Decision support system to help choose between an ITE or a BTE hearing aid

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Abstract

A decision support system (DSS) is used for analysing a situation and making decisions. The goal of this research is to mine a large set of heterogeneous audiology data and create a DSS to help audiology technicians to choose between an ITE or BTE hearing aid. Although, in many cases such a choice is clear cut, but at other times this system could be used as a second opinion to predict the hearing aid type. A number of data mining techniques, such as clustering of audiograms, association analysis of variables (such as, age, gender, diagnosis, masker, mould and free text keywords) using contingency tables and principal component analysis on audiograms were used to find candidate variables to be combined into a DSS. The DSS was created using the techniques of logistic regression, Naïve Bayesian analysis and Bayesian networks, and these systems were tested and validated on test data to see which of the techniques produced the better results. This DSS takes air and bone conduction frequencies, age, gender, diagnosis, masker, mould and some free text words associated with a patient as input and gives as the output a decision as to whether the patient would be more likely to prefer an ITE or a BTE hearing aid type.

The highest agreement between predicted results and actual hearing aid type in the data were obtained using Bayesian networks, with 93 to 94 percent similarity overall, with a precision of 0.91 for ITE and 0.96 for BTE. The reason for this might be that the Bayesian network also considers interaction between variables while the other two techniques (logistic regression and Naïve Bayesian analysis) consider only the individual variables. One of the important features of this DSS is that once the final choice of hearing aid type is predicted, the decision process can be tracked back to see which factors (variables) contributed how much to the final decision.

The theoretical upper bound of classifier performance is the inter-annotator agreement (Altman, 1991), in this case the rate at which two expert audiologists would assign the same hearing aid to the same patient. Unfortunately, this type of data was not included in the audiology database.

Motivation for the research

- People with hearing loss are found to have:
  - Serious depression due to loss of hearing
  - Problems in speech and communication
  - Avoiding public places due to unsafe environment like heavy traffic.
- In a study it was found that (Bertoli et al., 2009)
  - 85% people use their hearing aid(s) regularly
  - 12% only occasionally and
  - 3% never, as they may or may not be happy with their hearing aids.
- About 15% of the world's population experiences the symptoms of tinnitus (ringing in the ears) at some time in their lives (Baguley and McFerran, 2002) and this increase with age (Lockwood et al., 1998, Martines et al., 2010).
- Research from the British Tinnitus Association (BTA, 2009) states that
  - About 10% of the UK population experience tinnitus frequently and
  - Approximately 5% of the adult population in the UK experience persistent or troublesome tinnitus.
- There is the need for a second opinion in difficult-to-decide cases for hearing aid type and tinnitus masker with an explanation how that decision was arrived at.

Why data mining?

- Tremendous growth in the amount of data produced in the medical domain (Ananiadou, 2009) and each year the amount of data is increased and new terms emerge.
- The amount of audiology data used in this research is much more than the most of the studies been done in the past.
- Data mining of audiology data can overcome certain limitations with traditional audiology research, such as small data samples, data related to only certain categories, and the need to deal with data with different properties (such as numeric, categorical and textual).
- The availability of a large NHS audiology facility data (which is used in this research), overcomes the need for surveys / interviews / new hearing tests.

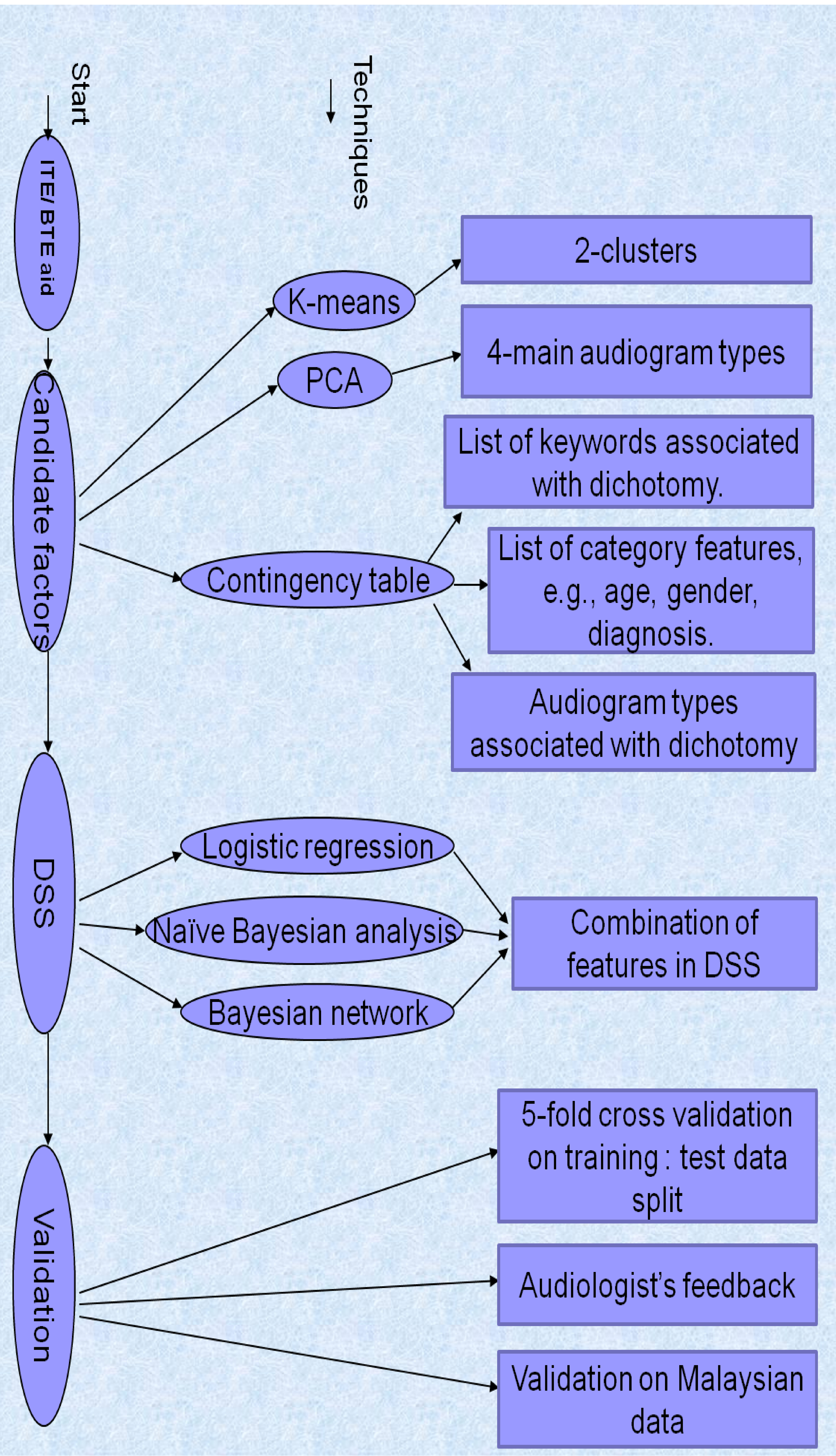
Audiology data repository

- A large NHS audiology facility
- 180,000 records, 23,000 patients
- Heterogeneous records
  - Audiograms
    e.g.,|105|75|80|95|95|95|40|60|70|70|70|
  - Categorical data
    e.g., |M|, |TINNITUS|, N8|, BE18|
  - Free text notes
    e.g., |IMPS. TAKEN FOR BINAURAL AIDS.|

Hypothesis and research questions

- **Hypothesis:**
  - The data mining of heterogeneous audiology data will give the opportunity to discover new features and associations that will be useful for audiologists in their work, in particular by developing a decision support system (DSS) to classify patients according to the following research questions:
- **Research Questions:**
  - Which factors influence the choice of ITE (in the ear) as opposed to BTE (behind the ear) hearing aids?
  - For patients diagnosed with tinnitus, which factors influence the decision whether to fit a tinnitus masker?

An overall work diagram of data mining of audiology data



Results

- The factors influencing the choice of ITE/BTE aids and tinnitus masker found in the literature are audiograms, age and gender. These factors were also found experimentally along with other factors diagnosis, mould and keywords in the free text field.
- The DSS was constructed using logistic regression, Naïve Bayesian analysis and Bayesian network.
- One of the feature of using these techniques is that they incorporate an explanation facility to enable one to look back and see which variables contributed exactly how much to the final decision of whether to fit a BTE or an ITE aid or a tinnitus masker.
- The Bayesian network considers the interaction between variables, while logistic regression and Naïve Bayesian analysis consider only the individual variables in isolation.
- Among all three techniques, Bayesian network produced the better results for ITE/BTE aids, while for tinnitus maskers, there was not enough data.
- For the analysis of results obtained from DSS precision, recall and F-measures were used.

Validation of results

- The final model was tested using 5-fold cross validation for logistic regression, Naïve Bayesian analysis and the Bayesian network, and was able to replicate the decision of the audiologist whether to fit an ITE or a BTE hearing aid with the results shown in Table 1 and Table 2.

Overall similarity for	Percentage range
Logistic regression	82 to 85
Naïve Bayesian analysis	80 to 81
Bayesian network	93 to 94

Table 1: Overall similarity of results with logistic regression, Naïve Bayesian analysis and Bayesian network.

	Precision		Recall		F-score	
	ITE	BTE	ITE	BTE	ITE	BTE
Logistic regression	0.79 to 0.87	0.82 to 0.85	0.84 to 0.88	0.74 to 0.85	0.83 to 0.86	0.79 to 0.83
Naïve Bayesian analysis	0.86 to 0.88	0.74 to 0.76	0.74 to 0.76	0.86 to 0.88	0.80 to 0.81	0.80 to 0.82
Bayesian network	0.91	0.96	0.97	0.88	0.94	0.92

*Note: Bayesian network produced almost similar values for Precision, Recall and F-score for all five cross folds.
Table 2: Precision, Recall and F-score for logistic regression, Naïve Bayesian analysis and Bayesian network.

- For all five fold cross validations, the results obtained for the models developed were better than both random (50%) and the ZeroR baseline.
- The constructed models and the data behind them were validated by presenting them to the audiologist at a large NHS audiology facility for comments and suggestions for improvements. The audiologist did not feel that there is a need for a DSS system in the clinic for the specific question of predicting BTE vs. ITE, since hearing aid prescription is a very well documented professional practice taking into account a number of variables. However, we have developed a methodology which might be suitable for other questions in audiology, such as the prediction of hearing aid satisfaction.
- The techniques developed in this thesis for the construction of prediction models were also used successfully on a different audiology data set from Malaysia. The results obtained for models developed on the Malaysian data were better than both random (50%) and the ZeroR baseline.

Summary of contributions

- This work has used an unconventional method (data mining) to predict outcomes in audiology for two main research questions.
- Research based purely on data mining is new in audiology research. It includes identification of factors which contribute to the decisions.
- The DSS were constructed from a large heterogeneous audiology data set.
- The techniques developed in this thesis may be capable of processing medical data in general.
- This audiology data set is unique, as it contains records of patients prescribed with both ITE and BTE hearing aids. The work in this thesis has made use of this unique opportunity to study factors relating to the choice of an ITE as opposed to a BTE hearing aid.

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