Artificial Neural Networks and the Treatment of Migraine

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Abstract

In treating migraine, if precipitants (something that initiates an individual migraine attack) can be identified migraines can be more easily managed as the migraineur decreases or avoids exposure to the known precipitant. Finding these precipitants proves a difficult task. The data is patient reported and tends to have errors and gaps. An algorithm that deals with this data needs to be able to degrade gracefully. Solutions using feedforward Artificial Neural Networks (ANN) are proposed.

There are many treatments for migraine available, each with a small success rate. A feed-forward ANN solution is proposed for determining the treatment methods most likely to be successful for a particular patient based on personal parameters. Again the data here is imperfect; it most likely has errors and omissions. There is some precedence of successfully using ANNs for related problems in medicine.

Contents

1 Introduction

1.1 Why study migraine?

Migraine is a serious problem that affects 17 percent of the adult population of Canada and approximately 250,000 Canadian children, according to the Migraine Association of Canada [35]. Other North American and European countries also report figures in the range of 15 to 20 percent of their adult population [34, 20].

Migraine occurs predominantly in people aged 25 to 55 [20]. Most people in this age range are active in the work force. This results in migraineurs (people who suffer from migraines) having to take time off work in order to deal with their migraines or being less productive at their jobs on days when they are experiencing migraine [13]. For those with frequent migraines it may even keep them from full-time employment [29]. That's almost 1 in 5 people who suffer from a neurological disorder that causes them to be temporarily cognitively impaired at what may seem to be random intervals.

Migraines cost the US economy 5.6 to 17.2 billion dollars (US) per year in terms of productivity loss [10]. Additionally, there are the costs of visits to physicians and emergency departments, increased medical claims, and pharmaceutical costs. Patients in primary care with headache cost at least 87% more to care for than their similar age and same gender counterparts without headache [29].

Migraine is not merely a bad headache. It is a neurological disorder. Even simple tasks like bending down to pick something up off the floor can be difficult during a migraine [4]. The most serious impact is its social impact on the victim [10]. Migraine limits effectiveness at work and school. It disrupts home activities and family relationships. Socializing with friends and family can be impossible during a migraine due to the pain and discomfort caused by the condition [4]. The negative impact of migraine on performance and on quality of life is significantly larger than that of episodic tension-type headache [4].

1.2 What is migraine?

The most common symptom is throbbing severe head pain. Other common symptoms are nausea, vomiting, photophobia (sensitivity to light), osmophobia (sensitivity to smell), and phonophobia (sensitivity to sound). There may also be dizziness, light headedness, blurred or double vision, anorexia (loss of appetite), constipation, diarrhea, chills, tremors, cold extremities, ataxia (inability to coordinate voluntary muscular movements), and dysarthria (difficulty speaking). Difficulty in concentration and memory loss have been reported [10]. Not surprisingly, some migraineurs are fatigued for several days after an episode. The frequency of migraines varies from person to person. It ranges from years between episodes to a daily occurrence. One to four attacks per month is average.

Migraine is defined by the IHS (International Headache Society) as "an idiopathic, recurring headache disorder manifesting in attacks lasting 4 to 72 hours." This means the source of the headache is unknown and the problem is chronic. "Migraine headache is typically unilateral, pulsating, moderately to severely intense, aggravated by routine physical activity, and associated with nausea, photophobia, and phonophobia" [10]. The actual mechanism behind migraine is unknown.

1.3 The Rest of the Paper

In the rest of this essay I will discuss some problems in migraine treatment that may be solved with artificial neural networks. First I will discuss migraine precipitants (something that can initiate an individual attack), and migraine parameters. This will be followed a section in which background on artificial neural networks will be provided. Then I will discuss the actual problems and propose a method of solving them, which I will later justify. Lastly there will be sections on recent research in migraine, and similar areas where artificial neural networks have been used.

2 Migraine Precipitants

A migraine precipitant, commonly referred to as a trigger, is something that can initiate an individual attack. Precipitants vary greatly from migraineur to migraineur. Knowing an individual's precipitants makes a great difference in managing migraine since they can often be avoided. Actually determining these precipitants can sometimes prove quite difficult, because there are many different possibilities, most migraineurs have more than one precipitant, and sometimes the precipitant is a combination of things occuring concurrently. Precipitants may take anywhere from hours to days to have their effect [5]. In this section I will list and discuss some of the common triggers.

2.1 Changes in Lifestyle

Changes in regular daily activities can precipitate migraines. Stressful times, or the period just after a stressful time may trigger migraines [5]. For those migraineurs with these types of triggers it is best to have as little variation as possible in their daily routine. Here is a table of common examples:

Precipitants: Changes in Lifestyle

missing a meal [10]	over sleeping [10]	stress [10]:
dieting [10]	too little sleep [5]	- marital
delaying meals [5]	fatigue [10]	- family
insufficient food (including total abstinence) [5]	excessive exercise [5]	- work
	travel [5]	- social relationships

2.2 Environmental Factors

The physical environment can precipitate migraine. The following are some common triggers:

Precipitants: Environmental Factors

excess noise [5]	excess cold [5]
excess light [5]	excess heat [5]
excess smells [5]	changes in weather or barometric pressure [10]

2.3 Internal Factors

Various internal factors may be of influence in triggering migraine. Migraine may be precipitated by other kinds of pain, most commonly head or neck pain. Inflammation or other causes of pain arising from the eyes, teeth, masticory apparatus, sinuses or neck may also precipitate migraine [5]. Natural and artificial hormones are both candidates for potential migraine triggers; in particular, hormones released during menses and estrogens in oral contraceptives and hormonal supplements [10]. Oral contraceptives can increase the frequency, severity, duration and complications of migraine [10]. There has been some report of allergy precipitating migraine [5].

2.4 Food

The easiest precipitants to control are food based. Although the relationship of diet to headache is controversial [10], it is generally agreed that there is some correlation. A significant difficulty in identifying food triggers is that symptoms may be misinterpreted as precipitants of attacks, thus a craving for sweet foods that accompanies the early stages of migraine may incorrectly be blamed as a trigger [5].

Foods containing vasoactive (having an effect upon the blood vessels) substances, such as tyramine, are recognized as potential precipitants of migraine [10]. Phenylethylamine, found in chocolate, may also trigger migraine [10]. Excessive consumption of caffeine in beverages and analgesics may provoke headaches if the caffeine is withdrawn [5, 10]. A table of common food triggers follows:

Precipitants: Food

chocolate [10]	fermented or pickled foods [10]	red wine [10]
cheese [10]	alcoholic beverages [10]	tyramine [10]
caffeine [10]	MSG (monosodium glutamate) [10]	nitrates [5]
aspartame [10]	nitrites (used to maintain red of cured meats) [10]	

3 Parameters of Migraine

The exact mechanism of migraine is not known but there are some parameters that appear relevant. The most significant of these may be gender. Women are three times as likely as men to suffer from migraine [20]. There is a definite gender bias but the disease is not exclusive to women. In youth the gender split is much less significant. Similar numbers of males and females aged 12 to 17 suffer from migraine according to the second American Migraine Study (5.2% of males vs. 7.1% of females) [20], but for all age groups above 18 the ratio is the aforementioned three to one. This ratio even holds for those over 60 [20], which is somewhat unexpected since a popular theory is that the increased number of female sufferers is due to circulating hormones related to menstruation [24]. If this were a complete explanation, it is expected that the difference should disappear after menopause, but it does not. The details of migraine may be different for males and females, with females being more likely to report light sensitivity, sound sensitivity and nausea [20]. The duration of migraine associated activity restriction is greater among females [20].

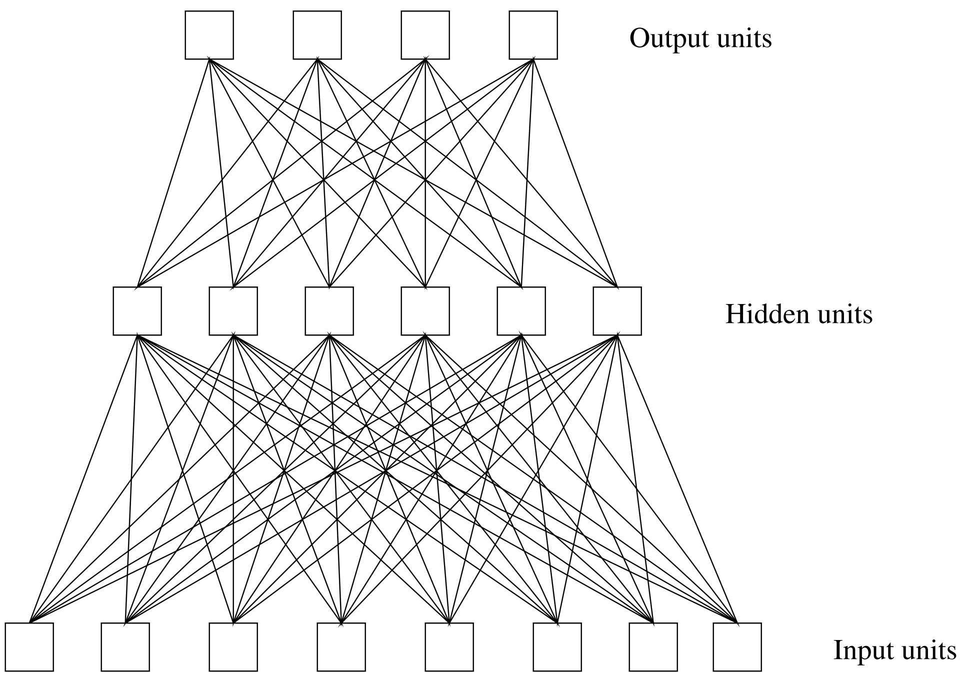
Age is another noticeable parameter. Incidence of migraine peaks at the 30-39 age group and decreases noticeably for those aged 50-59 reaching the low levels seen of migraine in youth after age 60 [20].

There are thought to be genetic factors in migraine vulnerability. This idea is partially supported by the finding that incidence of migraine is higher in Caucasians than African Americans within the United States [20]. In addition, it is found that incidence of migraine is higher in studies from the United States and Western Europe than in studies from Africa and Asia [20]. As well, there is a greater likelihood of an individual having migraine if one of their parents suffer from migraine; the likelihood is even higher if both parents have migraine. There are still those who suffer migraine even though neither parent does, so the genetic influence is one of increased tendency, not sole cause.

There is potentially conflicting information on the role of socioeconomic factors and migraine. According to [27] there is no noticeable role for employment status or education in incidence of migraine. According to [20] there is greater incidence of migraine among those in the lowest income bracket. The sample space for [20] is nearly 100 times that of [27], so it may be that the difference was not detectable at the higher level of granularity. The difference may be due to social causation, social selection or both. It is uncertain, as are the exact relationships of all the parameters mentioned here.

4 Basic Description of Artificial Neural Networks

An artificial neural network (ANN) or connectionist architecture is a multi-layer system that generates a desired response to an input stimulus. There is a set of input units that a pattern of activity is encoded on, a set of output units that are used to encode a response, and a set of intervening layers or hidden units which detect features in the input on a which a response in based [9].



All units in the ANN are processing units of the same type. A processing unit has an input function that determines how it computes the signal(s) it is receiving. The internal level of activity is calculated using an activation function, and an output function is used to calculate the signal to send elsewhere. The signal is sent to another processor via a weighted connection [9]. The processing unit design was inspired by neuroscience– specifically the idea that neurons are either on or off. An activation function returns a value between 0 and 1. Near-zero represents “off”, and near-one represents “on” [9].

The network learns by adjusting the weights on the connections between processing units. The set of connection weights determine how information flows between processors. Different types of ANN are the result of the different kinds of information flow that are possible from system to system. A network that is about to be trained starts out with random weights on its connections. An input pattern is presented, and an output is produced. The error on each output is calculated and this information is used by a training rule to adjust the weights. The error is sent backwards through the network. This process is repeated many times with each pattern in the set of training input [9].

Feedforward networks are quite good at recognizing patterns [1]. In a feedforward network information can only flow in the direction of inputs to outputs, as opposed to a recurrent network where information is allowed to flow from input to output and output to input. The bidirectional flow of a recurrent network enables the system to receive input sequentially and alter its response appropriately depending on what has been received so far [1, 9], which makes it able to detect temporal regularities which is not required for this problem. Something more complicated than a feedforward network is not likely to be needed here.

5 Proposed Research Areas

5.1 Finding Precipitants

Sometimes an individual's migraine trigger is simple and easy to find, however they can also be a combination of seemingly unrelated things, which makes them much harder to find. Here are two approaches that may help with this problem, and possibly be combined. As far as I know, there has not been any research done on this. I will discuss my reasons for choosing artificial neural nets for these approaches to the problem in following sections.

The trigger(s) may be found by monitoring an individual's exposure to potential triggers and recording the occurrence of migraine, then running artificial neural net algorithms on it to to find a pattern. This may be difficult due to the large number of potential triggers. Such a large number of inputs can result in a rather large search space or a fairly complicated machine learning approach. Not only does it complicate the search space, but it makes it more difficult a task for the migraineur. For this approach it is important to remember that an actual human patient has to record the data. This means the number of things to keep track of shouldn't be prohibitively large. It also means there is potential for error in the data as humans are not perfect recording devices. Keeping a migraine diary is already a common suggestion made to migraineurs by physicians and migraine organizations, so it is a reasonable task if the list of potential triggers isn't too large. A smaller set of the most common ones could be tried. This is basically equivalent to the current practice of having a patient keep a diary of when they are exposed to various more common potential precipitants, along with a record of their migraines. The benefit comes from having a machine look for patterns that may be impossible for humans to detect.

The second approach to finding triggers makes use of the parameters of migraine; age, gender, ethic background, genetics, and socioeconomic status. Any other possible parameters, like other illnesses, should also be used since it is unlikely that the currently known parameters make a complete list. There doesn't seem to be any research trying to link triggers with parameters of migraine. It seems quite possible that certain classes of patients are more likely to experience certain triggers. There are some differences in the experience of migraine in relation to some parameters. For instance, female migraineurs are more likely to report light sensitivity, sound sensitivity and nausea than male migraineurs [20]. These differences could carry over into the domain of precipitants. With the exception of hormones, each trigger is treated as if it is equally likely for all migraineurs. Artificial neural nets can probably be used to find patterns here. Data would have to be collected from patients who had successfully found their precipitants. Details such as gender, age, socioeconomic status, ethnic background etc. could be recorded, and a correlation between these factors and precipitants could be searched for. If any correlations are found, they could provide a better starting point in searching for an individual migraineur's triggers. This information could provide an idea of which triggers are most useful to watch for. Better yet, these correlations could be used to select the smaller set of triggers for an individual migraineur to record in the first approach.

I think there is merit to trying either of these approaches on their own, but that the largest gain would be from combining them. The second approach on its own is not likely to provide an exact answer. I would expect, at best, a guideline of the most likely precipitants for a specific migraineur. The first approach on its own has the drawback of the number of potential precipitants being very large. This is difficult for the patient who has to keep the diary of exposure to them, and creates a larger search space.

The large number of potential triggers, noisy incomplete data, and lack of an expert available to consult are properties that limit the effectiveness of some machine learning algorithms. For instance, Bayesian nets are best served when an expert is at least available to indicated which variables directly affect other variables. In this domain that information is not known. More on this will be discussed later, in the sections where I justify my choice of artificial neural networks.

5.2 Determining Treatment

In treating migraine there are a great many treatments to try, each of which has a limited success rate. Choosing the treatments to try first can prove very difficult, much like finding triggers. A migraineur may respond well to just one form of treatment or may require a combination. There are a large number of drugs to choose from, in addition to alternative medicine approaches such as accupuncture, therapeutic massage, physiotherapy and biofeedback. Each approach takes time in order to determine its effectiveness, most often requiring a month or more. This experience can prove frustrating and expensive for the patient.

A useful tool would be something that predicts the treatment methods that are most likely to succeed for a given migraineur based on a set of parameters. These treatments could be tried first, potentially decreasing the wait for some level of relief or manageability of the disorder. Data would need to be collected from migraineurs who had discovered successful treatments for their conditions. I recommend recording as many of the parameters of migraine as possible, even suspected parameters that may or may not prove useful.

The relationship, assuming there is one, between these parameters and successful treatment methods is unknown. It is quite possible that more than one treatment or combination of treatments would prove effective for any given migraineur. This makes for quite a complicated pattern recognition task. Potential error in input needs to be allowed for, since data would be collected from patients and physicians. It would likely be useful to include any other ailments or disorders as part of the parameters recorded. There are instances where the same medication may treat more than one condition. For example, gabapentin is an anti-epilepsy drug that may also be used for migraine prophylaxis [11]. There are instances where a migraine medication may aggravate a pre-existing condition. An example would be tri-cyclic antidepressants which can be effective in migraine prophylaxis [32], but increase the risk factor for ischaemic heart disease [15].

5.3 Appropriateness of Artificial Neural Networks

The relationship between the input and output for these problems is not known. Something that is good at finding patterns is needed. The solution needs to be able to handle incomplete, imperfect data. ANNs can handle this kind of data; they degrade gracefully. There can be errors in the input and/or the training data and it will still perform well [9]. The data for these problems is imperfect and likely incomplete. A system that can still perform well with such data is needed.

The difficulty with ANNs is that they can be quite difficult to reverse engineer. That is, extracting what rule it learns for getting the correct output from the input, or determining what type of pattern it has discovered will most likely be hard and time consuming. This makes ANNs not a very good candidate for finding a pattern in an individual's migraine diary. It is not enough for the network to accurately predict if a migraine will occur. It is necessary for the migraineur to know what pattern was found. In particular, of all the potential triggers and combinations of potential triggers which ones actually affect the patient.

A way to solve the above problem is to change the format of the problem. Use all of the diary information as the input, including the occurrences of migraine. Instead of having the ANN learn to predict when a migraine will occur, have it predict what the triggers are. That is, have the output be the likelihood that a potential trigger is in fact a trigger for this specific individual. In this situation reverse engineering isn't necessary, however the data collection will be more complicated since diaries of migraineurs whose triggers are known would need to be collected. The network would be trained using a diary for input and the known triggers of the migraineur as the correct output. A potential problem with this approach is that the data to be collected may prove prohibitively large. As before, the data is being provided by humans and therefore may be incomplete and imperfect.

For the problem of predicting the most likely precipitants given a set of parameters, neural networks appear to be a good choice. All that is needed is to get an output of the likelihood of various precipitants given the input of specific values for various parameters of migraine. How this answer is arrived at does not need to be known. The same thing applies to the problem of predicting the treatments that are most likely to succeed. Given the input of specific instances of various parameters of migraine, an output of which treatments are most likely to succeed is desired. How the likelihood that any given treatment will succeed is arrived at is not required to be known.

5.4 Why Not Use Bayesian Nets?

5.4.1 Brief Description of Bayesian Nets

Bayesian networks, also known as belief networks, are directed acyclic graphs that represent dependencies between variables [28]. The nodes of the graph are a set of random variables, and a directed edge from **a** to **b** means that **a** directly influences **b** (where **a** and **b** are nodes in the graph). The parents of a node are those nodes that have edges directed to it. There is a conditional probability table for each node that quantifies the effect its parents have upon it [28].

The networks are called Bayesian because they use Bayes rule [$P(B|A) = P(A|B)P(B) / P(A)$]for manipulating conditional probabilities. The direct conditional dependence relationships, which are represented by the edges, are decided by a domain expert. Once this network topology has been specified it only remains to provide the conditional probabilities for the nodes that participate in direct dependencies since any other probability values can be computed using them [28].

5.4.2 The Difficulty with Bayesian Nets

The primary reason that Bayesian nets were not recommended to solve the problems with triggers or determining treatments is that there is no domain expert. The relationships between the potential triggers, occurrence of migraine, and parameters of migraine are not known. There are not currently any experts at predicting an individual's migraine triggers, so there is no one to guide the development of the network topology. The same reasoning applies to determining migraine treatments. It is not even known if a relationship exists between personal parameters and successful migraine treatment. If a relationship does exist, there is certainly not an expert at this time to guide the network development.

A second difficulty in using Bayesian nets is the lack of statistical information available. The conditional probabilities for any of the variables in the problems presented are not known. Arguably, data will need to be gathered to train the ANNs, so one might propose that this same data be used to generate statistics. This increases the size requirement for the data and requires that the data constitutes a valid statistical sample. Patient provided data for migraine is not currently easy to find, and the luxury of being overly selective about it can not currently be afforded.

It is possible that the trigger finding and treatment selecting problems could be massaged to fit Bayesian nets, but I think they fit more easily into an ANN format. If at some future date much more data for the problems is available and there are some experts to consult, Bayesian nets may become the better choice.

5.5 Why Not Use Decision Trees?

5.5.1 Brief Description of Decision Trees

A decision tree takes a set of properties that describe a situation as input, and produces an output value [28]. The basic algorithm requires that the input and output values are discrete. The tree is trained with a set of already classified inputs. When inducing the tree from the training data, if all examples at a particular node belong to one output category a leaf node is created, otherwise the tree branches on the property that comes closest to splitting the examples into separate categories. If the algorithm reaches a point where there are no more properties left to branch on, and the data is still not fully in one category, the classification is decided based on the majority. [28].

5.5.2 The Difficulty with Decision Trees

Decision trees should be able to handle possible errors and omissions in the data, as well as the possibility of not having enough attributes to fully describe the situation. The output produced is discrete, so providing the likelihood that a given treatment will be effective is not really possible. Decision trees are good at classifying things, so it would be straight forward to have a decision tree determine which treatments should be tried and which should not. However, this is not nearly as useful as a ranking for the likelihood of success of each treatment, which implies an order.

The same difficulty applies to the problems with triggers. It is preferable to have a ranking of which potential triggers should be looked to base a decision on. Some situations may call for looking at the top five candidate triggers while it may be appropriate to look at the top ten at other times.

When determining the triggers of an individual based on the data from their migraine diary, it is welcome to have a mechanism that degrades gracefully. If the decision tree incorrectly classifies the potential triggers, the patient is left where (s)he started. If the likelihoods that the potential triggers affect the patient are given, then if the most likely trigger turns out to not have an affect, it is clear which one to try avoiding next.

It is possible that a solution to the problems presented in this essay could be found using decision trees. The difficulties mentioned here are unlikely to be insurmountable. I have proposed solutions using ANNs only because they seem the simplest approach to these problems at this time.

6 Recent Research

6.1 Migraine

There is currently a lot of research being done on migraine. One of the most predominant areas of research is the effectiveness and safety of various drugs as preventatives and/or abortives. Some work is done on using older well known drugs like aspirin as a prophylaxic [3], but the most popular drug family right now is the triptans [30, 31, 7, 18, 26]. More commonly known triptans are Imitrex (Sumatriptan), Zomig (Zolmitriptan), Amerge (Naratriptan), and Maxalt (Rizatriptan). Triptans are migraine abortive drugs, and are currently the only drugs that were developed specifically for migraine. Most other drugs that are used in migraine treatment were discovered serendipitously while treating other types of ailments. It is not known how the drugs used for prophylaxis exert their beneficial effects in migraine [2].

Research that surveys the population in general and migraineurs in particular is also being done. There are studies about quality of life and the non-monetary costs of migraine [12]. Many of these compare the burden of migraine with that of other chronic pain problems. The general finding is that migraine is more debilitating than chronic tension headache, or chronic pain in other parts of the body than the head [23, 16, 22, 4]. The cost of migraine in terms of treatment and lost work days is also of interest. Studies have been done that estimate the amount of money lost annually to migraineurs having to take sick days or having decreased productivity at work [13, 29]. Data is being gathered on the prevalence of migraine in various countries and on possible characteristics of migraine sufferers [20, 34].

6.2 Personalized Medicine

Related areas of research to that proposed in this paper are pharmacogenetics and pharmacogenomics, which are related in that they are a form of personalized medicine. “Pharmacogenetics and pharmacogenomics deal with the genetic basis underlying variable drug response in individual patients” [21]. Treatment is selected based on the study of sequence variation in certain genes or on the study of the genome. This type of work is being studied with regard to breast [14] and colon [21] cancer treatments.

Research towards personalized medicine in migraine could be applied to many other areas of medicine. There are plenty of areas that could benefit from a system that predicts which treatment methods are most likely to be successful. There is much to be gained if the number of ineffective treatments an individual must endure can be reduced or eliminated. There are many things to try when coping with migraine, but the success rate of each is small. Eliminating the number of potential precipitants to keep track of and increasing the likelihood of finding them is also of great benefit. If triggers can be avoided or removed from the environment, migraines can be controlled with very little or no other treatments. This means there are no potential side effects from drugs to worry about, and no treatment costs.

6.3 Related Problems where Artificial Neural Networks Have Been Used

6.3.1 Processing Unexact Information in a Medical Used Multiparadigm System [17]

Kaeding suggests a hybrid system of ANN and rule-based knowledge systems for an expert system used for diagnosis and optimization of therapy for disease of the optic fundus. Her expert system has four sources of data available to it: patient, physician, laboratory and technical methods of examination, and mathematical models to simulate physiological processes [17]. The patient data is subjective and incomplete. The physician data may be the result of both conscious reasoning and reasoning based on unconscious associations and inferences [17]. Since the information that comes from these two human sources may be fuzzy and uncertain, Kaeding proposes ANNs to deal with them. The technical methods and mathematical models are better represented using rule-based knowledge bases.

The problems outlined in this essay only have human data to work with. The rule-based knowledge bases are not applicable here. Only the part of Kaeding's expert system that is made up of the

ANN is relevant. She reports realization of this concept by the expert system VISIS. This suggests there has been some success using ANN for dealing with the imperfect medical data supplied by patients and physicians.

6.3.2 Using Artificial Neural Nets to Predict Academic Performance [8]

Cripps uses feedforward ANNs to predict degree program completion, earned hours and GPA for college students in developmental studies based on a set of parameters that describe students. This set of parameters includes age, gender, ACT score (a standardized college entrance examination), race, reading level, writing level, math level, financial status and "bad check" status [8].

Degree program completion and earned hours were predicted with two hidden layer feedforward ANNs. For predicting GPA, ANNs with one to three hidden layers were tried. The ANNs with one or two hidden layers did not train satisfactorily but good results were had with the ANN with three hidden layers. Cripps then tried removing various inputs (parameters like age, race, etc.) to test if the ANN could still train successfully. For instance, the model was still trainable if gender or race were removed from the inputs but not if both of them were removed. Anything that was required in the inputs for the model to successfully train was said to be correlated with GPA.

Neural networks were successful in predicting degree completion, earned hours and GPA. The parameters used were details about individuals much like in the problems mentioned in this paper. Cripps does not feel that data for all relevant parameters were available. For example, he would have liked to include whether or not a student lived on campus. His data was not necessarily complete.

The relationship between what he wanted to predict and the parameters he was looking at was unknown. This relates well to the problems mentioned in this paper.

7 Conclusion

Migraine is an important research area, and the problems of finding triggers and determining treatments can be greatly assisted by computing science. The findings could be used to motivate further research in related areas of personalized medicine. The largest obstacle is most likely data collection, but it may be possible to overcome this by collecting data over the internet. A recent study on the feasibility of conducting migraine research over the internet produced some very favourable results [19].

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