

OTTHO: An Artificial Player for a Complex Language Game

Giovanni Semeraro, Pasquale Lops, Marco de Gemmis, and Pierpaolo Basile

Dept. of Computer Science - University of Bari
Via E. Orabona, 4 - 70125 Bari - Italia
{semeraro,lops,degemmis,basilepp}@di.uniba.it

Abstract. This paper describes OTTHO (On the Tip of my THOught), an artificial player able to solve a very popular language game, called “The Guillotine”, broadcast by the Italian National TV company. The game demands knowledge covering a broad range of topics, such as politics, literature, history, proverbs, and popular culture. The rule of the game is simple: the player observes five words, generally unrelated to each other, and in one minute she has to provide a sixth word, semantically connected to the others. In order to find the solution, a human being has to perform a complex memory retrieval task within the facts retained in her own knowledge, concerning the meanings of thousands of words and their contextual relations. In order to make this task executable by machines, machine reading techniques are exploited for knowledge extraction from the web, while Artificial Intelligence techniques are used to infer new knowledge, in the form of keywords, from the extracted information.

1 Background and Motivation

The literature classifies games related to the language in two main categories: *word games* and *language games* [5]. *Word games* do not involve true language, because word meanings are not important. An example of word game is *Scrabble*, in which players take turn placing letters in a grid to form words. *Language games*, such as crosswords or “Who wants to be a millionaire?”, strongly involve natural language, since word meanings play an important role. Language games draw their challenge and excitement from the richness and ambiguity of natural language, which is, on the other side, the main source of complexity for machines. OTTHO is a system designed to provide solutions for *The Guillotine* game, in which the player is given a set of five words (*clues*), each linked in some way to a specific word that represents the *unique* solution of the game. Words are unrelated to each other, but each of them is strongly related to the solution. Once the five clues are given, the player has *one minute* to guess the right answer. For example, given the clues *sin*, *newton*, *doctor*, *pie*, *new york*, the solution is *apple*, because in the popular Christian tradition the apple is the forbidden fruit in the Book of Genesis, that is the symbol of the original *sin*, *Newton* discovered the gravity by means of an apple, “an apple a day takes the *doctor* away” is a

proverb, the apple *pie* is a fruit cake, and *new york city* is called “the big apple”. Often the solution is not so intuitive and only players with a strong background knowledge are able to find the correct word. Indeed, in order to find the solution, a human being has to perform a complex *memory retrieval* task within the facts retained in her own knowledge, concerning the meanings of thousands of words and their contextual relations [9].

No fixed sets of rules are sufficient to define the game play, thus solving the game depends exclusively on the background knowledge of the system, which is created by *machine reading* techniques. They analyze *unstructured* information stored in open knowledge sources on the Web, such as dictionaries and Wikipedia, and build a memory of linguistic competencies and world facts that can be effectively exploited by the system for a deeper understanding of clues. Relatedness between terms, providing the evidence of a strong relationship between words, is the key factor for finding a set of candidate words that likely contains the solution. To this purpose, OTTHO exploits a reasoning mechanism based on Spreading Activation techniques [4, 3] which allows matching clues with the background knowledge. The main motivation for designing an artificial player for this game is the challenge of providing the machine with both the cultural and linguistic background knowledge which makes it similar to a human being, with the ability of interpreting natural language documents and reasoning on their content. Our feeling is that the approach presented in this work has a great potential for other more practical applications besides solving a language game, which are mentioned in the last section of the paper.

2 System Description

An extended knowledge base must be built for representing the *cultural* and *linguistic* background knowledge of the artificial player. After a deep analysis of the correlation between the clues and the solution, the following knowledge sources have been processed to build the memory of the system:

- **Encyclopedia** – the Italian version of Wikipedia;
- **Dictionary** – the De Mauro Paravia Italian on-line dictionary (no longer available);
- **Compound forms** – groups of words that often go together having a specific meaning, crawled from the IntraText Digital Library (<http://www.intratext.com/bsi/listapolirematiche/indalfa.htm>) and the on-line dictionary TLIO - Tesoro della Lingua Italiana delle Origini (<http://ovipc44.ovi.cnr.it/Tliopoli/>);
- **Proverbs and Aphorisms** – the Italian version of Wikiquote;
- **Movies** – descriptions of Italian movies crawled from the Internet Movie Database (<http://www.imdb.com/>);
- **Songs** – Italian songs crawled from OnlyLyrics (<http://www.onlylyrics.com/>);
- **Books** – book titles crawled from several web sites.

The above mentioned types of sources have different characteristics, therefore an important problem is to define a uniform representation of the information they store, which is discussed in the next section.

2.1 The Memory of the System: Cognitive Units

Formerly we modeled each source as a term-term matrix whose cells represent the degree of correlation between the term on the row and the one on the column, according to specific heuristics [8]. In the new version of the system, we adopt a novel strategy based on the ACT theory of fact memory [1], according to which information in long term memory of human beings is encoded as *Cognitive Units* (CUs) that form an interconnected network. A cognitive unit is a piece of information (e.g. a proposition) we can hold consciously in our focus of attention, together with all the links (many of which are unconscious) that can be established with other parts of our cognitive structure. According to this idea, we see knowledge sources as repositories of CUs.

Because of the heterogeneity of the knowledge sources involved in the process, two problems must be solved in the implementation of the step that turns knowledge sources into a unique *machine-readable* knowledge base, with concepts represented in a homogeneous format:

- identification of the basic unit representing a concept in each specific knowledge source (e.g. a Wikipedia article, a lemma in a dictionary);
- definition of a unique representation model for cognitive units in the background knowledge.

Since the information provided by the knowledge sources is represented in textual form, we regard a CU as the structured textual description of a concept. For each knowledge source included in the memory of OTTHO, the basic unit describing a concept is chosen: a *lemma* in the Dictionary, an *article* in Wikipedia, etc. Basic units are turned into CUs by machine reading techniques which analyze the text and build the corresponding descriptions of recognized concepts. Each CU is represented by two fields:

1. **head** – words identifying the concept represented by the CU;
2. **body** – words describing the concept.

In a more compact way:

CU = [head|body]

For example, the Wikipedia article that provides the description of the concept *Artificial Intelligence*¹ is turned into the corresponding CU and stored in a repository of cognitive units:

¹ http://en.wikipedia.org/wiki/Artificial_intelligence

```
CU_124 = [Artificial Intelligence (3.56) |AI (1.23),  
          machine (1.14), computer science (2.58),  
          Alan Turing (2.77)]
```

Keywords in CUs are assigned a weight representing how important they are for that concept, similar to the bag of words approach in Information Retrieval (IR). The main advantage of this representation strategy is that an IR model can be adopted for retrieving relevant CUs associated with a keyword. 743,192 CUs have been defined: 584,527 for the Encyclopedia, 126,741 for the Dictionary, 10,744 for Compound Forms, 11,257 for Proverbs and Aphorisms, and 9,923 for Songs, Movies and Books. The complete description of the machine reading process can be found in [7]. This kind of “knowledge infusion” into the system creates a memory of world facts and linguistic knowledge.

As depicted in Figure 1, *clues* are used to query the memory of OTTHO, i.e. the CU repository, in order to retrieve the most appropriate “pieces of knowledge” related to them. Both clues and retrieved CUs are then passed to the reasoning algorithm, which produces a *new* list of keywords associated with them, which are possible solutions of the game. The reasoning mechanism is described in the following section.

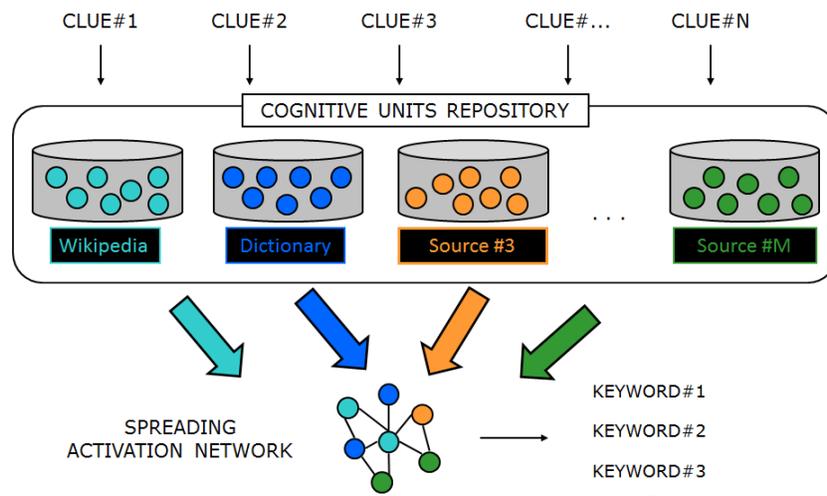


Fig. 1. Process for finding candidate solutions for a run of the game

2.2 The Brain of the System: Spreading Activation Network

Spreading activation has proved to be a model with a high degree of explanatory power in cognitive psychology [1]. One of the merits of this model is that it captures the way knowledge is represented as well as the way it is processed. In this model, knowledge is represented in terms of nodes and associative pathways between the nodes. Specifically, concepts are represented in memory as nodes, and relations between concepts as associative pathways between the corresponding nodes. When part of the memory network is activated, activation spreads along the associative pathways to related areas in memory. The spread of activation mechanism selects the areas of the memory network that are more ready to further cognitive processing.

Since words and their meanings are stored in the mind in a network-like structure [1], we adopted this model as the reasoning mechanism of OTTHO. In the network for The Guillotine game, called SAN - Spreading Activation Network, nodes represent either words or CUs, while links denote associations between them, obtained from CU repositories. Links are weighted with a score that measures the strength of the association.

The SAN for a run of the game is built in 3 steps: (1) nodes corresponding to clues are included in the SAN; (2) clues are connected to the most appropriate CUs retrieved by a search mechanism which queries the CU repositories by using clues; (3) retrieved CUs are connected to nodes representing the most informative terms associated with them. An example of SAN is depicted in Figure 2. All in all, the SAN is the part of the background knowledge of the system which is related to the clues of the game to be solved. The spreading process over the SAN starts from clue nodes and propagates first to CUs and then to words connected to CUs. In fact, it is a search process which selects, among all the nodes in the SAN, those which are strongly connected to clues, and therefore are good candidate solutions. Technical details about the spreading algorithm are reported in [7].

3 Into and Beyond the Game

Figure 2 shows the OTTHO user interface. In this scenario, the system supports the human player by showing, within the text area on the bottom-left, some candidate solutions for the clues visualized on the top-left of the window. A timer is displayed on the clues, near the OTTHO logo, which warns the player on time to provide the answer. The SAN is depicted on the right. The solution for this run is *letto (bed)*, which actually appears in the list of suggestions.

Figure 3 emphasizes the part of the SAN in which the solution is found. Notice that the solution is connected with the clue “galline” since the idiom “andare a *letto* con le *galline*” (“to go to bed with the chickens”, that means “very early”) was found in the CU repository. By clicking on the CU node of the idiom *a795* and then on the “information” button on the top of the SAN, the explanation for the solution is shown by OTTHO in the “polirematiche” box on the left.

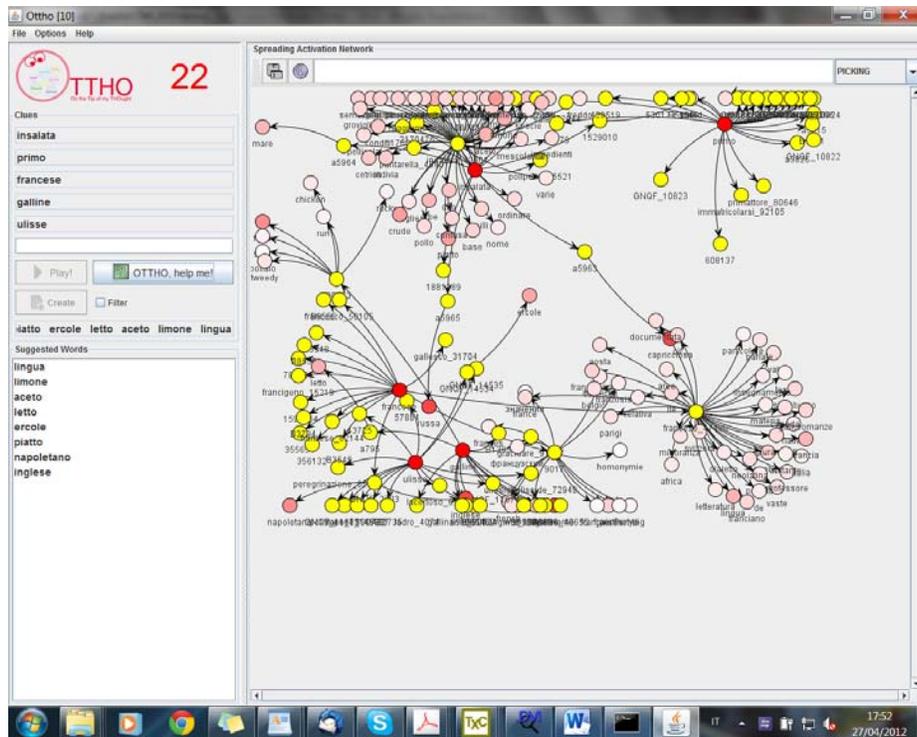


Fig. 2. A run of the game

The system, besides supporting the player, could also assist authors of the game for the verification of the uniqueness of the “official” solution. Indeed, the “create” button (on the left of the GUI) allows users to propose their own clues and to verify whether other words, in addition to the official answer, are consistent with the clues. In conclusion, the proposed system has a great potential for other practical applications both in the area of Information Retrieval and Information Filtering. For example, words suggested by OTTHO could be used by search engines for intelligent query expansion [2] or by content-based recommender systems for the computation of similarity between items [6].

References

1. Anderson, J.R.: A Spreading Activation Theory of Memory. *Journal of Verbal Learning and Verbal Behavior* 22, 261–295 (1983)
2. Carpineto, C., Romano, G.: A survey of automatic query expansion in information retrieval. *ACM Comput. Surv.* 44(1), 1 (2012)
3. Collins, A.M., Loftus, E.F.: A Spreading Activation Theory of Semantic Processing. *Psychological Review* 82(6), 407–428 (1975)

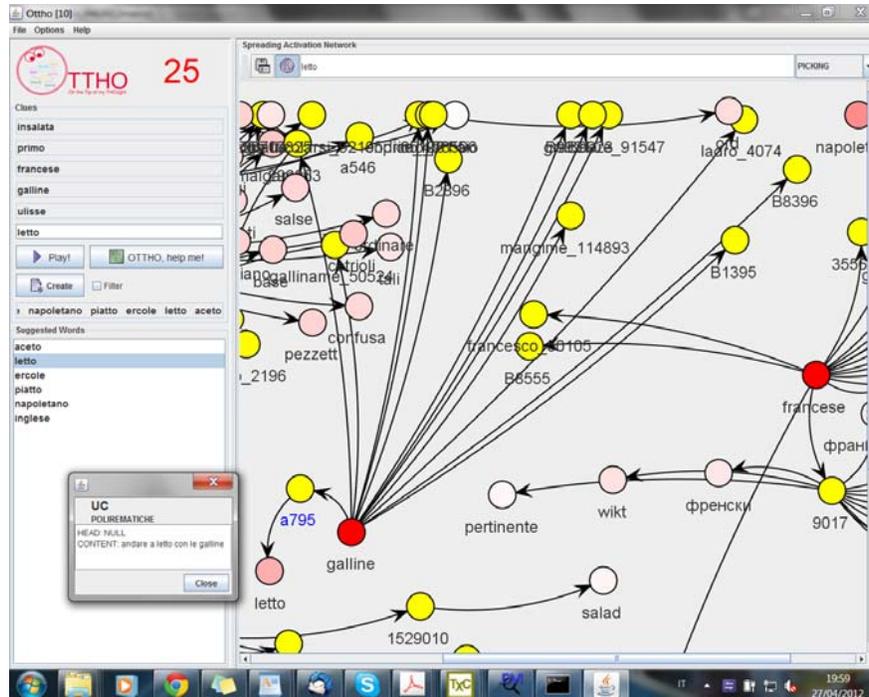


Fig. 3. Solution found in the SAN with explanation by OTTHO

4. Crestani, F.: Application of Spreading Activation Techniques in Information Retrieval. *Artificial Intelligence* 11(6), 453–482 (1997)
5. Littman, M.L.: Review: Computer language games. In: *Revised Papers from the Second International Conference on Computers and Games*. pp. 396–404. CG '00, Springer-Verlag, London, UK (2002)
6. Lops, P., de Gemmis, M., Semeraro, G.: Content-based Recommender Systems: State of the Art and Trends. In: *Recommender Systems Handbook*, pp. 73–105. Springer (2011)
7. Semeraro, G., de Gemmis, M., Lops, P., Basile, P.: Knowledge Infusion from Open Knowledge Sources: an Artificial Player for a Language Game. *IEEE Intelligent Systems* DOI: <http://doi.ieeecomputersociety.org/10.1109/MIS.2011.37>. In press
8. Semeraro, G., Lops, P., Basile, P., de Gemmis, M.: On the Tip of My Thought: Playing the Guillotine Game. In: *Proc. of the 21st Int. Joint Conference on Artificial Intelligence*. pp. 1543–1548. Morgan Kaufmann (2009)
9. Spitzer, M.: *The Mind within the Net: Models of Learning, Thinking, and Acting*. MIT Press (2000)