

# Label Space

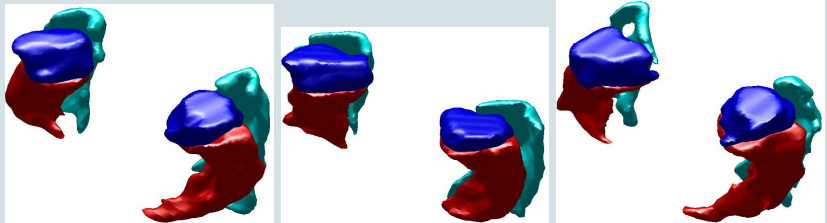
## A Coupled Multi-Shape Representation

James Malcolm<sup>1</sup>  
Martha E. Shenton<sup>2</sup>

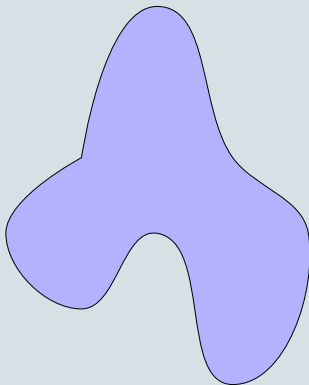
Yogesh Rathi<sup>2</sup>  
Allen Tannenbaum<sup>1</sup>

Georgia Tech, Atlanta, GA  
Brigham and Women's Hospital, Boston, MA



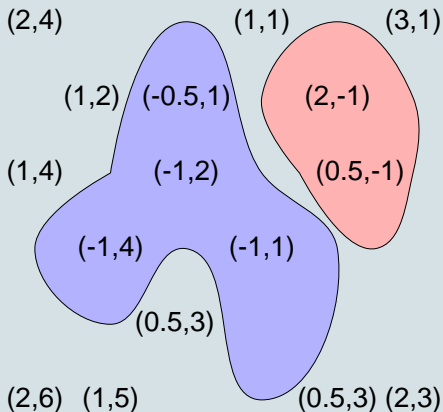


# Implicit maps



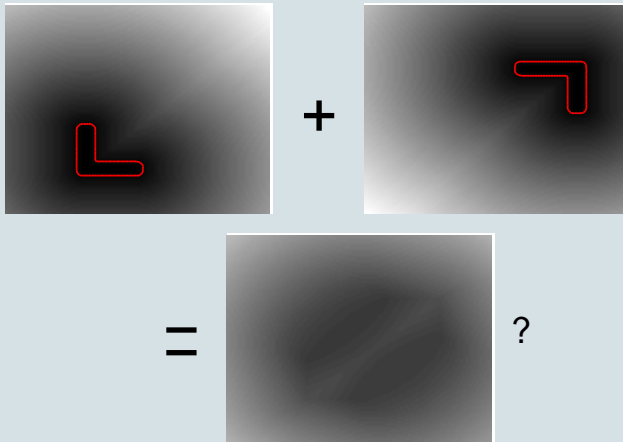


## Layered signed distance maps

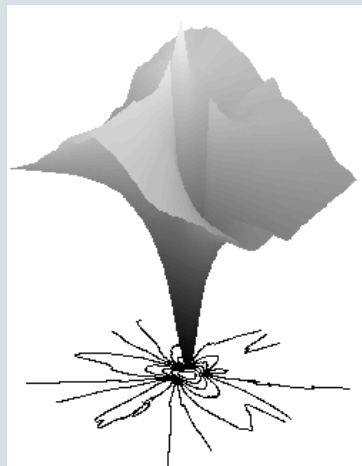
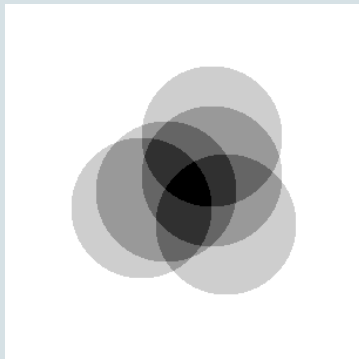


[Tsai et al. MIA, TMI 2003], [El Munim and Farag CVPR 2007]

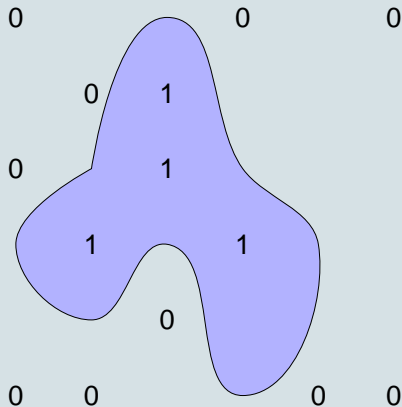
## SDM Addition



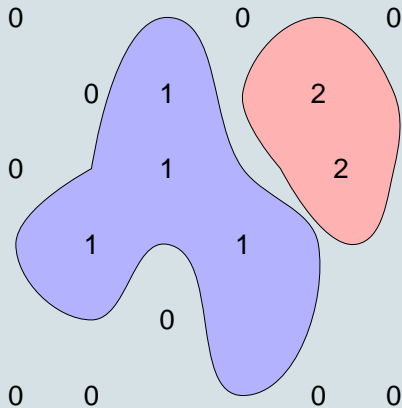
## SDM Variation



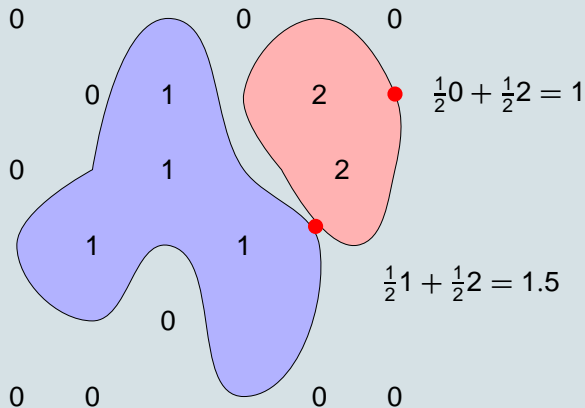
## Label maps



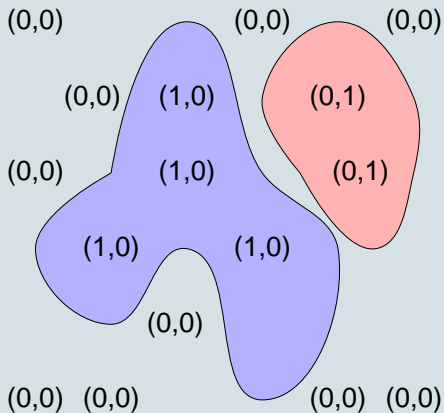
## Label maps



## Label maps

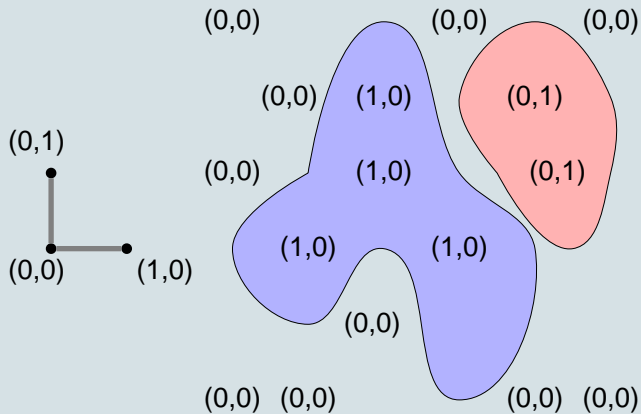


## Binary vector maps



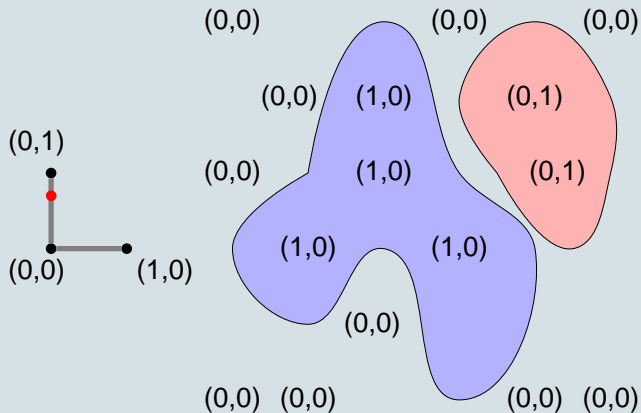
[Tsai et al. MedIA, TMI 2003]

## Binary vector maps



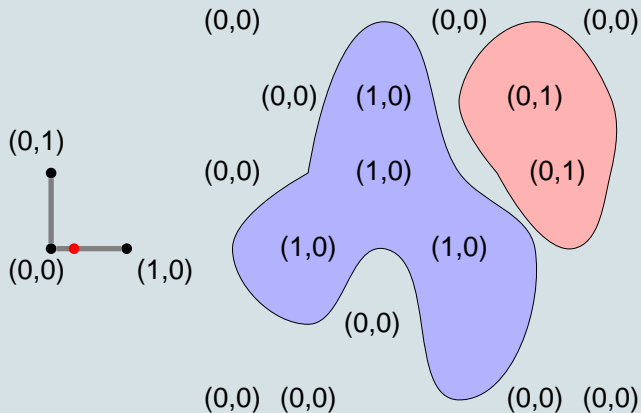
[Tsai et al. MedIA, TMI 2003]

## Binary vector maps



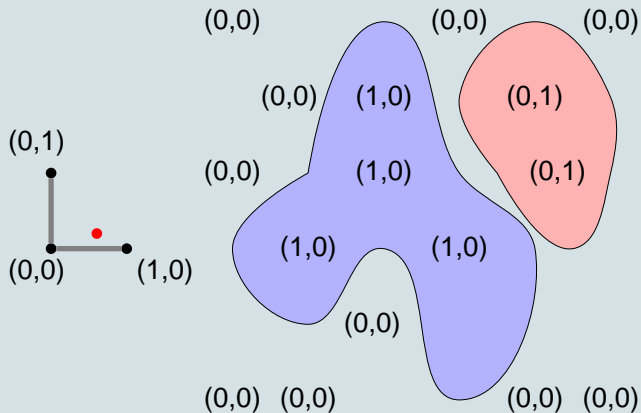
[Tsai et al. MedIA, TMI 2003]

## Binary vector maps



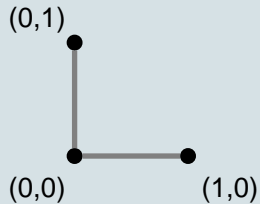
[Tsai et al. MedIA, TMI 2003]

## Binary vector maps

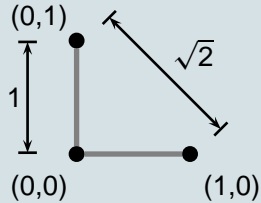


[Tsai et al. MedIA, TMI 2003]

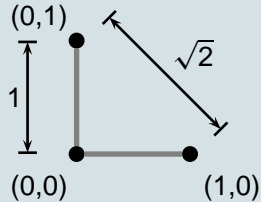
## Binary vector bias



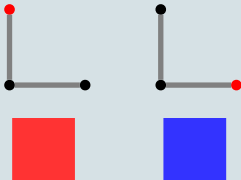
## Binary vector bias



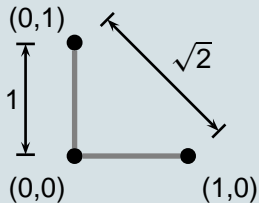
## Binary vector bias



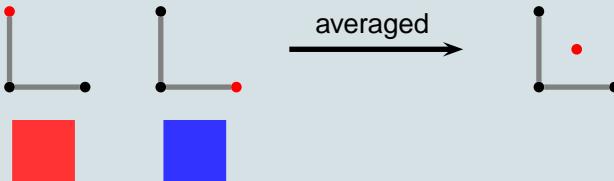
Smoothing: two labels, background



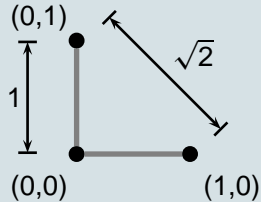
## Binary vector bias



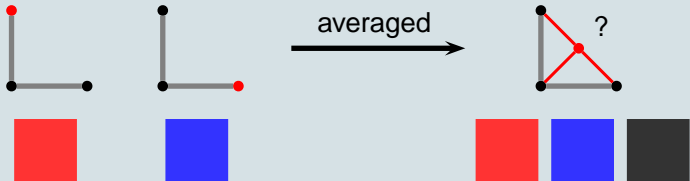
Smoothing: two labels, background



## Binary vector bias

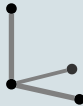


Smoothing: two labels, background



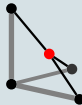
## Binary vector bias

Smoothing: three labels, background



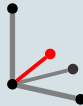
## Binary vector bias

Smoothing: three labels, background



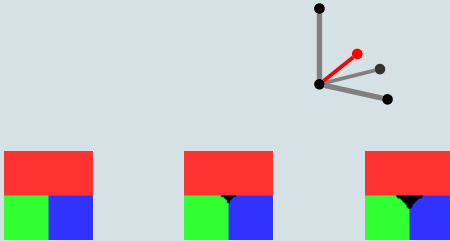
## Binary vector bias

Smoothing: three labels, background



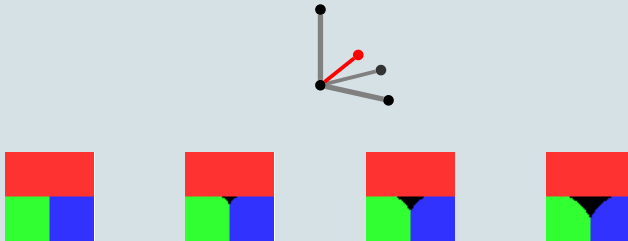
## Binary vector bias

Smoothing: three labels, background



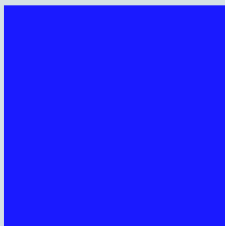
## Binary vector bias

Smoothing: three labels, background

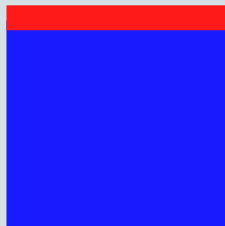


## Binary vector bias

Misalignment during registration:  $E = \|A - B\|^2$



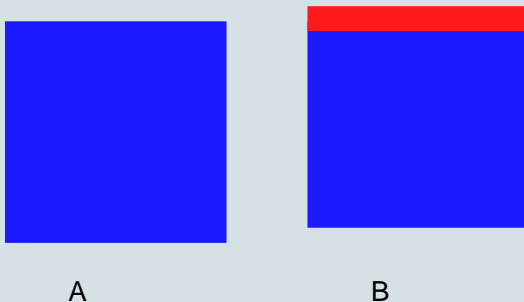
A



B

## Binary vector bias

Misalignment during registration:  $E = \|A - B\|^2$



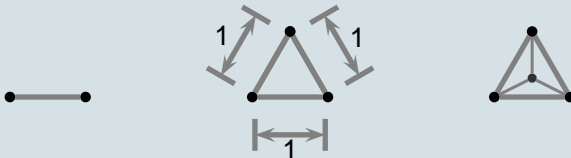
## Recap

- ▶ SDMs: interpolation error, excessive variation
- ▶ Binary vectors: bias affected smoothing, registration

## Label Space



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# Smoothing

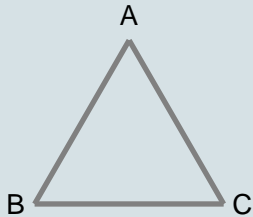
Binary vectors



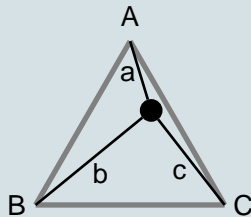
Label space



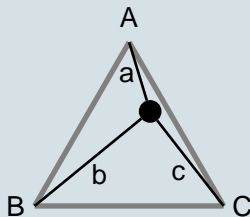
Probabilistically speaking...



Probabilistically speaking...



Probabilistically speaking...



$$P(A) = e^{-a}/Z$$

$$P(B) = e^{-b}/Z$$

$$P(C) = e^{-c}/Z$$

$$Z = e^{-a} + e^{-b} + e^{-c}$$

# Probabilities

Binary vectors



Label space



# Probabilities

Binary vectors



$\text{logit}^{-1}$  [Pohl 2007]

Label space



# Probabilities

Binary vectors

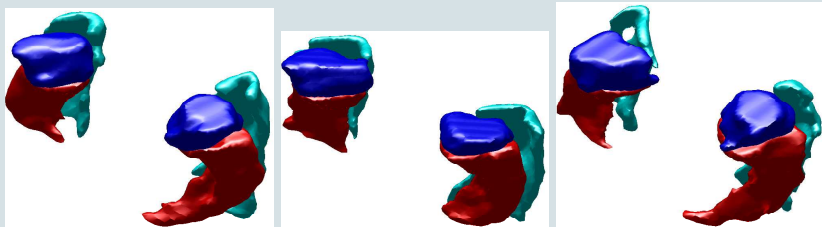


$\text{logit}^{-1}$  [Pohl 2007]

Label space



## Patient data



Provided by Brigham and Women's Hospital ( $n = 31$ )

Registered:  $d^2 = \sum \|m_i - \mu\|^2$

## Conditional probabilities



Pohl 2007

## Principle component analysis

Dice coefficient between image and preimage

Leave-one-out strategy

## Principle component analysis

Dice coefficient between image and preimage

Leave-one-out strategy

	SDMs	Binary vectors	Label space
Amy.	$0.783 \pm 0.0031$	$0.825 \pm 0.0014$	$0.855 \pm 0.0004$

## Principle component analysis

Dice coefficient between image and preimage

Leave-one-out strategy

	SDMs	Binary vectors	Label space
Amy.	$0.783 \pm 0.0031$	$0.825 \pm 0.0014$	$0.855 \pm 0.0004$
Hipp.	$0.782 \pm 0.0016$	$0.819 \pm 0.0006$	$0.843 \pm 0.0003$

## Principle component analysis

Dice coefficient between image and preimage

Leave-one-out strategy

	SDMs	Binary vectors	Label space
Amy.	$0.783 \pm 0.0031$	$0.825 \pm 0.0014$	$0.855 \pm 0.0004$
Hipp.	$0.782 \pm 0.0016$	$0.819 \pm 0.0006$	$0.843 \pm 0.0003$
Para.	$0.494 \pm 0.0033$	$0.561 \pm 0.0017$	$0.773 \pm 0.0003$

## Conclusions

Simple, unbiased, flexible

Probabilistic interpretation

Captures uncertainty