High-Level Context Architecture for Real Time Identification of Human Behavior

Claudia Villalonga[1,2], Oresti Banos[1], Hector Pomares[2], Ignacio Rojas[2], and Sungyoung Lee[1]

[1] Department of Computer Engineering, Kyung Hee University, Yongin, Korea
{*cvillalonga, oresti, sylee*}*@oslab.khu.ac.kr*
[2] Research Center for Information and Communications Technologies of the University of Granada, Granada, Spain
cvillalonga@correo.ugr.es, {*hector, irojas*}*@ugr.es*

Abstract. This work presents the Mining Minds High Level Context Architecture which enables the real time identification of human behavior. This architecture applies ontological inference to identify the user's context. It particularly builds on the Mining Minds Context Ontology, which comprehensively models high-level context based on low-level context, including the user's activities, locations, and emotions. The High Level Context Architecture has been implemented and online validated to prove its scalability and robustness.

Keywords: Context Inference, Context Recognition, Ontology, Ontological Reasoning, Human Behavior Identification

1 Introduction

The automatic identification of human behavior has evoked an enormous interest in the last years. Diverse technologies have been investigated to perform human behavior identification: geolocalization systems [6, 7], audio-visual fusion techniques [4], video systems [10] and on-body sensors [3, 8]. With the boom of the wearable and mobile technology, there are increasingly available commercial solutions which focus on the analysis of the user body motion to keep track of their physical activities [9, 5]. Human behavior identification is a complex problem that requires the analysis of multiple factors. Likewise, it requires to approach the person observation from various perspectives, including physical, mental and social aspects. Accordingly, current domain-specific solutions are seen to be certainly insufficient to deal with the magnitude of this problem. Instead, more complete platforms combining diverse technologies to infer people lifestyle and provide more personalized services are required. In this direction, Mining Minds [1, 2], a novel digital framework for personalized health and wellness support, provides technologies to infer low-level and high-level person-centric information, mainly the user context and behavior, and their physical, mental and social state. This paper presents the Mining Minds High-Level Context Architecture which builds on ontologies and applies ontological reasoning in order to infer abstract user's context.

2 An Architecture for High-Level Context Inference

The High-Level Context Architecture (HLCA) infers abstract context representations based on categories, such as physical activities, emotional states, locations and social patterns. These categories, which are derived from the wide-spectrum of multimodal data obtained from the user interaction with the real and cyber-world, are intelligently combined and processed at HLCA in order to determine and track context. HLCA builds on the Mining Minds Context Ontology [11] and applies ontological inference to identify the user's context. HLCA consists of four main components: High-Level Context Builder, High-Level Context Reasoner, High-Level Context Notifier, and Context Manager (Figure 1). In a nutshell, the operation of HLCA is as follows. The High-Level Context Builder receives low-level information - activities, emotions, and locations - identified by LLCA and generates the ontological concepts representing the user context. The Context Mapper interprets the received low-level information and transforms it into the corresponding ontological concepts for low-level context. The Context Synchronizer searches for concurrent low-level contexts, identifying other user contexts valid at the same moment in time. The Context Instantiator creates a new instance of an unclassified high-level context which links to the low-level contexts which compose it. The unclassified context is served to the High-Level Context Reasoner for its verification and classification. The Context Verifier checks the semantic and syntactic consistency of the unclassified context. The Context Classifier classifies the unclassified context into one of the different high-level contexts by applying ontological inference. Once a new context has been identified, the High-Level Context Notifier makes it available to the other Mining Minds layers for the creation of personalized health and wellness services and recommendations. The Context Manager provides persistence of the Mining Minds Context Ontology and supports the easy access and storage of context information.

The High-Level Context Architecture (HLCA) has been implemented in Java using the Jena (Semantic Web Framework)[3], including the RDF API, the Ontology API, and the Inference API. TDB, the Jena Triple Store, has been used as Context Storage for the persistence of the Mining Minds Context Ontology and context information. Pellet[4], an Open Source OWL DL reasoner for Java, has been utilized in the implementation of the Context Verifier and the Context Classifier.

The current implementation of the High-Level Context Architecture (HLCA) has been benchmarked in order to assess its scalability and robustness. The evaluation consisted in the generation of 50.000 random low level contexts which have subsequently been input to the HLCA for its mapping, synchronization, instantiation, verification, classification and notification. Figure 1 shows the mean and standard deviation of the elapsed time in the context identification for each of the components of the High-Level Context Architecture. As it can be observed,

[3] `https://jena.apache.org/`
[4] `https://github.com/complexible/pellet`

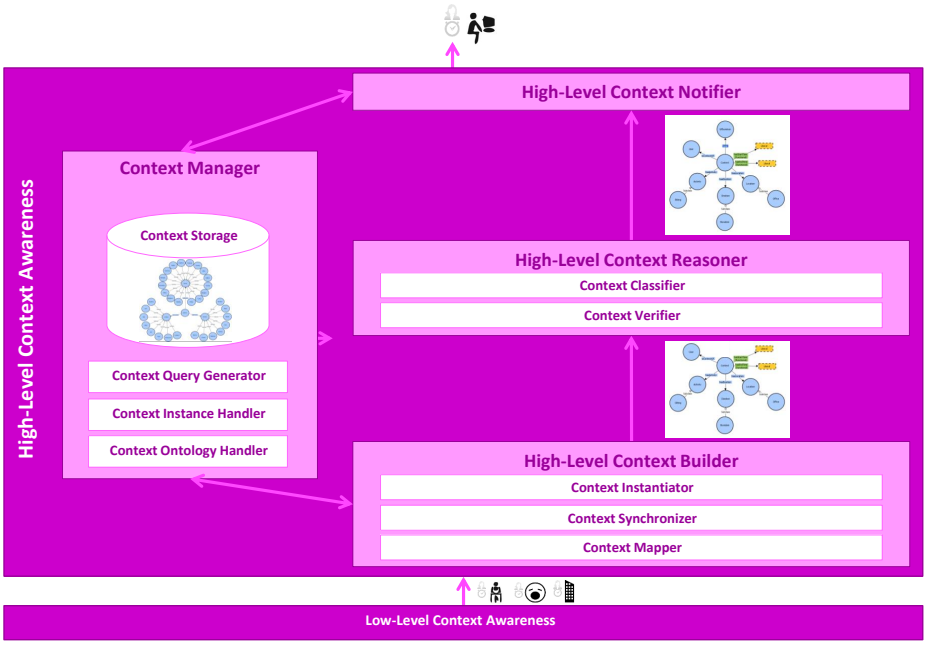

Fig. 1. High-Level Context Architecture operational description.

all the processes involving access to the Context Storage represent most of the computational time. Concretely, the write procedures invoked by the Context Mapper and High-Level Context Notifier nearly doubles the time required for the reading performed by the Context Synchronizer.

Table 1. Mean and standard deviation of the elapsed time (ms) in the context identification for each of the components of the High-Level Context Architecture.

	Context Mapper	Context Synchronizer	Context Instantiator	Context Verifier	Context Classifier	HLC Notifier	Total HLCA
Mean	622.51	313.88	0.68	16.89	19.50	776.39	1749.91
Std Dev	129.86	146.52	0.35	7.23	6.46	138.20	299.65

3 Conclusions

This work has introduced the Mining Minds High-Level Context Architecture which enables the comprehensive and holistic identification of human behavior. In Mining Minds, high-level context is inferred based on low-level context information, namely, activities, locations, and emotions, since activity and location

information might not be enough to detect some of the high-level contexts. Conversely to other existing systems which do not incorporate emotions for behavior recognition, the proposed architecture enables a more accurate high-level context identification. Moreover, the architecture is flexible enough to operate in real life scenarios in which emotion recognition systems may not always be available. The current prototype implementation of the Mining Minds High-Level Context Architecture has been proven to be scalable and robust to stress tests. Next steps include the evolution of the Mining Minds Context Ontology in order to include more recognizable high-level contexts, and to perform an evaluation of the Mining Minds High-Level Context Architecture with users.

Acknowledgments. This work was supported by the Industrial Core Technology Development Program, funded by the Korean Ministry of Trade, Industry and Energy (MOTIE), under grant number #10049079. This work was also supported by the Junta de Andalucia Project P12-TIC-2082.

References

1. O. Banos, M. Bilal-Amin, W. Ali-Khan, M. Afzel, M. Ahmad, M. Ali, T. Ali, R. Ali, M. Bilal, M. Han, J. Hussain, M. Hussain, S. Hussain, T. H. Hur, J. H. Bang, T. Huynh-The, M. Idris, D. W. Kang, S. B. Park, M. Siddiqui, L.-B. Vui, M. Fahim, A.-M. Khattak, B.-H. Kang, and S. Lee. An innovative platform for person-centric health and wellness support. In *Proceedings of the International Work-Conference on Bioinformatics and Biomedical Engineering*, 2015.
2. O. Banos, M. Bilal-Amin, W. Ali-Khan, M. Afzel, T. Ali, B.-H. Kang, and S. Lee. The mining minds platform: a novel person-centered digital health and wellness framework. In *Proceedings of the 9th International Conference on Pervasive Computing Technologies for Healthcare*, 2015.
3. O. Banos, M. Damas, H. Pomares, A. Prieto, and I. Rojas. Daily living activity recognition based on statistical feature quality group selection. *Expert Systems with Applications*, 39(9):8013–8021, 2012.
4. D. Datcu and L. Rothkrantz. Semantic audio-visual data fusion for automatic emotion recognition. *Emotion Recognition: A Pattern Analysis Approach*, pages 411–435, 2014.
5. Jawbone Up. Available online: https://jawbone.com/up (accessed on 30 Nov 2015).
6. L. Liao, D. Fox, and H. Kautz. Extracting places and activities from gps traces using hierarchical conditional random fields. *The International Journal of Robotics Research*, 26(1):119–134, 2007.
7. Q. Lin, D. Zhang, X. Huang, H. Ni, and X. Zhou. Detecting wandering behavior based on gps traces for elders with dementia. In *12th International Conference on Control Automation Robotics & Vision*, pages 672–677. IEEE, 2012.
8. A. Mannini, S. S. Intille, M. Rosenberger, A. M. Sabatini, and W. Haskell. Activity recognition using a single accelerometer placed at the wrist or ankle. *Medicine and Science in Sports and Exercise*, 45(11):2193–2203, 2013.
9. Misfit Shine. Available online: http://www.misfitwearables.com/products/shine (accessed on 30 Nov 2015).

10. P. Ribeiro and J. Santos-Victor. Human activity recognition from video: modeling, feature selection and classification architecture. In *Proceedings of International Workshop on Human Activity Recognition and Modelling*, pages 61–78. Citeseer, 2005.
11. C. Villalonga, O. Banos, W. Ali Khan, T. Ali, M. A. Razzaq, S. Lee, H. Pomares, and I. Rojas. High-level context inference for human behavior identification. In *International Work-conference on Ambient Assisted Living an Active Ageing (IWAAL 2015)*. Springer International Publishing, 2015.