Introduction and Objectives

Decision makers throughout the country face the challenge of managing their pavement networks every year. One essential aspect of pavement management is accurately understanding what the condition of the network is. The network condition is determined by visual inspection, also known as a Windshield Survey, using a series of ratings to represent pavement distress conditions. The Federal Highways Administration published the Distress Identification Manual for the Long-Term Pavement Performance Program which details the distress rating system. An example of rating the Fatigue distress is as follows:

The ratings are then related to a Remaining Service Life (RSL) in a table such as the following:

<table>
<thead>
<tr>
<th>Severity</th>
<th>None</th>
<th>High</th>
<th>Med</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extent</td>
<td>None</td>
<td>Med</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

It is often the case that the ratings given do not accurately represent the pavement condition because of several factors including the inspector mistaking one distress for another such as Fatigue for Block Cracking, estimating the wrong severity, estimating the wrong extent, and variations in the RSL corresponding to a certain rating. Until now, these inconsistencies have been ignored. The Fuzzy Logic method is one method for accounting for these variations.

Fuzzy Inference System

The Fuzzy Inference System uses probability functions called membership functions to give a probabilistic estimate of an outcome given certain conditions. It uses the theory of Fuzzy Sets, which is the theory that relates classes of objects with un-sharp boundaries in which membership is a matter of degree. In this instance the objects are the condition ratings and corresponding remaining service life, and the un-sharp boundaries are the severity and extent of the ratings. MatLab has a fuzzy logic toolbox that makes this process extremely simple. For more information on Fuzzy Logic, one good resource is the MatLab Fuzzy Logic Toolbox 2 User’s Guide.

Defining Input Membership

The first step in the fuzzy inference system is to define the probability that the rating given by the inspector accurately represents the extent and severity of the distresses. This probability can be defined in a function called the membership function. One such example of a membership function for the Fatigue rating is shown below.

Defining Output Membership

The second step is to define the probability that the ratings given in the previous step actually correlate to a certain pavement condition. This membership function would be determined by the pavement engineer based on past experience with pavement evaluations. An example of this membership function based on the input shown previously is shown below.

Aggregate All Outputs

Aggregation is the process by which the outputs of each of the previous membership functions are combined into a single result. In our example, the severity and extent defined in the input membership functions are aggregated together to return a final condition index. This process is accomplished by truncating the output membership function by the value of the input membership functions given an input for each input membership function. The truncated output functions are then aggregated together to form the result. This resulting function represents the probability that the inputs correlate to a certain output. This process is better explained graphically as follows.

Defuzzification

Defuzzification is the final process that takes the resulting probability function and estimates an average output value by calculating the centroid of the function. The corresponding “x” value of the centroid represents the average output value.

In this example the RSL can be calculated from the PCR given a pavement deterioration curve. This work does not attempt to define the pavement deterioration curve, but assumes a second order parabolic curve. For the example given, the RSL corresponding to the distress rating given is the difference between the time value for the condition calculated in the fuzzy Inference system, and the time of terminal failure for the pavement. This is shown in the following figure.

The final results can be shown as a surface plot representing the RSL values given the severity and extent.

Summary and Results

The fuzzy inference system accounts for human error in windshield surveys by applying the theory of Fuzzy Sets. The probabilities that the rating assigned by the inspector is representative, and that the corresponding RSL assigned is also representative, can now be considered in analysis. The method outlined thus far can be applied to all the ratings.

Future research would include more clearly defining the membership functions for the condition index as well as the severity and extent.

More Information

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