■ OBJECT AND MATERIAL EIGENFUNCTIONS – Cont'd.

• Laplacian eigenfunctions and neural networks:...

THE DEFINITION OF THE PER-FORMANCE FUNCTION IS OF SUPREME IMPORTANCE! All classification system parameter values and data processing steps will be "fine-tuned" to obtain optimal, or near-optimal, classification performance. The following questions – and their answers – lead to considerations for proper definition of system performance:

- What are appropriate danger levels one should assign to material classes $1,..., C$?

- What is the (estimated) impact, threat or damage that results when classifying class cl, $cl \in \{1,...,C\}$, as class 0 (false negative), i.e., FN_{cl}?

- What is the (estimated) cost or impact that results when classifying class 0 as class cl, $cl \in \{1,...,C\}$ (false positive), i.e., FP_{cl}?

- What is the (estimated) cost, impact or damage that results when classifying class cl, $cl \in \{1,...,C\}$, as class $\overline{cl}$, $\overline{cl} \in \{1,...,C\} \setminus \{cl\}$ (mis-classification), i.e., $MC_{cl,\overline{cl}}$, $cl \neq \overline{cl}$?

- What is the value of a TN result?

- What is the value of a TP_{cl}, $cl \in \{1,...,C\}$, result?

...

■ OBJECT AND MATERIAL EIGENFUNCTIONS - Cont'd.

• Laplacian eigenfunctions and neural networks: ...

cl_1 \ cl_2	O	1	...	C
O	$W_{0,0}$	$W_{0,1}$	...	$W_{0,C}$
1	$W_{1,0}$	$W_{1,1}$	...	$W_{1,C}$
⋮	⋮	⋮	⋮	⋮
C	$W_{C,0}$	$W_{C,1}$	...	$W_{C,C}$

Weight table.

The answers to the questions on the previous page — and additional relevant considerations — must guide the definition of the values in a "weight table" (left figure). The weight W_{cl_1, cl_2} defines the weight for classifying a material that actually is a class-cl_1 material as a material declared as a class-cl_2 material.

• THROUGHOUT IT IS ASSUMED THAT A CLASS-O MATERIAL IS NOT DANGEROUS AND THAT ALL CLASS-cl MATERIALS, $cl = 1, ..., C$, ARE DANGEROUS — ORDERED LINEARLY BY DEGREE OF DANGER, WHERE $cl = C$ REPRESENTS MAXIMAL DANGER.

It is imperative to keep in mind and consider the exact meaning of a weight W_{cl_1, cl_2} — and thus its proper use in the design of a performance function. We discuss all relevant cases in detail.

• $W_{0,0}$ Weight of a TN classification, i.e., weight of classifying a non-dangerous material as a non-dangerous material; the value of $W_{0,0}$ should impact performance "positively." •••

■ OBJECT AND MATERIALS EIGENFUNCTIONS – Cont'd.

- Laplacian eigenfunctions
  and neural networks:...

- $W_{i,i}$, $i \in \{1,...,C\}$

  Weight of a TP classifi-
  cation of a dangerous
  class-i threat material,
  i.e., weight of classifying a dangerous
  class-i material as a dangerous class-i
  material; the value of a weight $W_{i,i}$
  should impact performance "positively"
  — and one might consider using a
  monotonically increasing value sequence
  satisfying $W_{0,0} \leq W_{1,1} \leq W_{2,2} \leq ... \leq W_{C,C}$.

- $W_{i,j}$, $i,j \in \{1,...,C\}$, $i < j$

  Weight of an MC classification (mis-
  classification) of a dangerous class-i
  threat material, i.e., weight of classi-
  fying a dangerous class-i material wrongly
  as an even more dangerous class-j ma-
  terial; the value of a weight $W_{i,j}$ should
  impact performance "negatively," since
  a "class-j alarm" causes more expensive
  threat reaction steps than a "class-i alarm"
  — and one might consider using a mono-
  tonically decreasing value sequence satis-
  fying $(W_{i,i} >) W_{i,i+1} \geq W_{i,i+2} \geq W_{i,i+3} \geq ... \geq W_{i,C}$,
  $i = 1,...,(C-1)$.

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■ OBJECT AND MATERIAL EIGENFUNCTIONS – Cont'd.

• Laplacian eigenfunctions and neural networks: ...

• $w_{0,j}$, $j \in \{1, ..., C\}$

Weight of an FP classification of a non-dangerous class-0 material,

i.e., weight of classifying a non-dangerous class-0 material as a dangerous class-j threat material; the value of a weight $w_{0,j}$ should impact performance "negatively," since a "class-j alarm" causes expensive threat reaction steps — and one might consider using a monotonically decreasing value sequence satisfying $(w_{0,0} >) w_{0,1} \geq w_{0,2} \geq ... \geq w_{0,C}$.

• $w_{i,j}$, $i, j \in \{1, ..., C\}$, $i > j$

Weight of an MC classification (misclassification) of a dangerous class-i threat material, i.e., weight of classifying a dangerous class-i material wrongly as a less dangerous class-j material; the value of weight $w_{i,j}$ should impact performance "negatively," since a "class-j alarm" does not cause all necessary threat reaction steps that are required for a more dangerous "class-i alarm" — and one might consider using a monotonically increasing value sequence satisfying $w_{i,1} \leq w_{i,2} \leq ... \leq w_{i,i-1} (< w_{i,i})$, $i = 2, ..., C$.

...

■ OBJECT AND MATERIAL EIGENFUNCTIONS – Cont'd.

• <u>Laplacian eigenfunctions and neural networks</u>: ... • $W_{i,0}$, $i \in \{1, ..., C\}$

Weight of an FN classi-fication of a dangerous class-i threat material, i.e., weight of classifying a dangerous class-i material wrongly as a non-dangerous class-0 material; the weight $w_{i,0}$ should have a value that impacts performance "negatively," since a class-0 classification implies that no threat reaction steps are taken — and one might consider using a monotonically decreasing value sequence satisfying $(W_{0,0} >) W_{1,0} \geq W_{2,0} \geq ... \geq W_{C-1,0} \geq W_{C,0}$.

This detailed discussion of all weights $W_{c l_1, c l_2}$ provides us with the semantically meaningful condi-tions, in a qualitative sense, to be satisfied when defining the actual weight values, quanti-tatively. Before we discuss the more detailed establishment of weight values for a performance function in the general multi-class setting, we consider first the binary classification case. Thus, we are only concerned with weights $W_{0,0}$ (TN), $W_{0,1}$ (FP), $W_{1,0}$ (FN) and $W_{1,1}$ (TP). We will adopt a combinatorial, stochastic viewpoint to analyze the binary case.
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