Minimizing Musculoskeletal Disorders in Lathe Machine Workers

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Abstract

In production units, workers work under tough conditions to perform the desired task. These tough conditions normally give rise to various musculoskeletal disorders within the workers. These disorders emerge within the workers body due to repetitive lifting, differential lifting height, ambient conditions etc. For the minimization of musculoskeletal disorders it is quite difficult to model them with mathematical difference or differential equations. In this paper the minimization of musculoskeletal disorders problem has been formulated using fuzzy technique. It is very difficult to train non linear complex musculoskeletal disorders problem, hence in this paper a non linear fuzzy model has been developed to give solutions to these non linearities. This model would have the capability of representing solutions for minimizing musculoskeletal disorders needed for workers working in the production units.

Keywords: Artificial Intelligence, Expert System, Fuzzy Logic

1. INTRODUCTION

The ability to maintain balance between health and production targets is increasingly important within workers of different industry. Workers tend to exert their bodies to various types of musculoskeletal disorders unknowingly and tend to lose both on the financial end as well on the health end. Generally these types of disorders tend to decrease the efficiency of the workers over a length of time especially for those who are highly exposed to repetitive tasks. The ligaments of the shoulder muscle as well as of the low back muscles are the major effected muscles among lathe machine workers. Musculoskeletal disorders are the condition where a part of musculoskeletal system gets injured over time due to repetitive task. Musculoskeletal disorders are the disorders where the human body gets traumatized in either a minor or major way over a period of time. These disorders are caused in most of the industries where the workers work day and night for their bread and butter without having any sufficient knowledge how to pursue their work so as to have the right balance between health and money earned [1]-[7]. Normally it is observed that workers tend to exert their body to such undesirable levels that it becomes difficult for themselves even to bear the pain which occurs after some time.

Main Causes of MSD’s that were observed in Lathe machine workers are:-

- Prolonged unhealthy posture while working.
- Lower back support is inadequate for the worker.
- Continuous bending of the spinal cord.

- Set up of the workstation is ergonomically poor.
- Adverse work environment.
- Continuous lifting of heavy automobile components from ground height.

Thus the challenges in designing the workstation for repetitive lifting task workers can be broadly categorized as follows:
a. Optimizing differential lifting heights
b. Minimizing musculoskeletal disorders
c. Increasing the efficiency of workers
This paper concentrates on minimizing musculoskeletal disorders for lathe machine workers of automobile industry. Initially brief overview of main artificial intelligent techniques is presented then illustration is given in which FUZZY model is developed followed by results and conclusions.

2. ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI) is the area of computer science focusing on creating machines that can engage on behaviors that humans consider intelligent. The ability to create intelligent machines has intrigued humans since ancient times and today with the advent of the computer and 50 years of research into AI programming techniques, the dream of smart machines is becoming a reality. Researchers are creating systems which can mimic human thought, understand speech, beat the best human chess player, and countless other feats never before possible. Main branches of AI are, Expert Systems (ESs), Artificial Neural Networks (ANNs), Genetic Algorithms (GAs) and Fuzzy Logic (FL) In the past various AI techniques have been used in robotics, pattern recognition, forecasting, , manufacturing, optimization, signal processing, etc. These techniques are particularly useful in system modelling where complexities involved are very high [8]-[10]. Brief overview of different artificial intelligent techniques is as follows:

2.1 Artificial Neural Networks

An artificial neural network (ANN) is a mathematical model that is inspired by the structure and/or functional aspects of biological neural networks. Artificial neural network consists of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. Modern neural networks are non-linear statistical data modeling tools which are usually used to model complex relationships between inputs and outputs or to find patterns in data. An ANN is typically defined by three types of parameters:

1. The interconnection pattern between different layers of neurons
2. The learning process for updating the weights of the interconnections
3. The activation function that converts a neuron's weighted input to its output activation.

There are three major learning paradigms, each corresponding to a particular abstract learning task. These are supervised learning, unsupervised learning and reinforcement learning.

In supervised learning, we are given a set of example pairs $(x,y), x \in X, y \in Y$ and the aim is to find a function $f: X \rightarrow Y$ in the allowed class of functions that matches the examples. In other words, we wish to infer the mapping implied by the data; the cost function is related to the mismatch between our mapping and the data and it implicitly contains prior knowledge about the problem domain. Tasks that fall within the paradigm of supervised learning are pattern recognition (also known as classification) and regression (also known as function approximation). The supervised learning paradigm is also applicable to sequential data (e.g., for speech and gesture recognition).

In unsupervised learning, some data x is given and the cost function to be minimized, that can be any function of the data x and the network's output, f. The cost function is dependent on the task (what we are trying to model) and our a priori assumptions (the implicit properties of our model, its parameters and the observed variables). Tasks that fall within the paradigm of unsupervised learning are in general estimation problems; the applications include clustering, the estimation of statistical distributions, compression and filtering.

In reinforcement learning, data x are usually not given, but generated by an agent's interactions with the environment. At each point in time t, the agent performs an action y_t and the environment generates an observation x_t and an instantaneous cost c_t, according to some (usually unknown) dynamics. The aim is to discover a policy for selecting actions that minimizes some measure of a long-term cost; i.e., the expected cumulative cost. The environment's dynamics and the long-term cost for each policy are usually unknown, but can be estimated [11], [12].

2.2 Fuzzy Logic

Fuzzy logic is a form of many-valued logic; it deals with reasoning that is fixed or approximate rather than fixed and exact. In contrast with "crisp logic", where binary sets have two-valued logic: true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions.Fuzzy logic began with the 1965 proposal of fuzzy set theory by Lotfi Zadeh. Though fuzzy logic has been applied to many fields, from control theory to artificial intelligence, it still remains controversial among most statisticians, who prefer Bayesian logic, and some control engineers, who prefer traditional two-valued logic. [13]-[20]

2.3 Genetic Algorithm

A genetic algorithm (GA) is a search heuristic that mimics the process of natural evolution. This heuristic is routinely used to generate useful solutions to optimization and search problems. Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover. In a genetic algorithm, a population of strings (called chromosomes or the genotype of the genome), which encode candidate solutions (called individuals, creatures, or phenotypes) to an optimization problem, evolves toward better solutions. Traditionally, solutions are represented in binary as strings of 0s and 1s, but other encodings are also possible. The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. If the algorithm has terminated due to a maximum number of generations, a satisfactory solution may or may not have been reached.

A standard representation of the solution is as an array of bits. Arrays of other types and structures can be used in essentially the same way. The main property that makes these genetic representations convenient is that their parts are easily aligned due to their fixed size, which facilitates simple crossover operations. Variable length representations may also be used, but crossover implementation is more complex in this case. Tree-like representations are explored in genetic programming and graph-form representations are explored in evolutionary programming. Once we have the genetic representation and the fitness function defined, GA proceeds to initialize a population of solutions randomly, and then improve it through repetitive application of mutation, crossover, inversion and selection operators.

2.4 Expert System

An expert system uses a knowledge base of human expertise for problem solving, or to clarify uncertainties where normally one or more human experts would need to be consulted. A wide variety of methods can be used to simulate the performance of the expert; however, common to most or all are the creation of a knowledge base which uses some knowledge representation structure to capture the knowledge of the Subject Matter Expert (SME); a process of gathering that knowledge from the SME and codifying it according to the structure, which is called knowledge engineering; and once the system is developed, it is placed in the same real world problem solving situation as the human SME, typically as an aid to human workers or as a supplement to some information system. Expert systems may or may not have learning components.

There are various expert systems in which a rule base and an inference engine cooperate to simulate the reasoning process that a human expert pursues in analyzing a problem and arriving at a conclusion. In these systems, in order to simulate the human reasoning process, a vast amount of knowledge needs to be stored in the knowledge base. Generally, the knowledge base of such an expert system consists of a relatively large number of "if/then" type statements that are interrelated in a manner that, in theory at least, resembles the sequence of mental steps that are involved in the human reasoning process. Because of the need for large storage capacities and related programs to store the rule base, most expert systems have, in the past, been run only on large information handling systems. [21]-[23]

3. ILLUSTRATION: MINIMIZING MUSCULOSKELETAL DISORDERS USING FUZZY LOGIC

A fuzzy model has been designed as shown in Fig. 1 and tested for minimizing musculoskeletal disorders within lathe machine workers. In this application a fuzzy model is built with the collected data to forecast MSD's. For the SUBJECT data was collected with four inputs:

(a) Age of the SUBJECT
(b) Weight lifted
(c) Frequency of Lift
(d) Lifting Height.

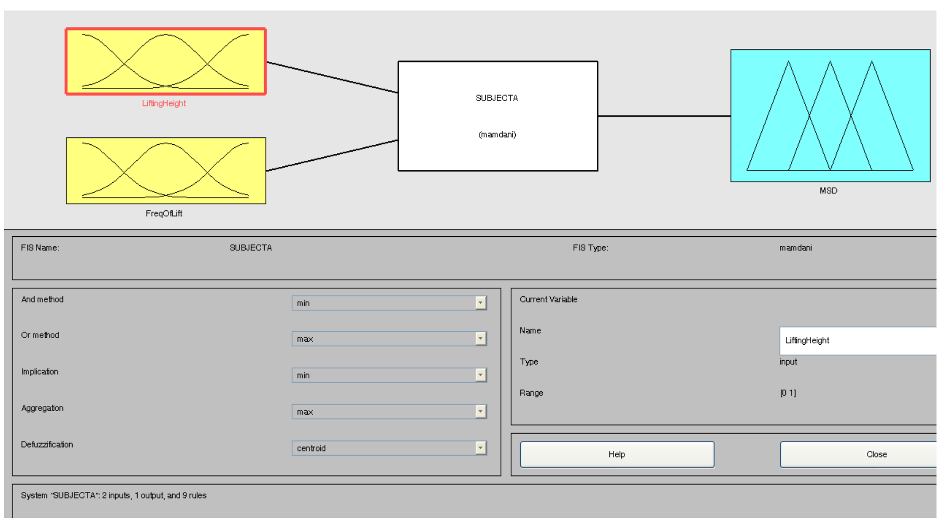

FIGURE 1: Fuzzy Model

Experimentation was done on the four SUBJECTS i.e. A, B, C and D of age groups between 25 to 35 years and their EEG was recorded. SUBJECTS were asked to lift multi cylinder crank shaft weighing 24 kgs. Based on the lifting sessions their EEG was recorded and the value of the musculoskeletal disorder was taken based on the graphs variation from the mean. The values of the four inputs were normalized and were taken as the input data. EEG of the subject is shown in Fig. 2

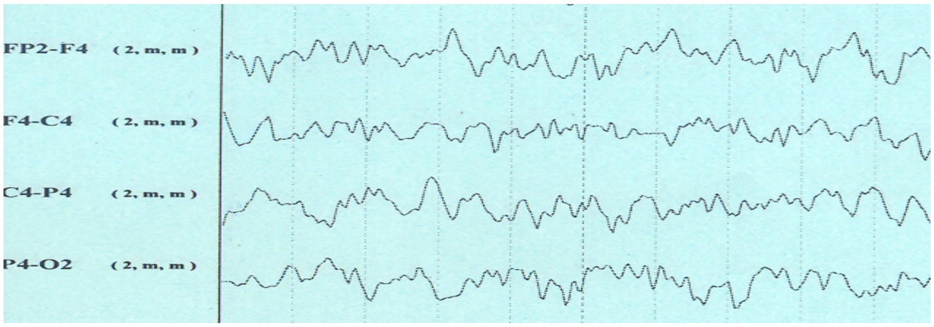

FIGURE 2: Electroencephalography

3.1 Design of Membership Functions

For developing our fuzzy model we used triangular membership functions for inputs as well as outputs. The membership functions are been overlapped as shown in Fig. 3 which gives the flexiblility to describe one fuzzy set only. The values for these fuzzy sets have been normalized in the range of [0.0, 1.0].

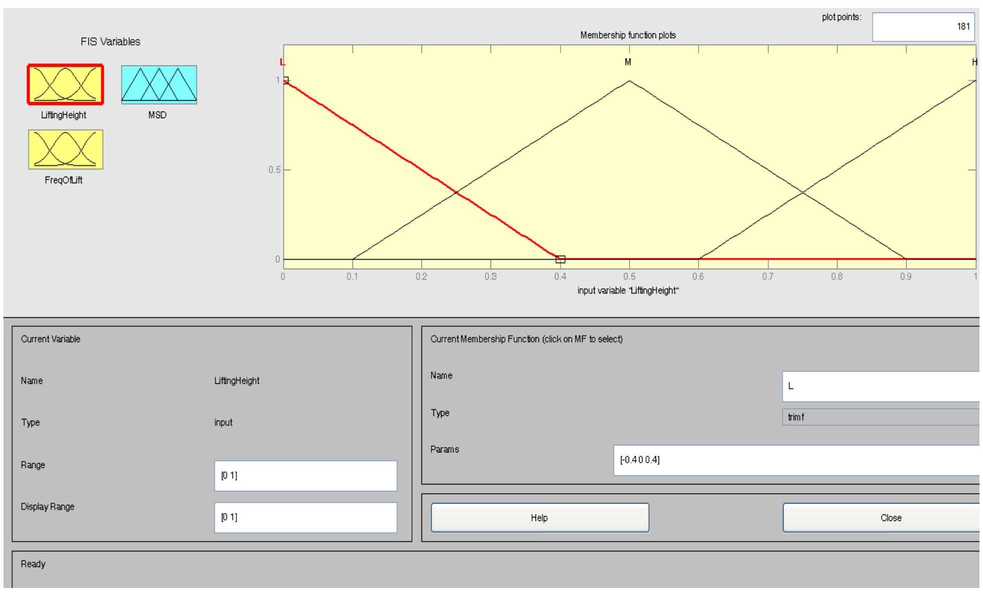

FIGURE 3. Membership Function

4. Output

Rule Viewer in Fig. 4 shows the output for the SUBJECTS taken within the age group of 25 to 35 years. If the value of the respective inputs is given to the fuzzy model then the prediction of musculoskeletal disorder developing within the SUBJECT body is known. The Surface View of the four SUBJECTS is shown in Fig. 5. MSD’s for three other SUBJECTS can be viewed in Table 1

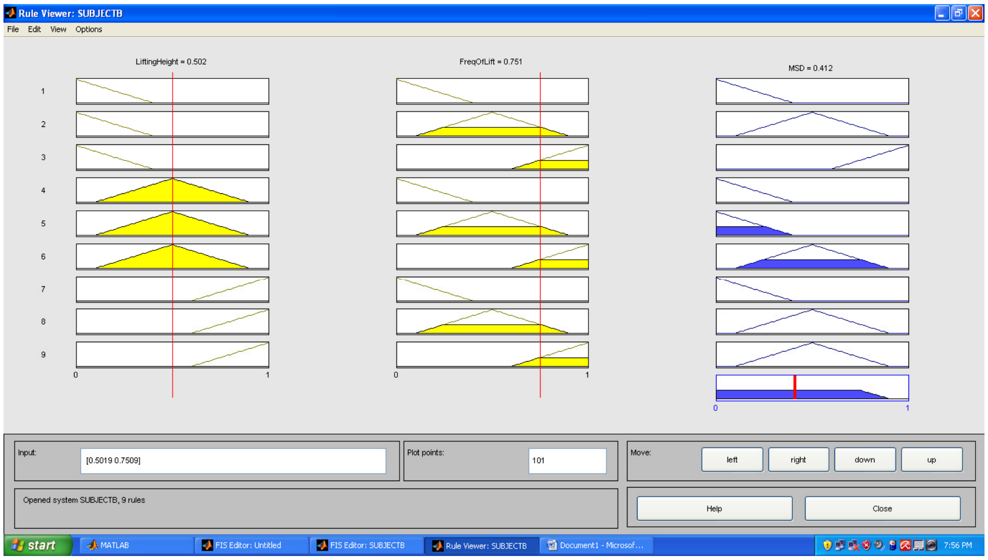

FIGURE 4. Rule Viewer

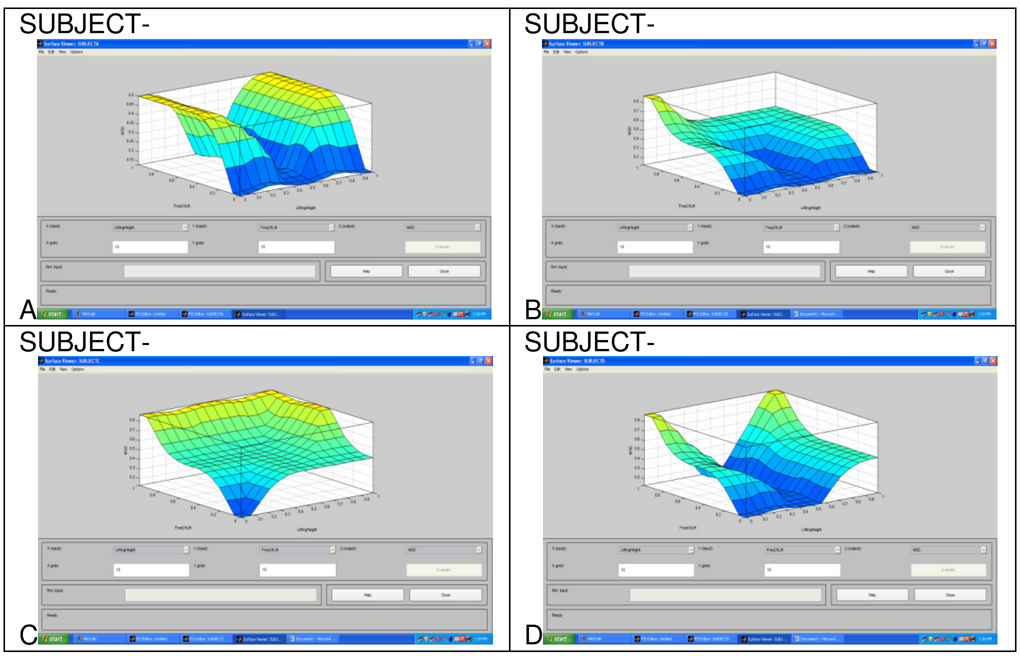

FIGURE 5. Surface View

SUBJECT E	Input 1 Lifting height	Input 2 Frequency of Lift	Output MSD
	.166	.176	.322
	.166	.504	.472
	.166	.837	.475
	.502	.163	.146
	.502	.493	.149
	.502	.803	.152

	.771	.167	.332
	.771	.507	.429
	.771	.796	.431
SUBJECT F	Input 1	Input 2	Output
	Lifting height	Frequency of Lift	MSD
	.17	.193	.344
	.17	.496	.477
	.17	.74	.543
	.502	.215	.156
	.502	.5	.149
	.502	.751	.312
	.774	.178	.345
	.774	.504	.432
	.774	.811	.453
SUBJECT G	Input 1	Input 2	Output
	Lifting height	Frequency of Lift	MSD
	.177	.159	.351
	.177	.504	.5
	.177	.792	.635
	.508	.193	.5
	.508	.5	.5
	.508	.781	.622

TABLE 1: Results of FUZZY Model

5. CONCLUSION

In this particular application, the fuzzy model predicted the musculoskeletal disorders for 25 to 35 years age group lathe machine workers. With the help of this model, it would be easier for the industries to make their workers comfortable by predicting the MSD's that could occur in their body due to repetitive lifting task. The management now could give the suitable lifting zone to the workers so that the chances of occurrence of MSD is minimized which has been the drawback till date as various researchers did give the proof of occurrence of MSD's but never gave the solution. Hence for the selected age group workers the normalized value of lifting zone should be in between 0.5 to 0.69 and the frequency of lift should be in between 0.01 to 0.2. Thus with this simulation both the management and the workers are in win-win situation as the overall workers health is taken care of and the causes of absenteeism of the workers is substantially reduced as the chances of occurrence of MSD's is minimized.

This fuzzy model as such does not model other machine workers engaged in performing different tasks, but they can be used to forecast with a separate network of a similar kind but with a different rules. To make this fuzzy model more general and foolproof, extra parameters such as temperature, humidity, etc. can be helpful for minimization of musculoskeletal disorders.

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