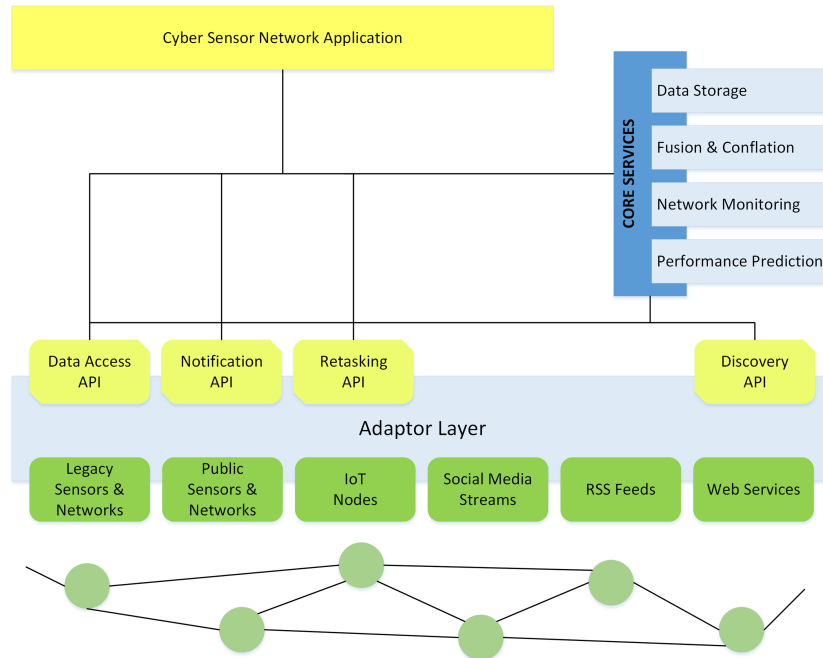


Figure 2. Schematic overview of the CSN-enabled SIXTH platform.

monitoring [10], Internet-of-Things [11], human activity recognition [12] as well as in many legacy business information systems is testimony to the ubiquity and robustness of the paradigm.

A. Design

To illustrate the viability of a CSN, a pre-existing middleware platform for physical sensors, SIXTH [13], was extended. SIXTH is realised using the Open Gateway Initiative (OSGi) framework; extensibility and modularity are fundamental characteristics as is support for heterogeneous sensing platforms. Figure 2 illustrates some of the key components. Adaptors encapsulate the glue software code, as it were, that links abstractions and the underlying information sources. All adaptors are configured and managed through a suite of APIs that are accessible directly from the Application Layer. A suite of core services is also available to all applications. Note that other middleware platforms, for example OpenSensorHub (<http://www.opensensorhub.org>), could, in principle, be augmented to support Cyber Sensors.

Fundamental to the notion of a CSN is the observation that in carefully designing a suite of core APIs and services, common abstractions for managing and interacting with Cyber Sensors, irrespective of the underlying information source, are identified. This results in an abstract model which must be instantiated by the software engineer as per the needs of the application in question. Three discrete functional components must be implemented:

1) Connection: How connection/disconnection with an arbitrary data source is managed.

2) Tasking: How data is captured and preprocessed. In the case of a physical sensor, it may involve reading the temperature every 15 minutes and converting to Celsius or Fahrenheit. In the case of a twitter feed, only tweets that contain a specified keyword might be reported.

3) Translation: All data is translated to an internal data format and augmented with appropriate metadata thus enabling its use by all available middleware services. For example, using the generic notification service, all registered services are made aware of the availability of new data.

B. Implementation

Figure 3 presents a simple visual representation of one prototype CSN developed for bushfire monitoring. It can clearly be seen how, given a specification of a query using a conjunction of the key word Bushfire and a bounded polygon around Tasmania, that it is possible to seamlessly discover and merge physical and social data streams into an integrated information collage. Data streams are collected and served in near real-time allowing subsequent monitoring and interrogation. When such data streams are multiplexed, a rich synthesis of data ranging from visual images, satellite imagery, social media and high quality calibrated sensed data emerges. Patterns of activation can serve to provide trend visualization, in this case synonymous with bush fire progression. The folding of such diverse data streams together can serve to consolidate and strengthen the confidence associated with a single data stream. Furthermore, participa-

tory sensing citizens-as-sensors [14] could potentially form nodes in such a CSN. Quality assurance can be achieved by cross referencing other data streams adjacently situated in the spatio-temporal domain.

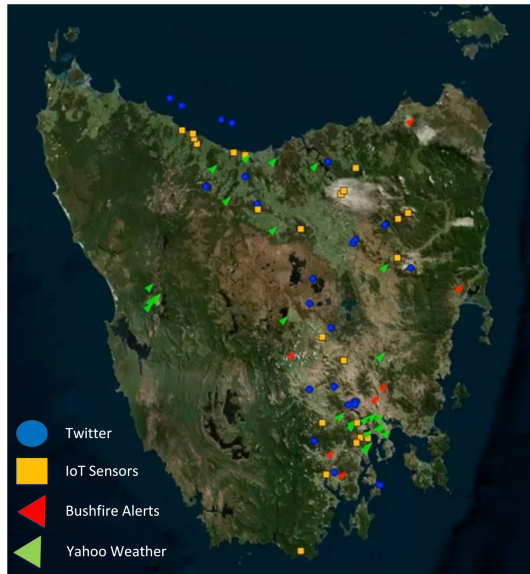


Figure 3. Spatial representation of a dataset generated by a CSN for a bushfire outbreak in Tasmania.

V. CONCLUDING REMARKS

As sensor systems and the WWW evolves, the range, diversity and complexity of dynamic, online data-sources will grow significantly. Cyber-Physical-Social systems offer intriguing possibilities for conflating radically different data streams; pertinent but diverse data sources can be identified, monitored and captured in a seamless and transparent fashion, as per the requirements of the domain in question. Such developments may well pose interesting challenges for research in Big Data going forward [15]. Cyber Sensor Networks offer an innovative, domain-agnostic methodology for mitigating such complexity. In particular, such networks leverage a wealth of experience accumulated over many years in the physical sensor network domain where the challenges inherent in developing ubiquitous middleware solutions have long been researched.

Future work will consider how a cyber-sensor networking approach might address the recurring problem of noisy and uncertain data, especially in the environmental monitoring domain. It is hypothesized that the integration of additional context parameters into the data analysis and filtering processes can demonstrably aid inference and decision making.

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REFERENCES

- [1] P. Hitzler, M. Krotzsch, and S. Rudolph, *Foundations of semantic web technologies*. CRC press, 2009.
- [2] A. Bröring, J. Echterhoff, S. Jirka, I. Simonis, T. Everding, C. Stasch, S. Liang, and R. Lemmens, "New generation sensor web enablement," *Sensors*, vol. 11, no. 3, pp. 2652–2699, 2011.
- [3] E. H. Chi, "The social web: Research and opportunities," *Computer*, vol. 41, no. 9, 2008.
- [4] T. v. Zyl, I. Simonis, and G. McFerren, "The sensor web: systems of sensor systems," *International Journal of Digital Earth*, vol. 2, no. 1, pp. 16–30, 2009.
- [5] B. L. Gorman, D. Resseguie, and C. Tomkins-Tinch, "Sensorpedia: Information sharing across incompatible sensor systems," in *Collaborative Technologies and Systems, 2009. CTS'09. International Symposium on*. IEEE, 2009, pp. 448–454.
- [6] W. K. Michener and M. B. Jones, "Ecoinformatics: supporting ecology as a data-intensive science," *Trends in ecology & evolution*, vol. 27, no. 2, pp. 85–93, 2012.
- [7] F.-Y. Wang, "The emergence of intelligent enterprises: From cps to cpss," *IEEE Intelligent Systems*, vol. 25, no. 4, pp. 85–88, 2010.
- [8] S. Zanero, "Cyber-physical systems," *Computer*, vol. 50, no. 4, pp. 14–16, 2017.
- [9] F.-Y. Wang, K. M. Carley, D. Zeng, and W. Mao, "Social computing: From social informatics to social intelligence," *IEEE Intelligent systems*, vol. 22, no. 2, 2007.
- [10] T. Fountain, S. Tilak, P. Shin, and M. Nekrasov, "The open source dataturbine initiative: empowering the scientific community with streaming data middleware," *The Bulletin of the Ecological Society of America*, vol. 93, no. 3, pp. 242–252, 2012.
- [11] M. A. Razzaque, M. Milojevic-Jevric, A. Palade, and S. Clarke, "Middleware for internet of things: a survey," *IEEE Internet of Things Journal*, vol. 3, no. 1, pp. 70–95, 2016.
- [12] O. Yurur, C. Liu, and W. Moreno, "A survey of context-aware middleware designs for human activity recognition," *IEEE Communications Magazine*, vol. 52, no. 6, pp. 24–31, 2014.
- [13] G. M. P. O'Hare, C. Muldoon, M. J. O'Grady, R. W. Collier, O. Murdoch, and D. Carr, "Sensor web interaction," *International Journal on Artificial Intelligence Tools*, vol. 21, no. 02, p. 1240006, 2012.
- [14] M. J. O'Grady, C. Muldoon, D. Carr, J. Wan, B. Kroon, and G. M. P. O'Hare, "Intelligent sensing for citizen science," *Mobile Networks and Applications*, vol. 21, no. 2, pp. 375–385, 2016.
- [15] S. De, Y. Zhou, I. Larizgoitia Abad, and K. Moessner, "Cyber-physical-social frameworks for urban big data systems: A survey," *Applied Sciences*, vol. 7, no. 10, p. 1017, 2017.