HAO: Hearing Aid Ontology

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Abstract

Hearing loss is the partial or complete inability to detect sound in one or both ears. This disorder is very common and can be associated with other pathologic expressions. The hearing loss plays an important role in the life of individuals and it is defined as social problem because it is a communication barrier and language development impediment. The most common treatment for it is the hearing aid that makes sound audible to the people affected by an hearing loss. This contribution describes the first ontology about the hearing aids collecting all the existing knowledge on these medical devices.

Keywords

hearing loss, hearing aid, human ear

1. Introduction

Hearing impairment (or hearing loss) is a common sensory disorder that is defined as the partial or complete inability to detect sound in one or both ears. This diverse pathology is associated with a myriad of phenotypic expressions and affects adults and children. It is a communication barrier and language development impediment. Therefore, it can have a huge effect on one's quality of life [1]. Most of the time, the best treatment is the use of a hearing aid that is a device designed to improve hearing by making sound audible to a person with hearing loss. Actually, hearing aids are medical devices.

Hotchkiss et al [2] have released the first ontology about the hearing impairment called Hearing Impairment Ontology (HIO)[1]. It is built around the central concept of 'Hearing Impairment'. The main class of HIO is 'Hearing Impairment' that defines the classification of this disease from four points of views which are cause, ear affected, onset, and physiopathology mechanism. HIO cites hearing aids as a treatment for hearing impairment without going into detail and defines the cochlear implant as a different class. This choice can be considered semantically correct since the cochlear implant is a medical device with the same goal of a hearing aid but differs from it because of its functioning. This fact implicates that the hearing aid modelling does not fit for the cochlear implant. For this reason, my contribution is a comprehensive knowledge of only hearing aids from the point of view of commercial activities of these devices. This work describes the Hearing Aid Ontology[2] (HAO) that collects for the first time existing knowledge of hearing aids and their manufacturing companies. HAO could be consulted by

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[1]Available here purl.obolibrary.org/obo/hio/releases/2019-10-31/hio.owl

[2]It will be free available here https://github.com/ausilianapoli/HAO-Hearing-Aid-Ontology under the Creative Common Attribution 4.0 Unported License https://creativecommons.org/licenses/by/4.0/legalcode

everyone through a SPARQL endpoint or a web application.

2. Proposed Ontology

The HAO is built around the central concept of 'Hearing Aid'. The classes of the HAO reproduce the technical characteristics of hearing aids. There are different types (i.e. ontology class `Types`) which vary in size, placing and technology and each of them is a class:

- `BAHA` which stands for *Bone Anchored Hearing Aid*: it is a surgically implanted auditory prosthetic based on bone conduction; it can not be surgically implanted temporarily.
- `BTE` which stands for *Behind The Ear*: it is one of two major classes of hearing aids. They consist of a case that hangs behind the pinna.
- `CROS` which stands for *Contralateral Routing Of Signals*; it is a hearing aid that transmits auditory information from one side of the head to the other side of the head. Candidates include people who have poor word understanding on one side, no hearing on one side, or who are not benefiting from a hearing aid on one side.
- `Eyeglasses_Aids`: sounds are transmitted via a receiver attached from the arm of the spectacles which are fitted firmly behind the boney portion of the skull at the back of the ear (mastoid process) by means of pressure applied on the arm of the spectacles.
- `ITE` which stands for *In The Ear*; it is the other major class of hearing aids. These custom devices fit in the outer ear bowl (called the concha) or inside the ear canal completely.

Another main class is `Configurations` that contains configurations of each type of hearing aids: for example, a BTE hearing aid can have or not the receiver in the canal, or an ITE hearing aid can be completely hidden in the ear canal or not. All existing configurations are inserted as individuals and for each type they are:

- `BAHA` configurations:
  - `Surgical_Implant`;
  - `Softband` or `Headband` (they are semantically the same thing and this fact is modelled in the ontology using the property `owl:sameAs`).
- `BTE` configurations:
  - `RIC` which stands for *Receiver In the Canal* or `RITE` which stands for *Receiver In The Ear* (modeled as being essentially the same thing by means of the property `owl:sameAs`);
  - `No-RIC` or `No-RITE` (i.e., the counterpart of the previous).
- `CROS` configurations:
  - `Air_Conduction_Cros`: on the impaired side, a microphone is encased in a behind the ear (BTE) styled case or a custom, in the ear (ITE) piece; the receiver is on the other ear.

    - BiCROS: this system is utilized in patients who have single sided deafness who also have hearing loss in their better hearing ear; in addition to the configuration included in the CROS system, the BiCROS includes microphones on the better hearing side and both microphones are amplified and presented to the better hearing ear.
- Eyeglasses_Aids configuration is Bone_Conduction_Spectacles that means spectacles of eyeglasses contains bone receiver.
- ITE configurations:
    - ITC which stands for *In The Canal*;
    - CIC which stands for *Completely In the Canal*;
    - IIC which stands for *Invisible In the Canal*;

The ontology contains other individuals representing existing models of hearing aid produced by different main manufacturers; each of them is an instance of the appropriate class and is modeled using the following object/data properties:

- Object Properties:
    - hasConfiguration which has Types as domain and Configurations as range; its inverse is isConfigurationOf;
    - isDesignedFor which has Types as domain and {Adult, Child} as range; its inverse is hasDedicated;
    - forHearingLossSeverity which has Types as domain and {Mild-Moderate, Moderate-Severe, Severe-Profound} as range; its inverse is canBeTreatedBy.
- Data Properties:
    - hasConnectivity which has Types as domain and xsd:boolean as range;
    - hasTelecoil which has Types as domain and xsd:boolean as range;
    - hasWebSite which has Types as domain and xsd:string as range;
    - isDigital which has Types as domain and xsd:boolean as range;
    - isRechargeable which has Types as domain and xsd:boolean as range.

The above-mentioned properties are useful to define some classes as existential restrictions. Figure 1 gives an overview of the class hierarchy in HAO that will be described in detail (here the name of the root class is the *qualified name* of the class Hearing Aid in the HIO from which the proposed ontology is derived).

The human ear perceives sound waves by air conduction and bone conduction and so hearing aids are classified by the way of conduction. For this reason, there is the class Conduction that has, as subclasses, the classes Air_Conduction (i.e., the outer ear directs sound waves from the external environment to the tympanic membrane that transmits them to the inner ear by the ossicular chain) and Bone_Conduction (i.e., sound can reach the inner ear by conduction through the bones of the skull because it produces vibrations of the skull that are passed on the inner ear). Air_Conduction and Bone_Conduction are disjoint classes.

Another distinctive element for a hearing aid is whom will use it because some devices are specifically designed for adults or children. This is modeled using the class Hearing_Aid_Designed_For having as subclasses the classes Hearing_Aid_For_Adult and Hearing_Aid_For_Child.

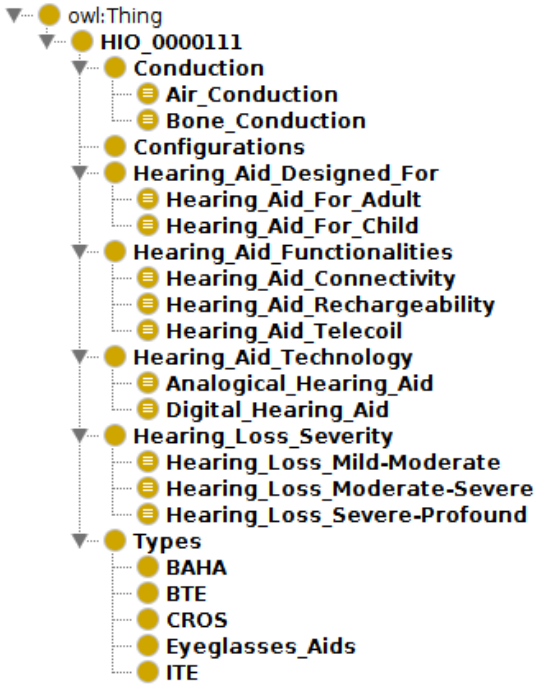

Figure 1: Class hierarchy in HAO.

Hearing aids have various functionalities and currently, these can be grouped into three main types i.e., connectivity, rechargeability, and telecoil. This is represented by the class `Hearing_Aid_Functionalities` and its three subclasses `Hearing_Aid_Connectivity` (recent hearing aids support connectivity because they can be fitted wireless and can receive sound directly from TV, phones, and Bluetooth microphone/speaker), `Hearing_Aid_Rechargeability` (the power alimentation can be zinc-air button battery or lithium rechargeable battery), and `Hearing_Aid_Telecoil` (the signal inside the phone's speaker is picked up by the hearing aid's telecoil i.e. a special loop of wire inside the hearing aid).

Hearing aids can be classified by hearing loss severity too. For example, some of them are not powerful enough for severe hearing loss. Three levels of severity of hearing loss are indicated and they are Mild-Moderate, Moderate-Severe, and Severe-Profound. To represent this in the ontology I introduced the class `Hearing_Loss_Severity` having three subclasses `Hearing_Loss_Mild-Moderate`, `Hearing_Loss_Moderate-Severe`, and `Hearing_Loss_Severe-Profound`. Finally, hearing aids can be analogical or digital according to their internal circuit. The ontology contains the class `Hearing_Aid_Technology` with its two subclasses `Analogical_Hearing_Aid` and `Digital_Hearing_Aid`. `Analogical_Hearing_Aid` and `Digital_Hearing_Aid` are disjoint classes. Worth noticing that `Analogical_Hearing_Aid` is an empty class because today all existing hearing aids are digital yet. I nevertheless put this class in this ontology for completeness of the topic.

HAO has been developed in *OWL 2* using the *Protégé*[3] editor and classified using the `Pellet`[4], `FaCT++ 1.6.5`[5], and `HermiT 1.4.3.456`[6] reasoners.

3. Use Cases

The proposed ontology could be a handbook for everyone gets involved in the topic of hearing aid. For this reason, its maintenance updating and adding of instances is significant.
In the field of hearing aids, there are two parts (i.e. clinicians and patients) separated by the hearing aid dispenser that is the most technical figure in this context. The clinicians take care of their patients evaluating the presence and the entity of the hearing loss and suggesting the type of a hearing aid. Next, the patients address their trusted hearing aid dispenser that offers them the best solution. In this process both clinicians and patients benefit from the HAO: the former could suggest specifically a hearing aid configuration and also a model based on the feedback of all own patients over time; the latter, instead, could understand better and explore the hearing aid subject, and independently compare the technical characteristics of own hearing aid with the others on the market.

4. Conclusion

In this note, I have briefly presented HAO that is an ontology collecting all existing knowledge about hearing aids. This ontology is the first in its field and standardizes human-and-machine-readable resources. It unambiguously defines concepts and terminology around hearing aids for researchers, patients, and clinicians. In the future, this ontology can become the back-end of a web service useful for clinical practice. People with no medical and technical knowledge could know and understand this subject. While, anyone, who is experienced, could be guided in the choice of a specific hearing aid model whose characteristics are clinical picture compliant.

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