Expert Systems with Applications 36 (2009) 4810–4821

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Object-oriented knowledge framework for modelling human mastication of foods

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ARTICLE INFO

Keywords:
Object-oriented model
Knowledge based systems
Human mastication
Food properties

ABSTRACT

To model human mastication of foods, an object-oriented knowledge framework is developed that consists of three class objects, one for the physiology related to the mastication, one for the masticatory measurements, and the other for the factors affecting mastication. Each class object is structured in a hierarchy of sub-objects according to the domain or literature knowledge. The knowledge about the relationships among the attributes of objects is represented by IF–THEN rules. These rules can be discovered from the experimental database following the knowledge discovery in database. A case study is presented where a foods chewing database involving EMG mandibular movement measurements is used, two decision trees are discovered with respect to the type of rheological properties and hardness, and the rules derived are expressed in the context of the knowledge framework.

1. Introduction

Human mastication is a complex process regulated by a brain stem central pattern generator CPG (Dellow & Lund, 1971) to decompose and transport food for further digestion. The process of the mastication involves the reduction of the size of food particles and the incorporation of salvia to increase the cohesion of the bolus, which is to produce the bolus ready for safe swallowing (Peyron, Mishellany, & Woda, 2004; Prinz & Lucas, 1995). This process can be characterised by the measurements of masticatory physiology (Harker, Redgwell, Hallett, & Murray, 1997; Thexton, 1992), such as electromyography (EMG) for muscular activity of mastication, rhythmical mandibular movements for opening and closing, salivary secretion, etc. In addition, human mastication can be highly adapted to the individual and the food. These masticatory measurements are therefore affected by the factors pertaining to the individual (e.g., dental status, chewing side, age, or gender), the food (e.g., sample size, hardness or rheological behaviour) (Woda, Foster, Mishellany, & Peyron, 2006a), and the situational factors for experiment control (e.g., day-to-day variability, sample supply order, sample control, subject control, specified chewing side, specified chewing cycles, etc.) (Foster, Woda, & Peyron, 2006; Lassauzay, Peyron, Albuisson, Dransfield, & Woda, 2000; Peyron, Lassauzay, & Woda, 2002).

There has been considerable work in developing systematic methods for evaluating the capability of a person to effectively chew foods. One such effort is the formal description, in terms of object-oriented method, to structure the mastication process and define its contributing attributes (Xu et al., 2007). This paper continues this effort to establish a comprehensive knowledge framework for modelling the mastication process and discovering the relationships among the masticatory physiology, measurements and factors.

An object-oriented framework to organize the hierarchies of the mastication knowledge is proposed. The framework contains two types of knowledge representation: (1) classes of *objects,* whose slots of attributes characterise the masticatory physiology, measurements, and factors; and (2) *rules* among the slots of objects to substantiate their relationships. The inheritance links of these objects regulate the measurements and factors, making the foods mastication experiments more controlled and comparable. The object-oriented design, which is the first feature of the framework, is performed using domain knowledge and literatures initially. It is then populated by the knowledge of relationships among the measurements of the mastication and factors affecting the mastication, which is the second feature of the framework. The knowledge is represented by rules about the relationships among the slots (or attributes) of objects. These rules can be discovered from the experimental database following the knowledge discovery in database (KDD) (Han & Kamber, 2001).

The knowledge framework of three class objects, the mastication physiology, the masticatory measurements and the factors affecting mastication classes in this paper, is conceptualised firstly. Each class object is then described and organized according to the domain or literature knowledge. A case study is finally used to demonstrate how the knowledge is discovered in a dataset of real foods chewing experiments and how the discovered knowledge is populated into the framework.

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doi:10.1016/j.eswa.2008.05.045

2. Design of mastication knowledge framework

For the purpose of foods evaluations, the mastication is characterised by the physiology related to the mastication, the masticatory measurements describing the chewing behaviours, and the factors affecting the mastication. The factors affecting the mastication class is further classified into sub-classes: individual characters, food properties, and situational factors. These class objects of the mastication knowledge can be represented in a framework as illustrated in Fig. 1.

In the framework the objects are known as frames (Russell & Norvig, 1995) and the links as inheritance relationships in a tree like taxonomy (Lucas & Gaag, 1991). Each arrow line between two objects stands for the *IS-A* relationship (Brachman, 1983). The objects may contain slots symbolised in rectangle, but their values are empty initially and only substantiated when a chewing database is given.

Besides the inheritance, there are different relationships existing among the slots of objects. These relationships explicate the rules among the values of parameters of the mastication and the factors of affecting mastication, which are used for modelling human mastication. But these rules are available only when the slots are substantiated by values given in a chewing experiment database.

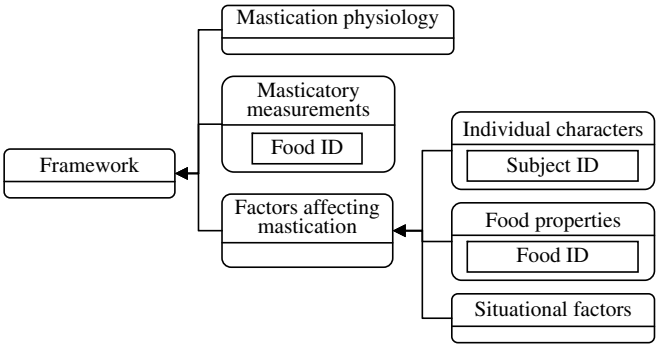

Fig. 1. Top class objects for the mastication knowledge framework.

3. Masticator physiology class

The physiology of human mastication (Lucas, 2004; Thexton, 1992; Tortora, 2005) provides the fundamental apparatus to implement a whole chewing process, which includes bone, muscle, nerve, secretion, etc for healthy adults. The maxilla (upper jaw) and mandible (lower jaw) form a basic structure of human oral cavity, and support the facial muscles and nerves. Temporomandibular joint (TMJ) connects mandible with maxilla to make the mandible moveable in all planes. The masticatory muscles, including masseter, temporalis, lateral pterygoid and medial pterygoid, provide the power, and the mandibular division of trigeminal (V) nerve innervate these muscles of mastication. The teeth are critical tools to break down food into particles. They can be classified into incisor, cuspid, premolar and molar. An individual tooth can be identified by ISO-3950 FDI two-digit notation. The surface of oral cavity is covered by oral mucosa for sensory feedback. Tongue inside the oral cavity transports the food bolus, and also provides the feedback of taste, tactile and thermal sensation to adjust human mastication. Meanwhile, the saliva respectively secreted from the parotid, submandibular and sublingual glands increases the cohesion of the food bolus which can be safe to swallow. The class of objects for describing the physiology is illustrated in Fig. 2.

4. Masticatory measurements class

A large variation of masticatory measurements has been explored between individual human adult subjects. But Lassauzay et al. (2000) and Woda et al. (2006a) found that there were no

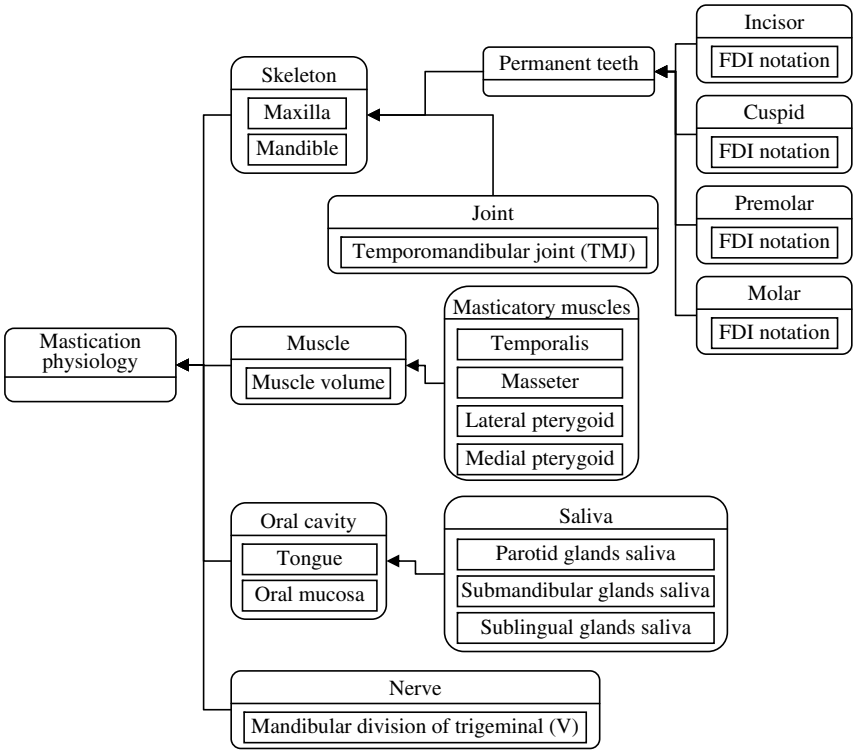

Fig. 2. The class of objects for the masticatory physiology.