SWH 2019 Keynote
Semantic AI for Healthcare: The HORUS.AI platform

Mauro Dragoni

Fondazione Bruno Kessler, Trento, Italy
dragoni@fbk.eu

1 Background

Automatically monitoring and supporting healthy lifestyle is a recent research trend, fostered by the availability of low-cost monitoring devices, and it can significantly contribute to the prevention of chronic diseases deriving from incorrect diet and lack of physical activity.

Chronic diseases, such as heart disease, cancer, and diabetes, are responsible for approximately 70% of deaths among Europe and U.S. each year and they account for about 75% of the health spending[1],[2]. Such chronic diseases can be largely preventable by eating healthy, exercising regularly, avoiding (tobacco) smoking, and receiving preventive services. Prevention at every stage of life would help people stay healthy, avoid or delay the onset of diseases, and keep diseases they already have from becoming worse or debilitating; it would also help people lead productive lives and, at the end, reduce the costs of public health.

In the last decades, health care systems in many countries have invested substantial effort in informing people about the benefits of adopting healthy behaviors in their lives [1]. Given the increasing popularity of mobile and personalized applications and devices (e.g., smart watches), a natural follow up of this effort is the development of platforms capable of providing user tailored advices, motivating people to adopt healthy behaviors. Although Internet-based and mobile technologies allow to collect data from personal devices, off-the-shelf wearable sensors, and external sources, exploiting these data to generate effective personalized recommendations and to engage people in developing and maintaining healthier patterns of living, is a challenging task. To carry out this task, a system providing personalized support for a healthy lifestyle has to take into account and reason on a considerable amount of knowledge from different domains (e.g. user attitudes, preferences and environmental conditions, etc.), in order to generate effective personalized recommendations, and to adapt the message in response to the environment and the user status.

However, engaging people in developing and maintaining healthier patterns of living is a challenging task as well. To this end, generating effective personalized recom-

[1] http://www.who.int/nmh/publications/ncd_report_full_en.pdf

[2] https://www.cdc.gov/media/releases/2014/p0501-preventable-deaths.html

mendations implies, for example, the justification of given suggestions and the adaptation of messages in response to the modification of the environment and of the user status. For this reason, as opposed to hardwired persuasive features, systems that applies general reasoning capabilities to provide flexible persuasive communication based on rich and diverse linguistic outputs are required. In this context, modeling persuasion mechanisms and performing flexible and context-dependent persuasive actions is more ambitious than most current approaches on persuasive technologies (see *Captology* [2]).

2 Content

Explainable Artificial Intelligence (XAI) aims at explaining the algorithmic decisions of AI solutions with non-technical terms in order to make these decision trusted and easily understandable by humans [3]. This is of great interest for both Machine Learning methods and symbolic reasoning in rule engines. The explanation of a reasoning process can be very difficult, especially when a system is based on a set of complex logical axioms whose logical inferences are performed with, for example, tableau algorithms [4]. Indeed, inconsistencies in logical axioms may be not well understood by users if the system limits to just report the violated axioms. Indeed, users are generally skilled to understand neither formal languages nor the behavior of a whole system. This is crucial for some applications, such as a power plant system where a warning message to the user must be clear and concise to avoid catastrophic consequences.

In this keynote I introduced the problem of adopting XAI systems within the healthcare domain and I discussed which are the main challenges that we need to address for design an effective, efficient, and reliable XAI approach that can be accepted within the healthcare domain. Then, I presented the XAI platform we realized, called HORUS.AI [5]: a system based on logical reasoning that supports the monitoring of users' behaviors and persuades them to follow healthy lifestyles [3].

The HORUS.AI platform is an AI-based system built upon the integration of semantic web technologies and persuasive techniques for motivating people to adopt healthy lifestyle or for supporting them to cope with the self-management of chronic diseases. The system collects data from users' devices, explicit users' inputs, or from the external environment (e.g. facts of the world) and interacts with users by using a goal-based metaphor. Interactive dialogues are used for proposing set of challenges to users that, through a mobile application, are able to provide the required information and to receive contextual motivational messages helping them to achieve the proposed goals.

HORUS.AI is constituted by two main layers: the Knowledge and the Dialog-Based Persuasive layers. The Knowledge Layer contains the knowledge bases modeling the specific domains for which users are monitored (e.g. diet), the rules provided by domain-experts, and the RDF-based reasoner that combines the modeled knowledge with the users' generated data. The concepts and rules of healthy behaviors are formalized as a TBox of the HeLiS ontology [6]. The axioms in HeLiS encode the Mediterranean diet rules that can be associated with user profiles. The user data about

[3] This work is compliant with good research practice standards. More details at:
http://ec.europa.eu/research/participants/data/ref/fp7/89888/ethics-for-researchers_en.pdf
http://www.who.int/medicines/areas/quality_safety/safety_efficacy/gcp1.pdf

her/his dietary behavior are acquired through a user's dietary diary with the help of a smartphone application. This information populates the HeLiS ABox with logical individuals. The reasoner combines knowledge and user's data (TBox and ABox) to infer the user behavior and generates inconsistencies if the user does not follow the rules of a healthy lifestyle. The results produced by reasoning operations are coded into motivational strategies and messages by the Dialog-based Persuasive Layer.

The Dialog-based Persuasive Layer creates and manages dialogues and generates motivational messages based on the information provided by the Knowledge Layer and learned from previous users' behavior. Once an inconsistency, i.e., an unhealthy user behavior, is detected the system shows the user a natural language message explaining the wrong behavior and its consequences. This translation from a logic language to plain text comprehensible by humans leverages a computational persuasion framework [7] and Natural Language Generation techniques [8]. The latter exploit dynamic and smart templates able to adapt to every persuasion strategy. This way, messages are tailored to specific users.

These two layers are supported by an Input/Output Layer exploited for directly communicating with users (i.e. dedicated mobile application or social media channels) by providing summaries of the acquired data, the chat containing the interactions between the users and the system, and graphical items showing the users statuses with respect to their goals. HORUS.AI has been validated within the context of different territorial labs and projects and the observed results demonstrated the suitability of HORUS.AI in real-world scenarios. In particular, I reported the validation we performed within a pilot project (named *Key To Health*) run into Fondazione Bruno Kessler where a mobile application linked to the HORUS.AI platform has been used by a group of 120 users for 49 days.

References

1. Intille, S.S.: Ubiquitous Computing Technology for Just-in-Time Motivation of Behavior Change. In: Proceedings of UbiHealth 2003: The 2nd International Workshop on Ubiquitous Computing for Pervasive Healthcare Applications. (2003)
2. Fogg, B.J.: Persuasive Technology: Using Computers to Change What We Think and Do. Morgan Kaufmann Publishers (2002)
3. Adadi, A., Berrada, M.: Peeking inside the black-box: A survey on explainable artificial intelligence (XAI). IEEE Access **6** (2018) 52138–52160
4. Baader, F., Horrocks, I., Sattler, U.: Description logics. In: Handbook of Knowledge Representation. Volume 3 of Foundations of Artificial Intelligence. Elsevier (2008) 135–179
5. Dragoni, M., Bailoni, T., Maimone, R., Marchesoni, M., Eccher, C.: HORUS.AI - A knowledge-based solution supporting health persuasive self-monitoring. In van Erp, M., Atre, M., López, V., Srinivas, K., Fortuna, C., eds.: Proceedings of the ISWC 2018 Posters & Demonstrations, Industry and Blue Sky Ideas Tracks co-located with 17th International Semantic Web Conference (ISWC 2018), Monterey, USA, October 8th - to - 12th, 2018. Volume 2180 of CEUR Workshop Proceedings., CEUR-WS.org (2018)
6. Dragoni, M., Bailoni, T., Maimone, R., Eccher, C.: Helis: An ontology for supporting healthy lifestyles. In: International Semantic Web Conference (2). Volume 11137 of Lecture Notes in Computer Science., Springer (2018) 53–69

7. op den Akker, H., Cabrita, M., op den Akker, R., Jones, V.M., Hermens, H.: Tailored motivational message generation: A model and practical framework for real-time physical activity coaching. Journal of Biomedical Informatics **55** (2015) 104–115
8. Gatt, A., Krahmer, E.: Survey of the state of the art in natural language generation: Core tasks, applications and evaluation. J. Artif. Intell. Res. **61** (2018) 65–170