Automatic Mapping of Motivational Text Messages into Ontological Entities for Smart Coaching Applications

Claudia Villalonga[1(✉)], Harm op den Akker[2], Hermie Hermens[2,3], Luis Javier Herrera[1], Hector Pomares[1], Ignacio Rojas[1], Olga Valenzuela[4], and Oresti Banos[3]

[1] Research Center for Information and Communications Technologies, University of Granada, Granada, Spain
{cvillalonga,jherrera,hector,irojas}@ugr.es
[2] Roessingh Research and Development, Telemedicine Group, Enschede, The Netherlands
{H.opdenAkker,h.hermens}@rrd.nl
[3] Center for Telematics and Information Technology, University of Twente, Telemedicine Group, Enschede, The Netherlands
{h.j.hermens,o.banoslegran}@utwente.nl
[4] Department of Applied Mathematics, University of Granada, Granada, Spain
olgavc@ugr.es

Abstract. Unwholesome lifestyles can reduce lifespan by several years or even decades. Therefore, raising awareness and promoting healthier behaviors prove essential to revert this dramatic panorama. Virtual coaching systems are at the forefront of digital solutions to educate people and procure a more effective health self-management. Despite their increasing popularity, virtual coaching systems are still regarded as entertainment applications with an arguable efficacy for changing behaviors, since messages can be perceived to be boring, unpersonalized and can become repetitive over time. In fact, messages tend to be quite general, repetitive and rarely tailored to the specific needs, preferences and conditions of each user. In the light of these limitations, this work aims at help building a new generation of methods for automatically generating user-tailored motivational messages. While the creation of messages is addressed in a previous work, in this paper the authors rather present a method to automatically extract the semantics of motivational messages and to create the ontological representation of these messages. The method uses first natural language processing to perform a linguistic analysis of the message. The extracted information is then mapped to the concepts of the motivational messages ontology. The proposed method could boost the quantity and diversity of messages by automatically mining and parsing existing messages from the internet or other digitised sources, which can be later tailored according to the specific needs and particularities of each user.

Keywords: Ontology · Natural language processing · Motivational messages · Smart coaching

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1 Introduction

Daily life in modern industrialized societies is characterized by high rates of sedentary behavior, and a general lack of everyday physical activity. As a result, people living in developed nations face serious health challenges related to sedentary lifestyles and diseases arising from the lack of activity thereof [14]. This worrisome situation makes it crucial to find new ways to improve health so that people can live longer and age well. While research has traditionally focused on biomedical science and advances in clinical practices, recent efforts have made significant strides in finding novel ways to promote behavioral changes to improve health outcomes. In fact, avoiding unhealthy habits is currently a major epidemiological priority. To achieve this goal, innovative approaches that automatically and autonomously coach people in healthier behaviors are essential in leading to lasting, beneficial behavioral changes.

All people around the globe, from children to older adults, are or will be in need of health coaching solutions at some point in their lives. Virtual coaching solutions are therefore called upon to possibly be the only means to cope with such an enormous group of target users. As a matter of fact, virtual coaching is no longer a sci-fi concept and its use is increasing over time [5,13,19,23]. However, the effectiveness of these systems while changing and promoting healthier behaviours is at stake. One main limiting factor has to do with the frequent use of generic and impersonal motivational messages [17], which hardly hold in people's mind. In order to increase the effectiveness of these messages more personalized strategies are required [4,10].

Creating tailored motivational messages for coaching is difficult, costly and time consuming. Dedicated experts, such as the ones providing health counseling services, have to normally elaborate custom-made recommendations based on each individual characteristics, preferences and behaviors. In order to automate this process systems need to fully comprehend the content of existing motivational messages, available from the internet or other digitized sources, which can be later tailored according to the specific needs and particularities of each user. This understanding of messages may be achieved through the use of ontologies, which are semantic models enabling the automatic interpretation of the information encapsulated in the motivational messages.

The two main challenges for the automatic generation of tailored messages are: (1) using the semantics of existing messages to create new tailored messages and (2) automatically extracting the semantics of existing messages. The first challenge is addressed by the authors in an earlier work [20]. Therefore, this paper focuses on the latter challenge and presents a new method to automatically extract the semantics of motivational messages and to create the ontological representation of the messages. The method uses natural language processing to perform a linguistic analysis of the message. The extracted information is mapped to the concepts of the motivational messages ontology.

2 State of the Art

The generation of personalized advisory messages can be supported by the use of ontologies. In fact, there exist some solutions using ontologies for the creation of motivational messages. For example, an ontology-based method is defined as part of an eHealth service to produce customized recommendations [9]. The main message components and their structure are modeled in the proposed ontology which also describes the user general information, their abilities, interests and preferences. Furthermore, ontologies have also been used in the physical activity domain to model multimodal contexts [21] and to generate dynamic feedback. The appropriate feedback is derived from the ontology in [24] by pruning irrelevant branches based on context information. Predefined feedback messages, which could be delivered to the user, are modeled in this ontology. The selection process is adapted by deriving the probabilities about user preferences for certain message types. Finally, an ontology modeling the messages intention is used in [4], a practical framework for the automatic generation of real-time tailored messages in behavior change applications.

Ontologies have already been used to model motivational messages. However, these models only describe the structure of the message and its intention but not its actual content. Modeling the message content is quite important for the automatic selection of the most suitable messages to be delivered by the smart coach. In our previous work [20], we have proposed an ontological approach to comprehensively model motivational messages used by smart coaches in the domain of physical activity. The ontology describes the main characteristics of motivational messages, including the message metadata such as its length, type or composition but also information about the message content, e.g. place or object required to perform the recommended action. Apart from the ontology, our previous work describes the ontological querying method used by the smart coach to retrieve the most adequate message depending on the user's status, preferences and context.

Ontology learning has been used in many works to extract semantic information from unstructured data like text and semi-structured data like XML. For example, in [12] the authors make a comprehensive review of the available techniques for ontology learning from semi-structured and unstructured data and in [25] the authors focus on ontology learning from text. In the state-of-the-art research, natural language processing techniques are used in combination with statistical analysis or machine learning techniques to identify the grammar dependencies and to parse the discovered relation between syntactic entities in the text. Furthermore, ontology learning is not only a field of theoretical research, but several tools to perform ontology learning based on natural language processing techniques have been made available online; for example, Text2Onto [7], OntoLT [6], OntoLern [16] or Flax Clade PoC [2]. The main problem of using these available tools to extract the semantics of motivational text messages and to create the ontological representation of these messages is that they require long texts in order to apply the statistical analysis. Therefore, these tools are not suitable for detecting information out of short motivational messages which contain limited information. As such, a new method based on natural language processing has been developed.

3 Method

A method to automatically extract the semantics of motivational text messages and to create the ontological representation of these messages is here presented. The input to this method are plain text motivational messages created by a domain expert or retrieved from the internet or any other available digitized source. The output of this method is the ontological representation of the motivational messages, which could be used by smart coaches for translating behavioral findings into realizable actions.

The proposed method is composed of four different steps: (1) linguistic analysis of the text message using natural language processing techniques, (2) generation of the ontological representation of the message, (3) creation of new messages based on splitting complex messages, and (4) creation of new messages based on the knowledge modeled in the ontology.

3.1 Linguistic Analysis of the Message

The motivational messages are analyzed using natural language processing techniques in order to identify the content of the text message. The most important information that needs to be extracted from the motivational messages for physical activity coaching is the action described in the text messages, the location and the time in which this action takes place and the elements which might be required for the action to be executed.

The grammatical structure of the sentence is detected using a probabilistic natural language parser, which uses the knowledge gained from hand-parsed sentences to automatically parse any new sentences. This parser groups words that go together in phrases and detects which words are the verb, the subject or the object of the sentence. Furthermore, the parser provides the grammatical relations among words and the structure of the phrases in a tree representation. Detecting the predicate of the sentence is helpful in the recognition of the action that is recommended in the motivational message. The direct object that accompanies the verb is also part of the description of the action as it is an element required for the action to be executed. The temporal modifier of the predicate specifies a time; thus, it determines the time in which the action described in the motivational message takes place. The place modifier of the predicate specifies a the location in which the action described in the motivational message takes place.

In the linguistic analysis, not only is the grammatical structure of the sentence detected but also the part of speech. Using a log-linear part-of-speech tagger, each word in the sentence is assigned a tag about the part of speech to which it belongs, e.g., noun, verb or adjective. Part-of-speech information can be relevant to identify the main word of a phrase that has been recognized using the probabilistic natural language parser. For example, in case a direct object has three words, the part of speech analysis allows to determine that the word which is a noun is the head of the phrase.

Finally, recognizing the named entities in a sentence is also an essential part of the linguistic analysis. Using a linear chain conditional random field sequence model, it is possible to label the words in the sentence which are names of things, such as person, location, date and time. Identifying the named entities of the type location allows to determine where the action in the motivational message takes place. Similarly, the named entities of the type time indicate when the action in the motivational message takes place.

3.2 Generation of the Ontological Representation

The message, which has been linguistically analyzed in the previous step, is mapped into the concepts of the motivational messages ontology presented in [20]. This ontology describes several aspects of the motivational messages, such as its intention, its components and its content. Therefore, it defines classes like *Message*, *MessageComponent*, *Action*, *Time*, *Place* or *Element*. For more information about the ontology and how it has been designed please refer to [20].

An instance of the class *Message* is created to model the semantics of the motivational message. For each sentence in the message a new instance of the class *MessageComponent* is created. These instances of the class *MessageComponent* are linked via the property *hasComponent* to the instance of the class *Message*, i.e. to the actual message from which they are part. Once the structure of the message has been created, the actual content of the message is modeled. First, the plain text of the sentence is asserted as the value of the data property *hasContent* for the instance of the class *MessageComponent*. The main verb of the sentence and head of the predicate, detected by analyzing the grammatical structure of the sentence and the part of speech, is used as the action presented in the message. Therefore, it is mapped into the corresponding instance of the class *Action* and linked to the instance of the class *MessageComponent* via the property *hasAction*. Furthermore, if there are coordinated verbs to the main verb, these verbs are also mapped into the corresponding instance of the class *Action* and also linked to the instance of the class *MessageComponent*.

Apart from the action itself, the message contains some other information that further describes the action. The time in which the action takes place, identified as a temporal modifier of the predicate or as a named entity of type time, is assigned the corresponding instance of the class *Time* and linked to the instance of the class *MessageComponent* via the property *hasTime*. The place where the actions occurs, identified as a place modifier of the predicate or as a named entity of type location, is mapped into the corresponding instance of the class *Place* and linked to the instance of the class *MessageComponent* via the property *hasPlace*. The noun which is the head of the direct object of the sentence is mapped into the element required to perform the action. Thus, this object is mapped into the corresponding instance of the class *Element* and linked to the instance of the class *MessageComponent* via the property *hasRequiredElement*.

If there are coordinated nouns to the head of the direct object, these nouns are also mapped into the corresponding instance of the class *Element* and also linked to the instance of the class *MessageComponent*. Finally, in case the action presented in the message is negated, this is represented in the ontology as asserting to true the value of the data property *hasNegatedAction*.

3.3 Creation of New Messages Based on Splitting Complex Messages

The splitting method automatically creates simpler messages out of complex ones; thus, increasing the variety of motivational messages available for the virtual coaches. A motivational message which contains multiple different concepts is split into several messages which contain a single concept. In fact, the splitting method could be applied in different scenarios, for example, when multiple coordinated verbs conform the predicate of the sentence or when a direct object is composed of several coordinated nouns.

In case the predicate of the sentence contains several verbs joined via a coordinating conjunction, i.e., the message component describes several actions combined via a conjunction such us "and", "or" or "but", the message is split into as many messages as the number of verbs in the original message, and each newly created message only contains a single action. Therefore, a new instance of the class *Message* is created for each of the split messages and a new instance of the class *MessageComponent* is associated to it. Then, each action, which is already mapped into the instance of the class *Action*, is linked to the corresponding instance of the class *MessageComponent* via the property *hasAction*.

In case the direct object of the sentence is composed of several nouns linked via a coordinating conjunction, i.e., the message has a single action but several elements in the direct object, the message is split into as many messages as the number of nouns in the original direct object, and each newly created message contains an action with a single element in the direct object. Therefore, a new instance of the class *Message* is created for each of the split messages and a new instance of the class *MessageComponent* is associated to it. Then, the action mapped into the instance of the class *Action* is linked via the property *hasAction* to all the instances of the class *MessageComponent*. Finally, each element of the direct object, which is mapped to the instance of the class *Element*, is linked to the corresponding instance of the class *MessageComponent* via the property *hasRequieredElement*.

3.4 Creation of New Messages Based on the Knowledge Modeled in the Ontology

New messages can be derived from existing ones using the motivational messages ontology [20]. The domain knowledge modeled in the ontology, which describes the time and the location where the actions take place, is vital to derive new messages and make them more diverse. For example, the information about the multiple locations in which an action can take place is used to determine alternatives locations for the same action. Therefore, a motivational message which recommends an action that takes place in a given location could be cloned and generate a new message which proposes the execution of the same action but in another alternative location. In the proposed method, a new instance of the class *Message* is created for each of the possible alternative locations and a new instance of the class *MessageComponent* is associated to it. Then, the action in the original sentence, which is mapped into the instance of the class *Action*, is linked via the property *hasAction* to all the instances of the class *MessageComponent*. Finally, for each of the possible locations, the actual instance of the class *Place* is linked to the corresponding instance of the class *MessageComponent* via the property *hasPlace*.

4 Implementation

The presented method to automatically extract the semantics of motivational text messages and to create the ontological representation of these messages has been implemented in Java. Several existing open source tools and APIs have been utilized to facilitate the development of this method. The linguistic analysis of the text message is implemented using Stanford CoreNLP [15], a set of open source tools for natural language processing. The generation of the ontological representation is developed using Apache Jena (v2.11.2) [1], a semantic web framework which includes some APIs for handling RDF [8], OWL [22], and SPARQL [11].

For the linguistic analysis of the motivational messages, the parser provided by the Stanford CoreNLP software is configured to annotate the text in several different ways: obtaining the tokens, splitting the different sentences, recognizing the part of speech, identifying the lemma for each word, recognizing the named entities, and detecting the grammatical structure of the sentence. The parser generates a semantic graph which contains the grammatical relations between the phrases in the sentence, the part-of-speech tags (POS tags) for each word and the lemmas associated to these words. Furthermore, the parser also provides the list of named entity tags (NER tags) for each word in the sentence.

Once the motivational message has been linguistically analyzed, the relevant information is extracted and mapped into the concepts of the motivational message ontology; thus, creating the ontological representation of the message. First, the element identified as "ROOT" of the semantic graph and which has a POS tag named "VB" (verb) is mapped into the member of the class *Action* which has as name the lemma of the element. If the "ROOT" has some relation of type "cc" (coordination) and a relation of type "conj" (conjunct) to an element which has a POS tag named "VB", then this element, which is a coordinated verb, is mapped into the member of the class *Action* which has as name the lemma of the element. In case any of the verbs were phrasal verbs, they would have a grammatical relation of type "prt" (phrasal verb particle) to the particle. Thus, this element would also be taken into consideration and the actual verb plus the particle would be mapped into the ontology. All the mapped instances of the class *Action* are linked to the instance of the class *MessageComponent* via the property *hasAction*. Moreover, if the "ROOT" has a relation of type "neg" (negation modifier), i.e., the verb is negated in the sentence, the property *hasNegatedAction* for the member of the class *MessageComponent* is asserted to take the value *xsd:true* which is a datatype of the W3C XML Schema Definition Language (XSD) [18].

Apart from mapping the action itself, the element required to perform an action is also mapped into the ontology. In case the "ROOT" of the semantic graph having a POS tag named "VB" has also a grammatical relation of type "dobj" (direct object) to an element which has a POS tag named "NN" (noun singular), "NNS" (noun plural), "NNP" (proper noun singular) or "NNPS" (proper noun plural), then this element is mapped into the member of the class *Element* which has as name the lemma of the element. Moreover, if this element has some relation of type "cc" (coordination) and a relation of type "conj" (conjunct) to an element which has a POS tag named "NN", "NNS", "NNP" or "NNPS", then this element, which is a coordinated direct object, is mapped into the member of the class *Element* which has as name the lemma of the element. All the mapped instances of the class *Element* are linked to the instance of the class *MessageComponent* via the property *hasRequiredElement*.

Finally, the other elements of the message which further describe the action are also mapped into the ontology. If the list of named entity tags contains a NER tag named "TIME", then the element which has been assigned this tag represents the time in which the action takes place and it is mapped into the member of the class *Time* which has as name the lemma of the element. Similarly, if the list of named entity tags contains a NER tag named "PLACE", then the element which has been assigned this tag represents the location in which the action takes place and it is mapped into the member of the class *Place* which has as name the lemma of the element.

5 Use Case

The functioning of the proposed method is here described via a use case. Let us consider that a domain expert has created the following motivational message "You should walk the dog to the park early in the morning". Then the method is applied and its outcome is presented in Fig. 1.

In the first step the linguistic analysis of the message is performed. The grammatical relations among words can be observed in the first block of text in Fig. 1. For example "dobj(walk/VB-3, dog/NN-5)" indicates that the noun "dog" is the direct object of the verb "walk".

In the second step the ontological representation of the message is created. The relevant information obtained in the linguistic analysis is identified to create the ontological representation. Therefore, the instance *m_01* of the class *Message* and the instance *mc_01* of the class *MessageComponent* are created, and *m_01* is linked to *mc_01* via the property *hasComponent*. The action walking, which is the element identified as "ROOT" of the semantic graph and which has a POS

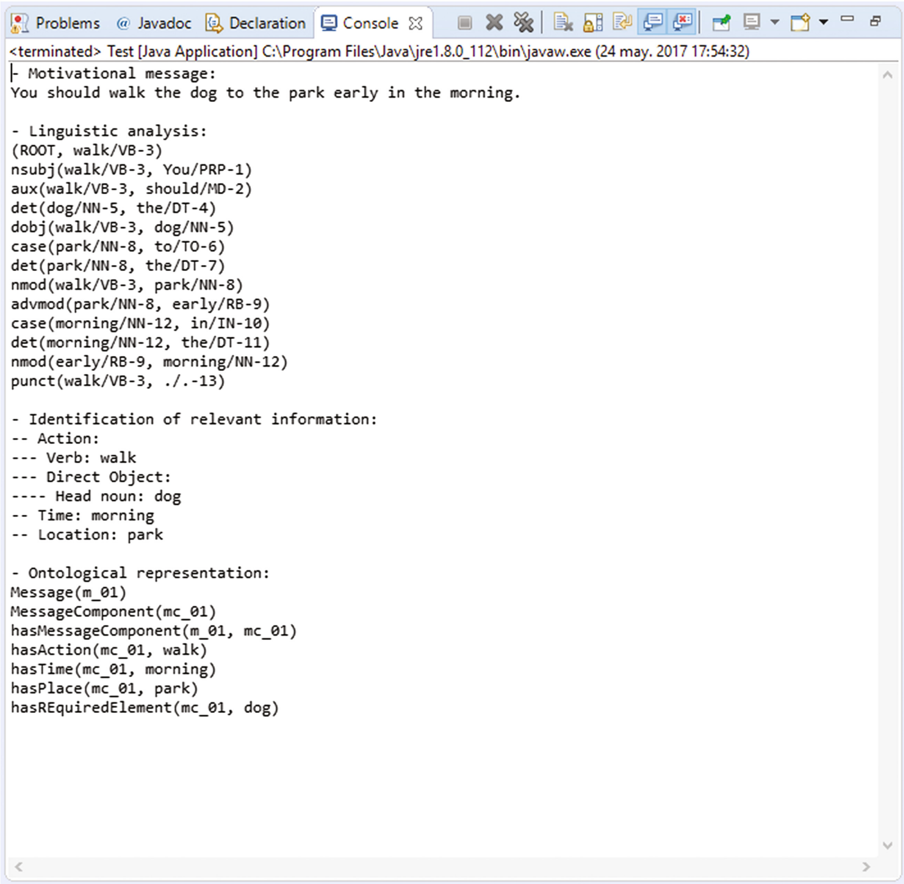

Fig. 1. Outcome of applying the method to automatically extract the semantics of the motivational message "You should walk the dog to the park early in the morning" and to create the ontological representation of this message.

tag named "VB", specifically "walk/VB-3", is mapped into the individual *walk* which is a member of the class *Action* and linked to the individual *mc_01* via the property *hasAction*. Moreover, the element "walk/VB-3" has a grammatical relation of type "dobj" to the element "dog/NN-5". Therefore, this element is mapped into the individual *dog* which is a member of the class *Animal*, a subclass of the class *Element*, and linked to the individual *mc_01* via the property *hasRequiredElement*. Finally, the time and place which further describe the action are also mapped into the ontology. The list of named entity tags contains a NER tag named "TIME" for the element "morning/NN-12"; thus, this element is mapped into the individual *morning* of the class *Time* and linked to the individual *mc_01* via the property *hasTime*. The list of named entity tags also contains a NER tag named "PLACE" for the element "park/NN-8"; thus, this element is mapped into the individual *park* of the class *Place* and linked to the individual *mc_01* via the property *hasPlace*. The resulting ontological representation of the motivational message can be observed in the last block of text in Fig. 1. Furthermore, a graphical representation of the message component *mc_01*, obtained using the open source ontology editor Protégé [3], is shown in Fig. 2.

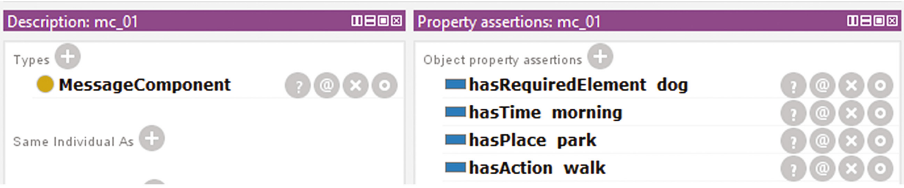

Fig. 2. Instance of the message component *mc_01* which has been created to capture the semantics of the motivational message "You should walk the dog to the park early in the morning".

The third and the forth step of the method, i.e., the creation of new messages based on splitting complex messages or based on the knowledge modeled in the ontology, do not produce any output for the message "You should walk the dog to the park early in the morning" since this message describes a single action and there is no domain knowledge in the ontology regarding the locations of this action.

6 Conclusions

This paper has presented a new approach for automatically extracting the semantics of motivational messages and creating the ontological representation of these messages. The method builds on natural language processing techniques to elaborate a linguistic analysis of the message body. The extracted information is then mapped to the concepts defined in the ontology of motivational messages. Some uses cases have been further presented in order to showcase the end-to-end process and its main outcomes.

The proposed method is intended to serve as a cornerstone element in the automatic generation of tailored coaching messages. In fact, the method is expected to significantly increase the quantity and diversity of messages by automatically mining and parsing existing messages from the internet or other digitized sources, which can be later personalized to each user needs and characteristics. This method allows domain experts, i.e. coaching experts, to simply add their coaching message suggestions to the database, while not having to be concerned with the technical underlying concepts of the coaching system. Automatically extracted relevant concepts can be used by an automated system to provide tailoring through simple filtering methods or mapping of user characteristics with the ontology domain concepts. Future work aims at contrasting this hypothesis and also testing a virtual coaching system building on this concept in the wild and for large cohort of people.

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