LLNL Presentation for ALERT AATR Program Review

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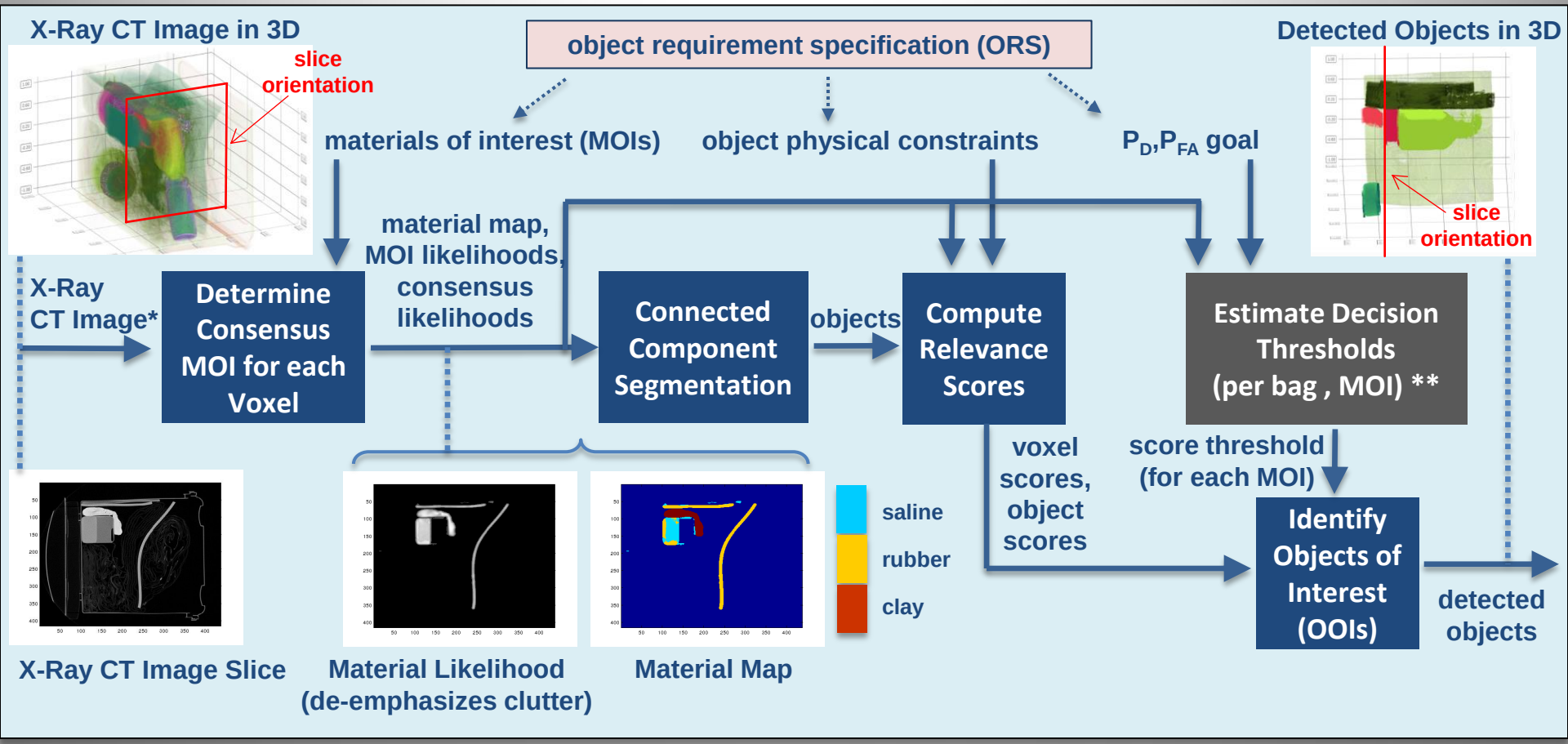
Executive Summary of LLNL's AATR



The OOIs considered were limited to saline, clay and rubber. However, OOIs could be defined for explosives, drugs or other contraband.

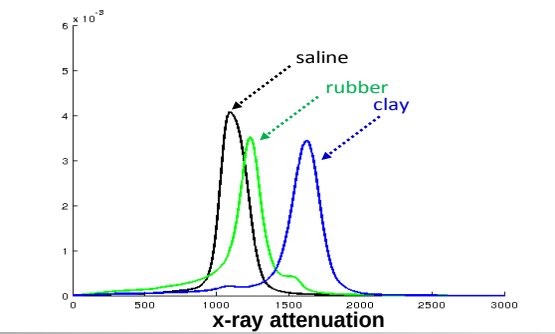
* It is assumed that the input X-Ray CT image has been corrected for artifacts.

** Automatic decision threshold estimation is on-going.

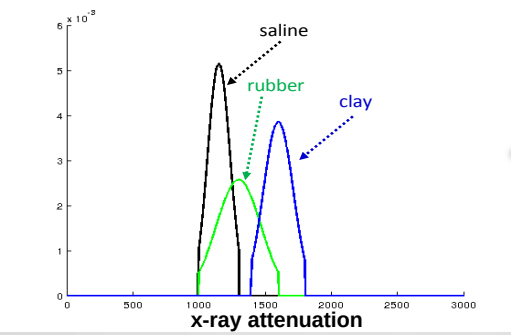
LLNL's AATR takes an ORS with 3 Elements as Input

Element that Prescribes Materials of Interest (MOIs)

sample PDFs *
(from voxels labeled by material type)

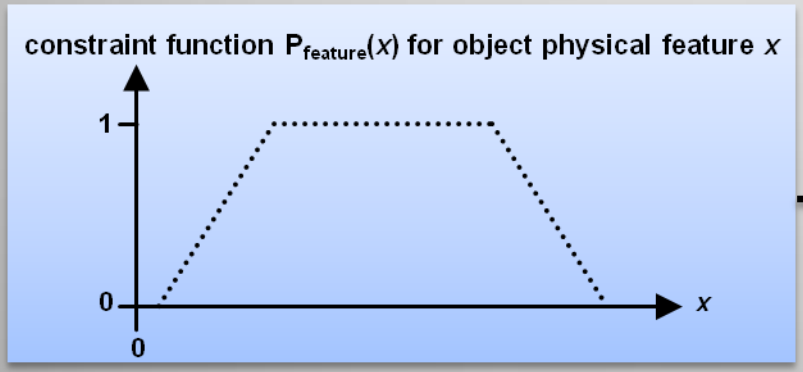


ROR-based PDFs
(emulate sample PDFs)



- **A region of responsibility (ROR) is a range of x-ray attenuations.**
- **An ROR is normally supplied for each MOI, and a PDF is fit to it.**
- **AATR performance is limited by the domain, shapes and overlaps in MOI PDFs.**
- **For our experiments, the MOIs were limited to saline, clay and rubber. However, OOIs could be defined for explosives, drugs or other contraband.**

Element that Prescribes Object Features of Interest (FOIs)



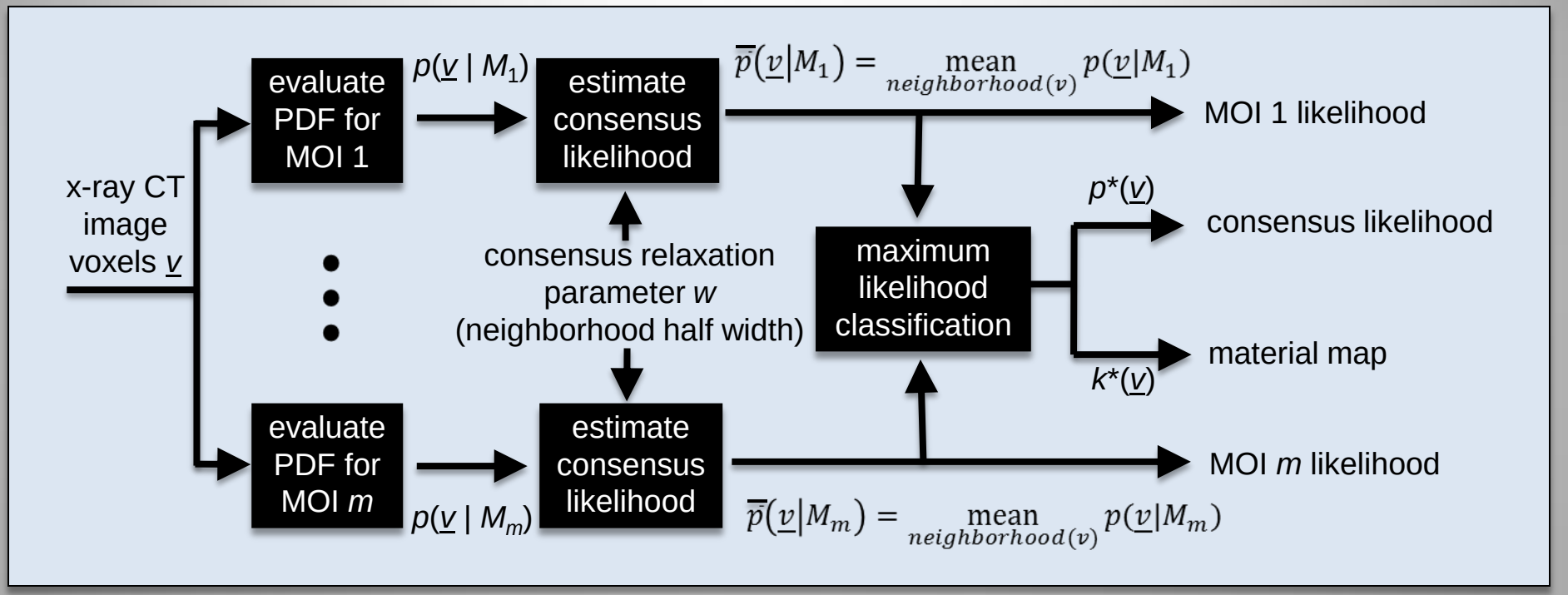
- **Since OOIs can potentially come in all shapes and sizes, we currently limit the FOIs to mass and thickness, which are very general physical features.**
- **Voxel mass is estimated from voxel dimensions, voxel linear attenuation coefficients (LACs) and a constant that relates LACs to mass per unit volume.**
- **Object thickness is estimated in 3 orthogonal passes over the map of segment IDs. Accuracy of estimate degrades for thin objects.**

Optional Element that Prescribes (P_D,P_{FA}) Goal

A detection and false alarm probability (P_D,P_{FA}) goal may be supplied for each MOI.

*** Derived from the ALERT T04 data set**

Consensus Relaxation Transforms X-Ray CT Images into Images of Relevance Scores (no Training Required)



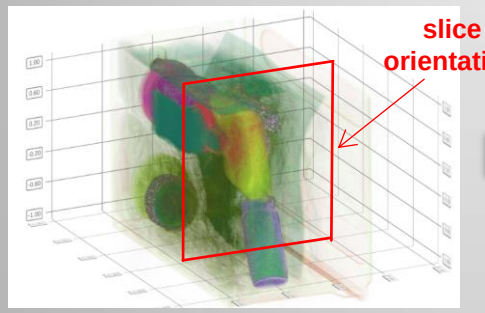
For each x-ray CT image voxel $\underline{v}$, compute the ID $k^*(\underline{v})$ of the most likely material composition (from 1 to m) and the likelihood $p^*(\underline{v})$ of that material. If the likelihood is too small, it is set to zero and the ID of the most likely material composition is set to zero (indicating background).

- For each voxel, a maximum likelihood classifier is applied to its consensus likelihood estimate. This classifier requires an ROR or PDF, but ***NO TRAINING***.

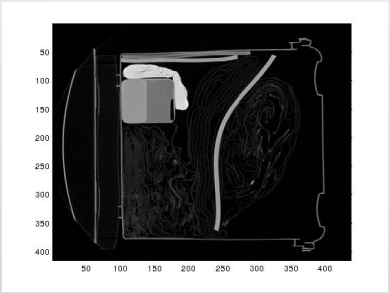
Example: Slices of a Consensus Relaxation Image

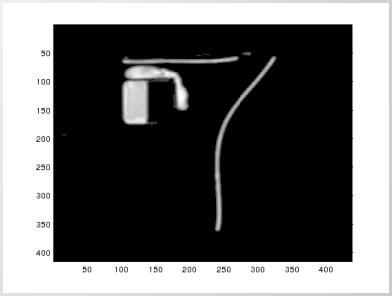
consensus likelihood image slice (clutter is de-emphasized)

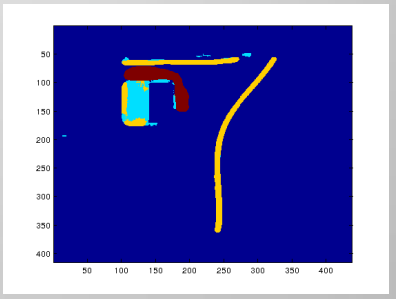
x-ray CT image rendered in 3D *



x-ray CT image slice







saline

rubber

clay

background

material map

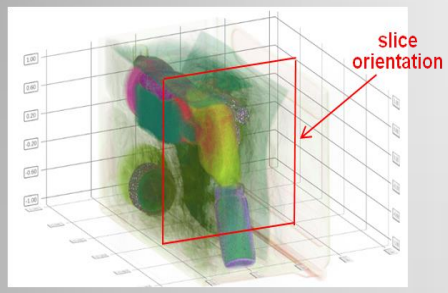
LLNL's AATR de-emphasizes the role of segmentation:

- **Simple connected component segmentation in 3D is applied to material maps with no object splitting or merging.**

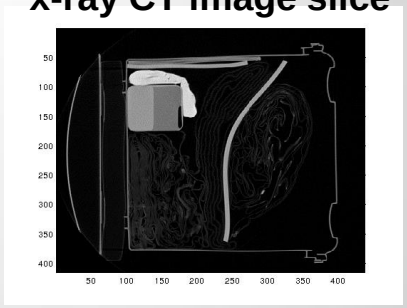
*** Courtesy of the ALERT T04 data set**

Example: Varying the Degree of Consensus Relaxation

x-ray CT image rendered in 3D *

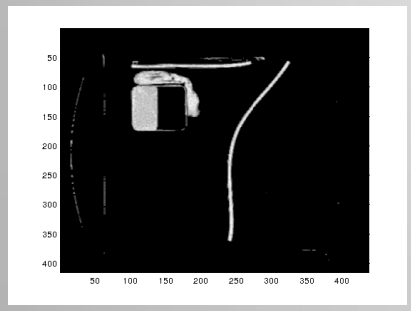


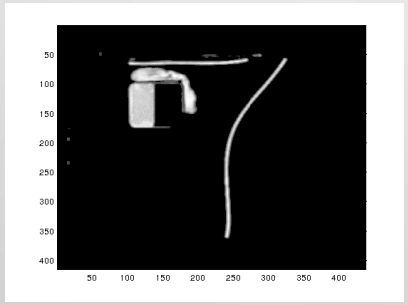
x-ray CT image slice

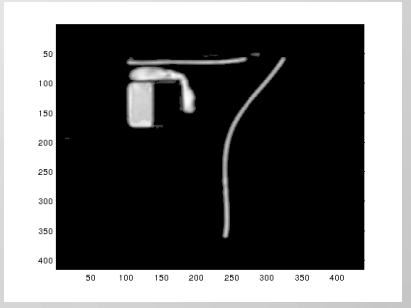


* Courtesy of the ALERT T04 data set

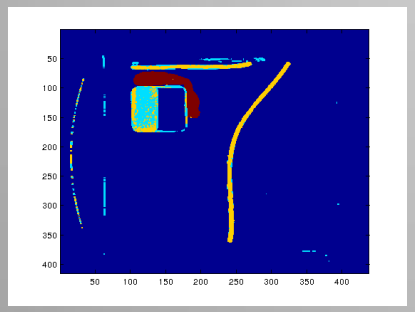
consensus material likelihood

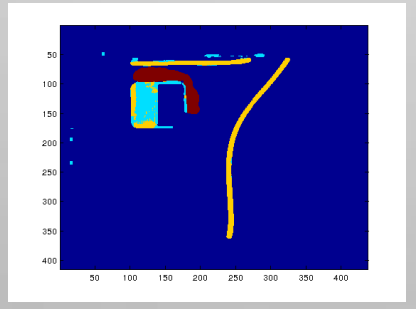


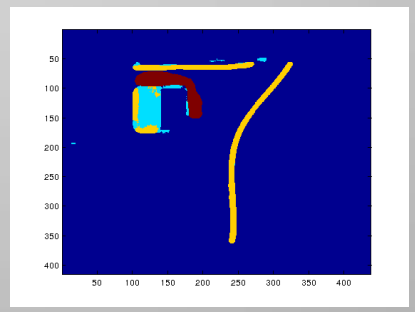




consensus material map







saline
rubber
clay
background

more fragmented / busy

less fragmented / busy

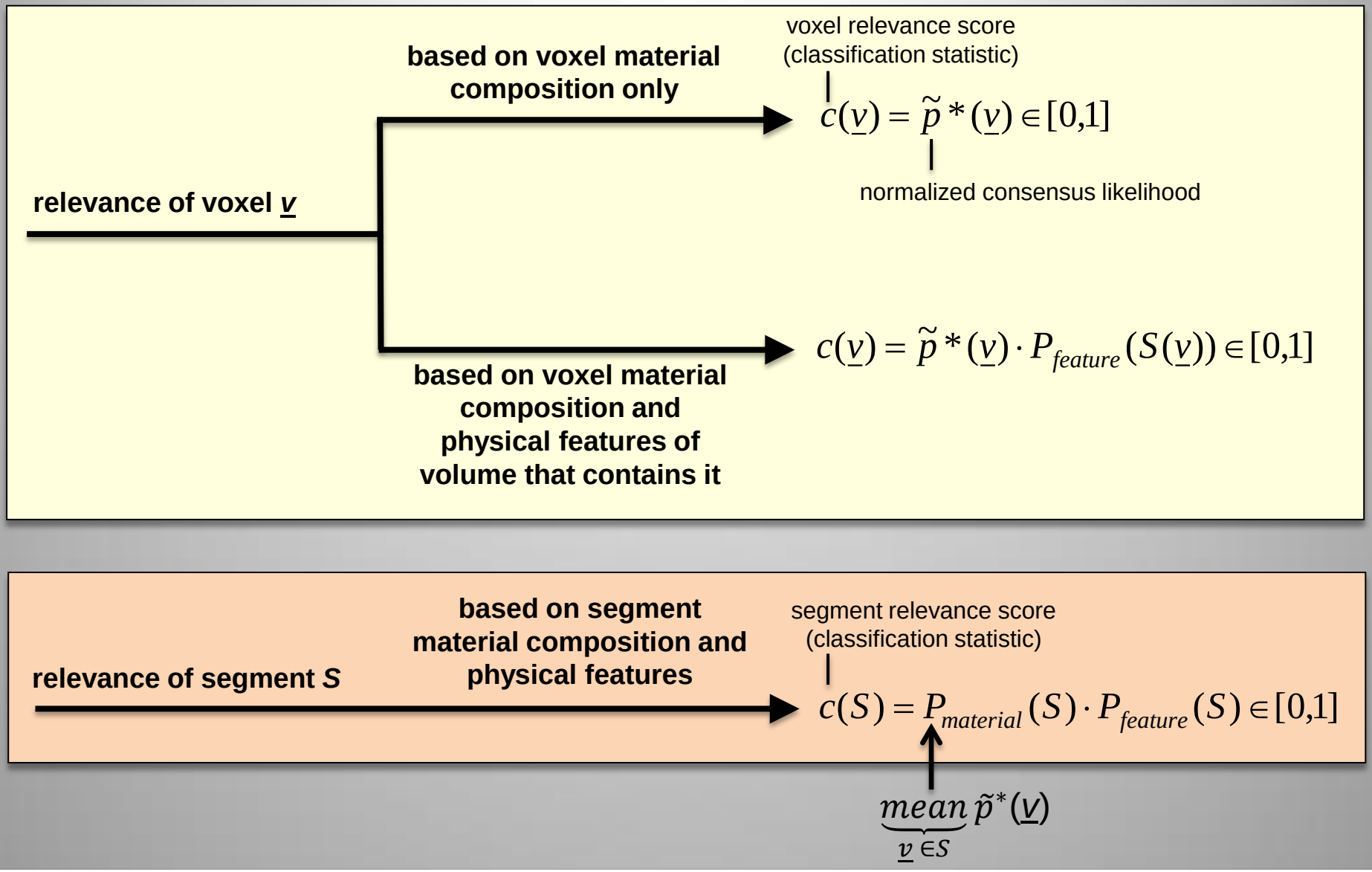
consensus neighborhood half-width (voxels)

w = 1

w = 2

w = 3

Relevance Scores for Voxels and Segments are Related



Performer Training / TO4 Data

AM 1: AROC

OOI	Required PD [%]	Required PFA [%]	AATR PD [%]	AATR PFA [%]
S	70	2	66	20
S	80	5	66	20
S	85	8	66	20
S	90	10	66	20
S	95	20	66	20

AROC	NOT DEFINED

AM 2: PD/PFA for Varying OOIs

OOI	Required PD [%]	Required PFA [%]	AATR PD [%]	AATR PFA [%]
C,S,R	90	10	82	24
C	90	10	95	24
S	90	10	72	24
R	90	10	82	24

AM 3: Varing PD Weight

OOI	Req PD [%]	Req PFA [%]	AATR PD [%]	AATR PFA [%]
C,S	C:90, S:90	10	C: 95, S: 66	26
C,S	C:20, S:90	10	C: 95, S: 66	26
C,S	C:90, S:20	10	C: 95, S: 66	26

AM 4: PD/PFA for Varying Mass

OOI	Min Mass [g]	Required PD [%]	Required PFA [%]	AATR PD [%]	AATR PFA [%]	Incremental Mass Rnge [g]	AATR Incremental PD [%]
S	400	90	10	53	11	N/A	N/A
S	300	90	10	22	6	300 - 400	33
S	100	90	10	50	16	100 - 300	53

AM 5: PD/PFA for Varying Thickness

OOI	Min Thickness [mm]	Required PD [%]	Required PFA [%]	AATR PD [%]	AATR PFA [%]	Incremental Thickness Rnge [mm]	AATR Incremental PD [%]
R	10	90	10	68	16	N/A	N/A
R	6.5	90	10	18	2	6.5 - 10	30
R	0	90	10	5	1	0 – 6.5	12

ALERT Testing / TO7 Data

AM 2: PD/PFA for Varying OOIs

OOI(s)	Required PD [%]	Required PFA [%]	AATR PD [%]	AATR PFA [%]
m1	90	10	94	11
m2	90	10	86	4
m3	90	10	85	2
m4	90	10	80	1

On-Going Efforts to Improve Performance Characterization and LLNL's AATR

- LLNL's AATR will soon be able to automatically estimate suitable decision thresholds on relevance scores that vary from image to image and MOI to MOI.
  - By allowing AATR decision thresholds to adapt to different MOIs and to the clutter in different bags, a level of performance that exceeds what the ROC curve predicts can potentially be achieved.

- LLNL has developed a (P_D,P_{FA}) performance measure based on similarity between consensus and ground truth images (NOT between image segments).
  - Unlike measures which match extracted objects to ground truth objects, our proposed measure provides a bag-holistic performance estimate rather than a segmentation performance estimate (i.e., it does not focus solely on how accurately objects extracted by the segmenter match ground truth objects).
  - The proposed method requires no heuristics on degree of overlap between extracted and ground truth objects.
  - Performance estimates will vary gradually (not abruptly) with gradual changes in extracted or ground truth objects.