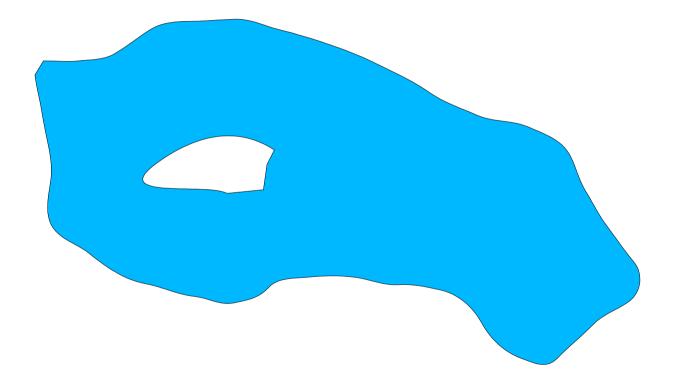
#### Continuous Semantics of Proto

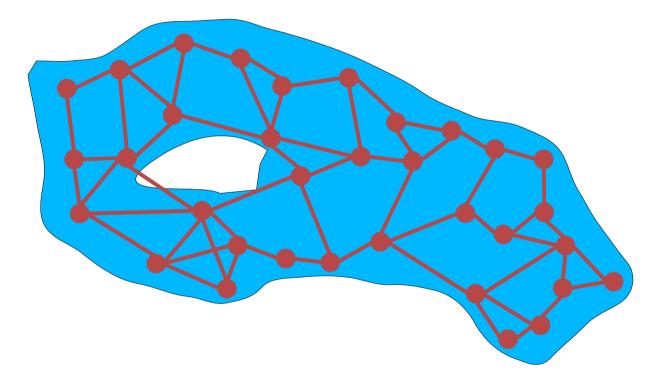
Jake Beal January, 2006 (Joint work w. Jonathan Bachrach)

# Outline

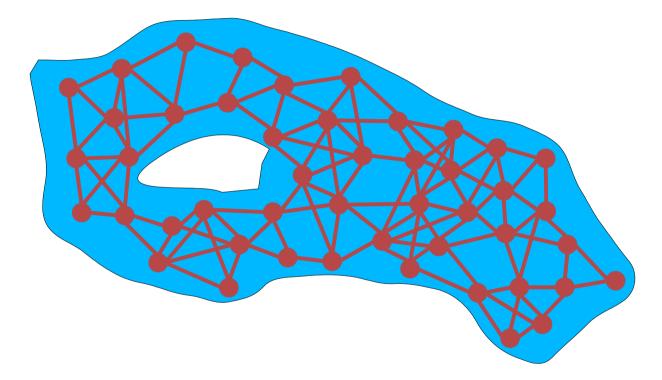
- Amorphous Medium
- Primitives, Abstraction, & Composition
- Managing space and time
  - Operations with spatial extent
  - Conditionals
  - State
  - Error handling
- Putting it all together



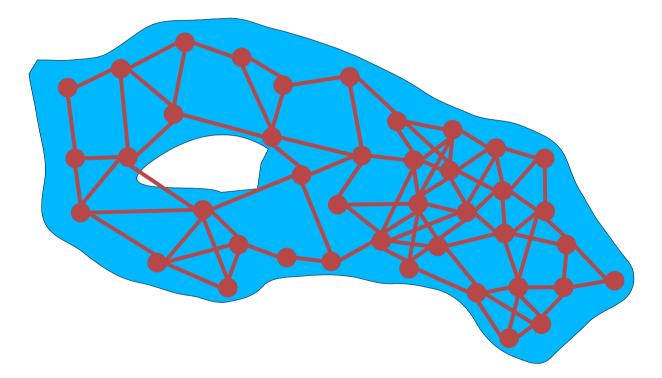
• Exa: sensor/actuator networks, smart materials, cooperative robotics, biofilms ...



Approx. space w. network like this...

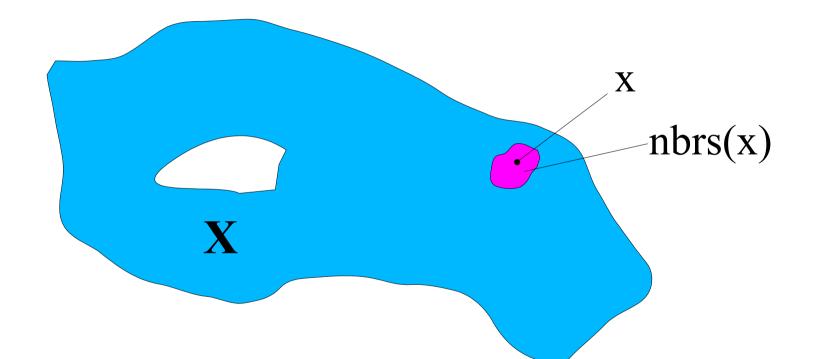


Approx. space w. network like this...this...



Approx. space w. network like this...this...or this? *We shouldn't have to care!* 

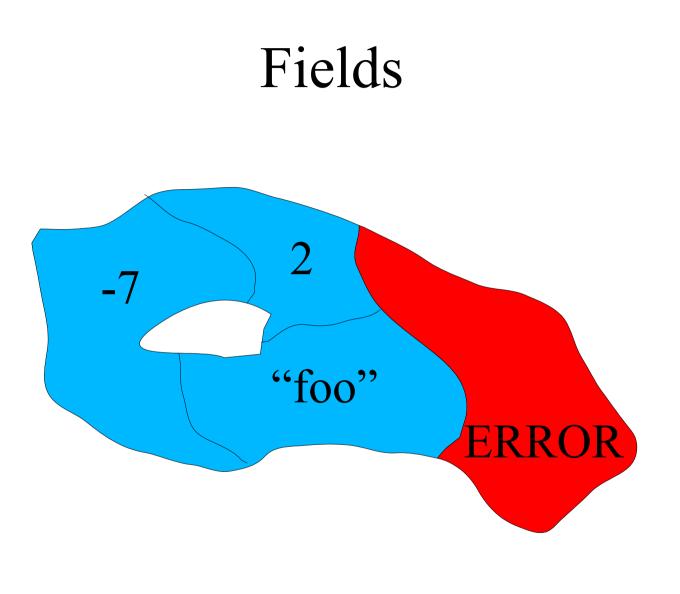
## Amorphous Medium



• Compact manifold with a device at every point

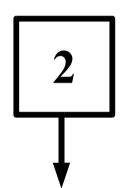
- Lagged internal state visible to neighbors

Ph34r th3 Unc0nt4bility!

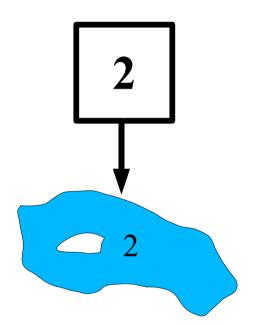


 $F: \mathbf{X} \rightarrow value$ 

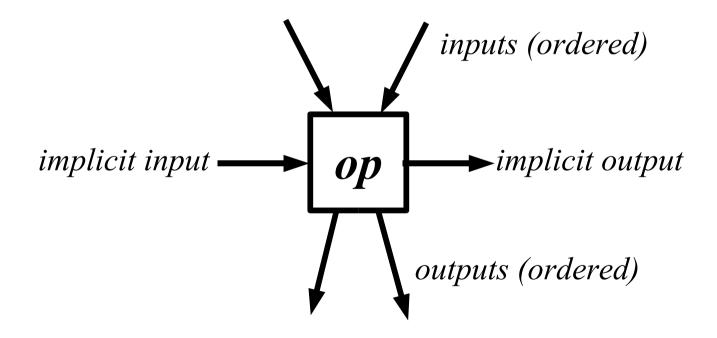
#### Primitives & Evaluation

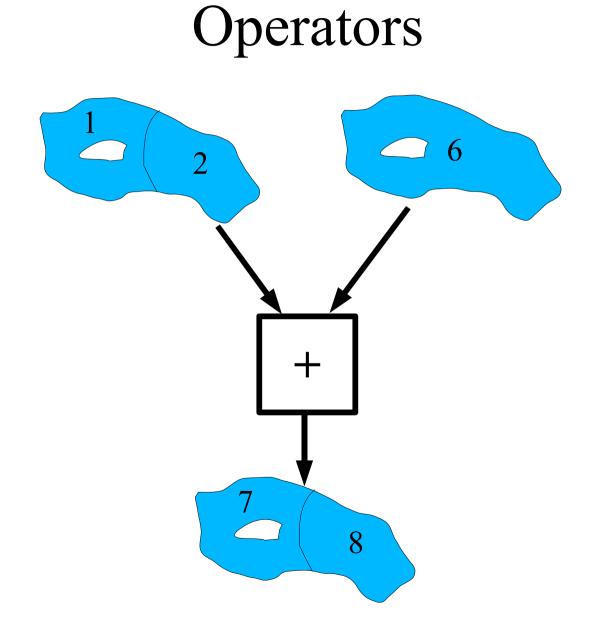


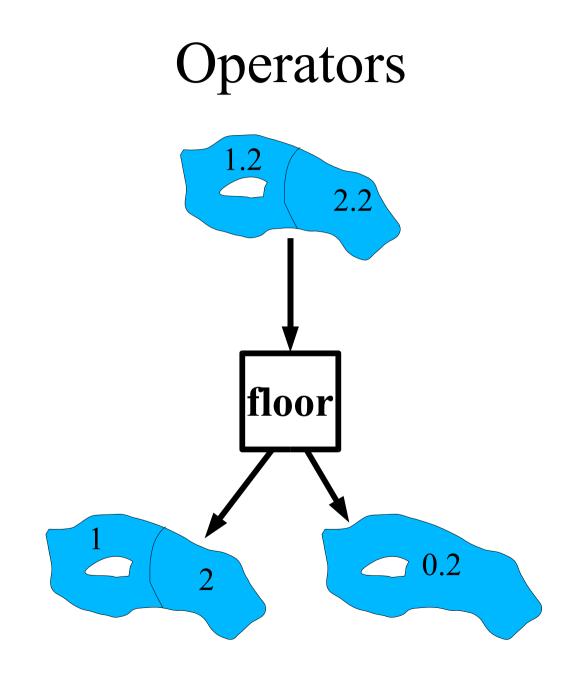
#### Primitives & Evaluation



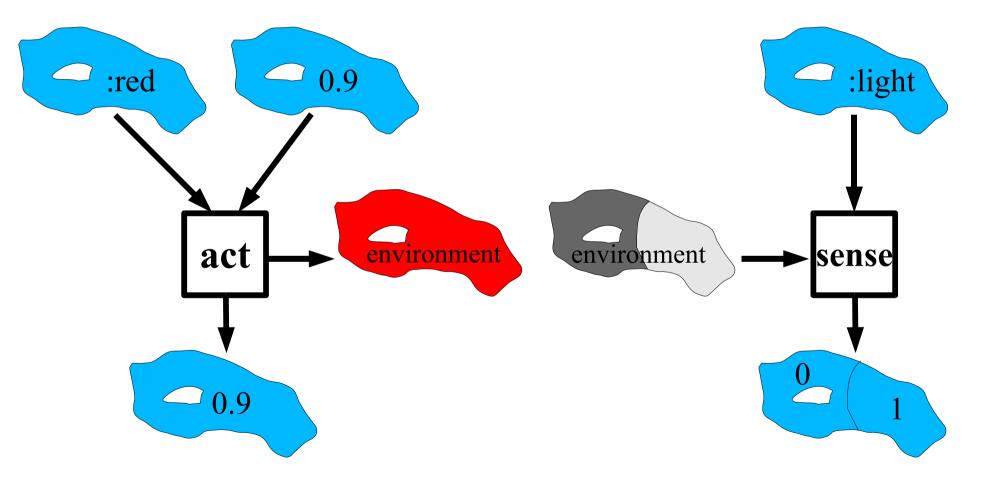
## Operators

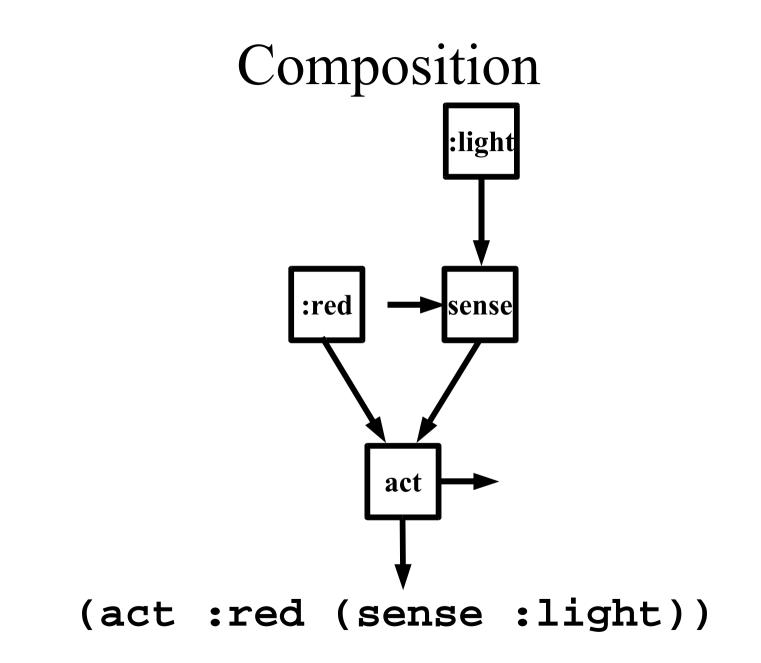


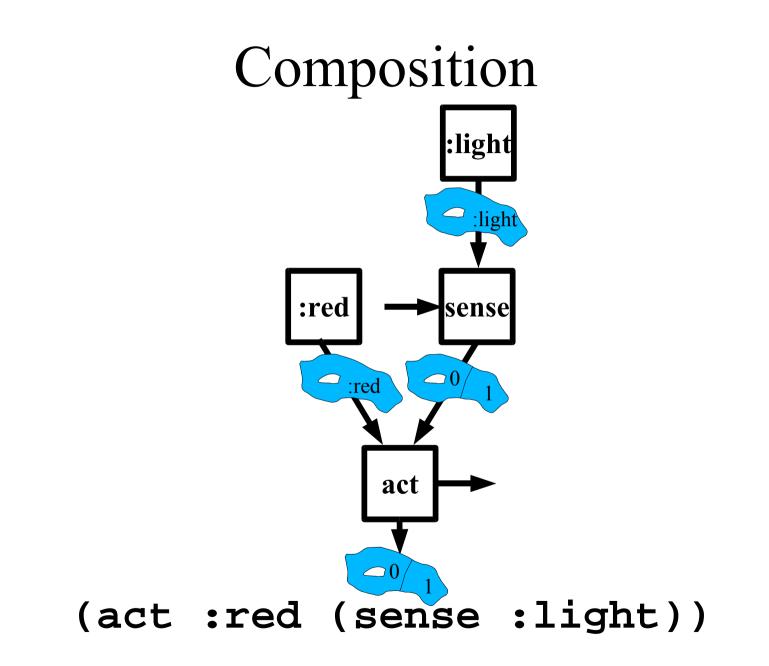


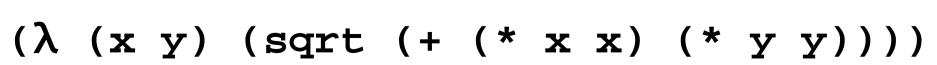


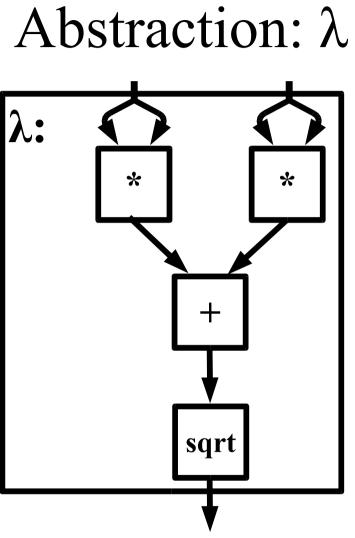
#### Operators

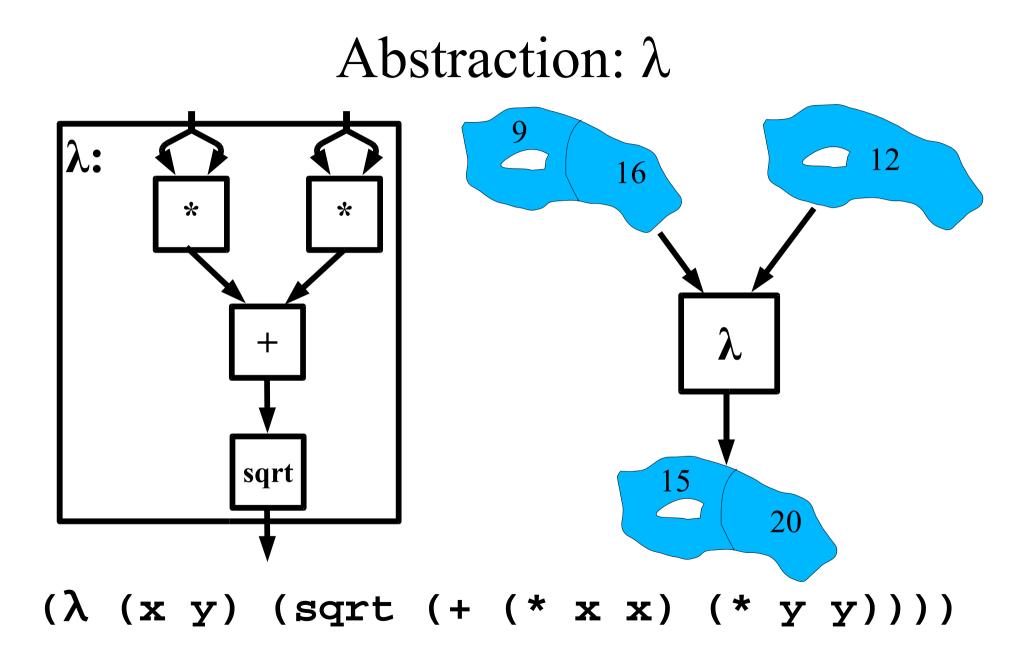


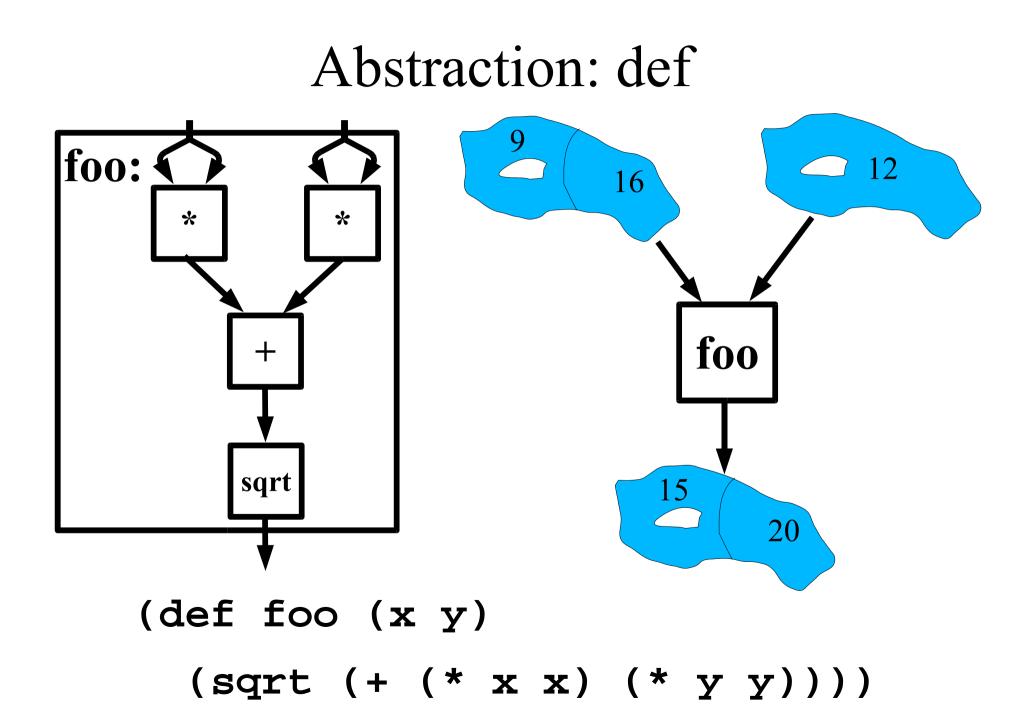


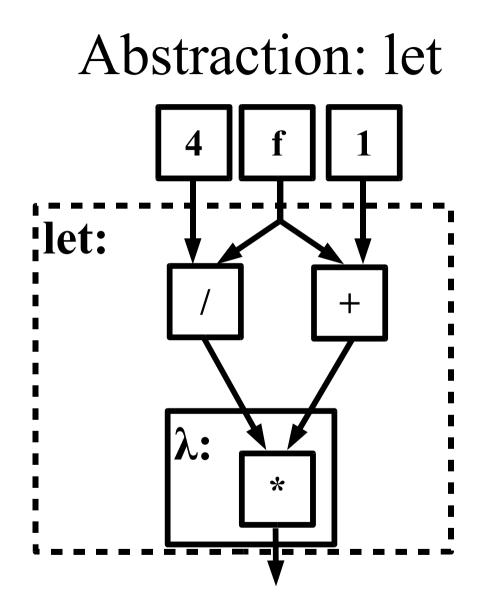




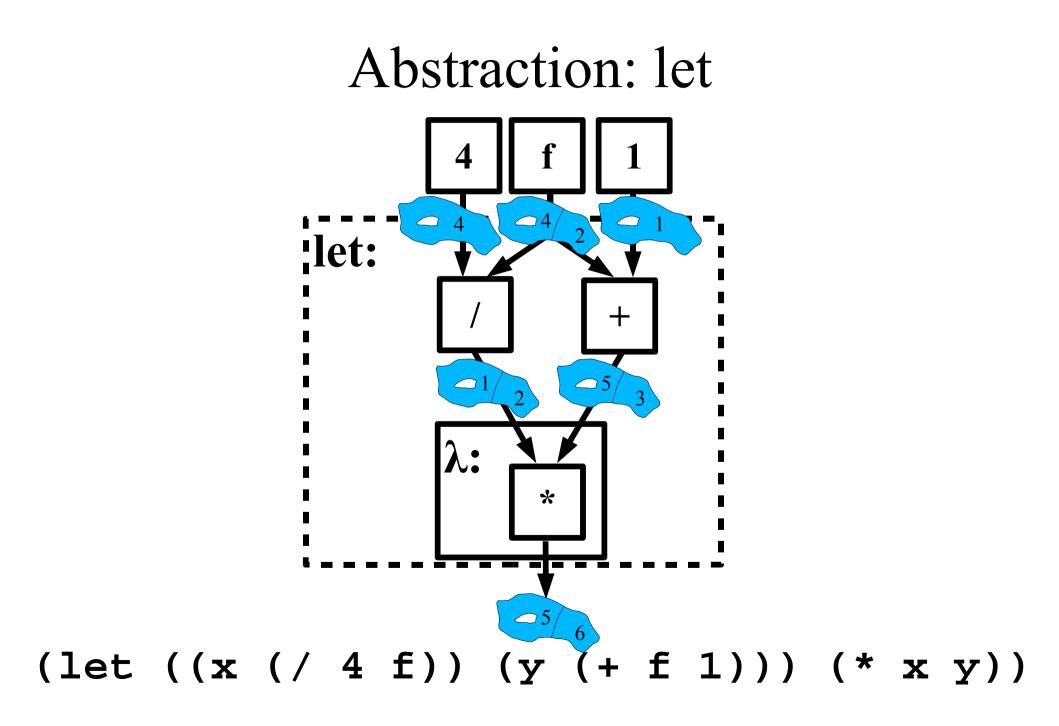




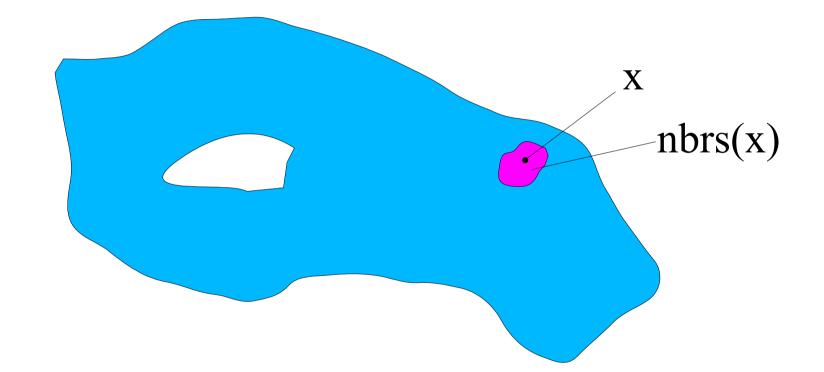




(let ((x (/ 4 f)) (y (+ f 1))) (\* x y))

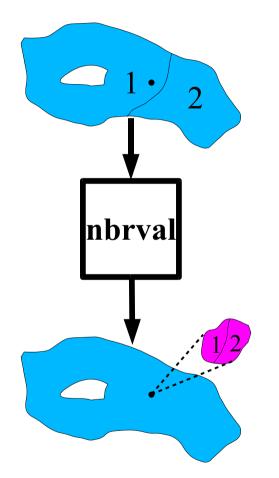


## Operations with Spatial Extent



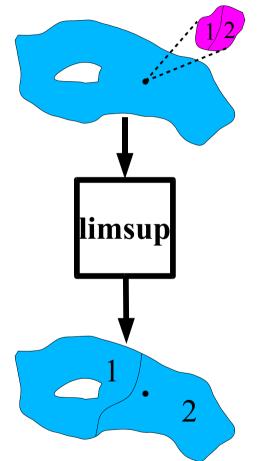
Implicit communication in reductions over nbr vals *Ph34r th3 Unc0nt4bility!* 

#### nbrval gathers neighbor values

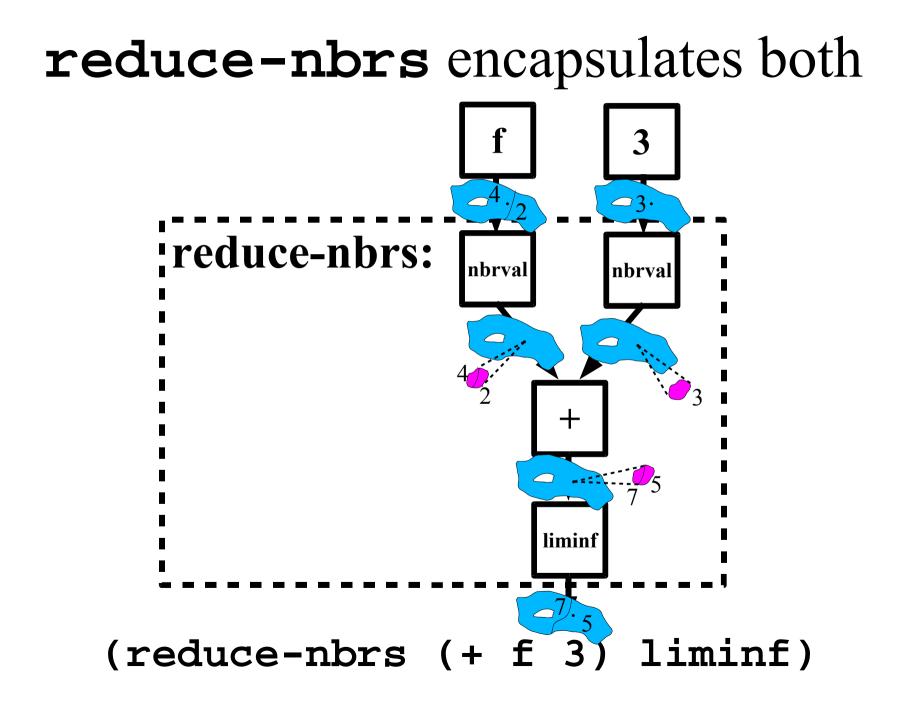


(nbrval f)  $\rightarrow$  field of fields of nbr values

## Quantifiers summarize nbr values



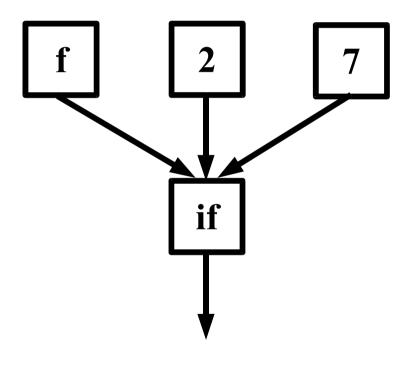
#### Available Quantifiers: limsup, liminf, integral, forall, exists



Other spatial operations

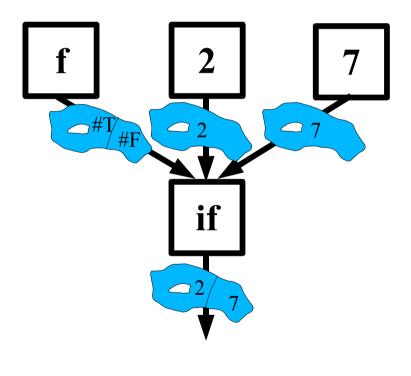
- nbr-dist
- nbr-lag
- random

#### Simple Conditional: if

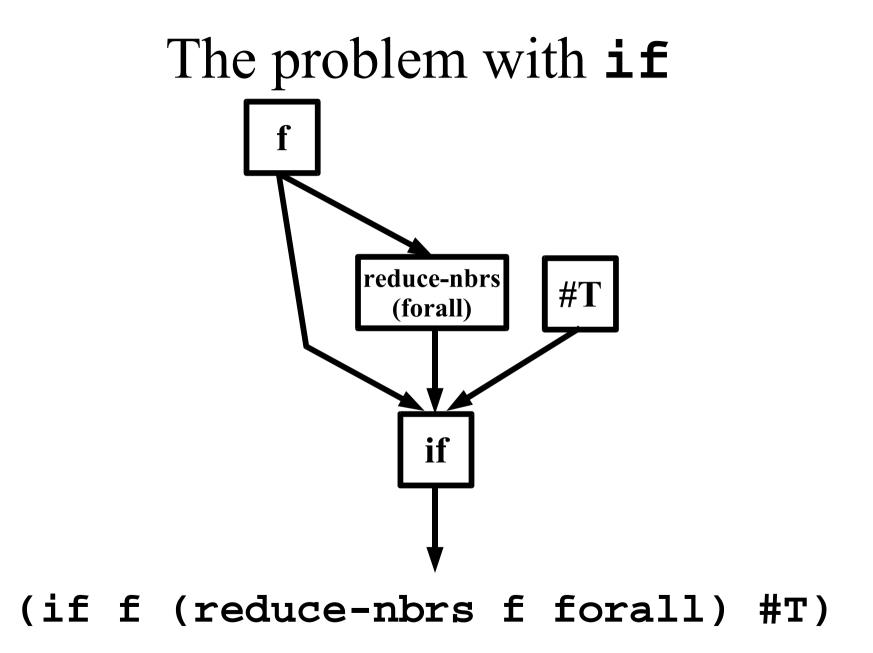


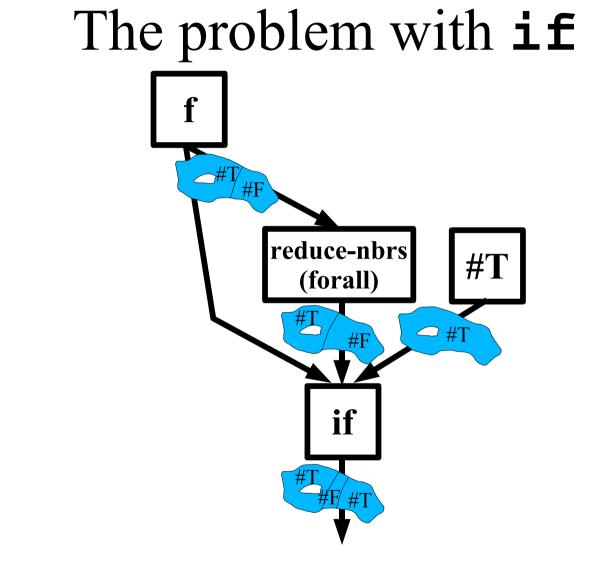
#### (if f 2 7)

#### Simple Conditional: if



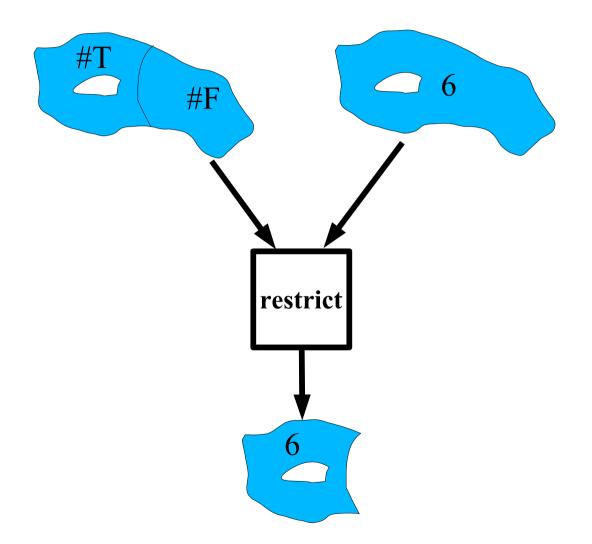
#### (if f 2 7)

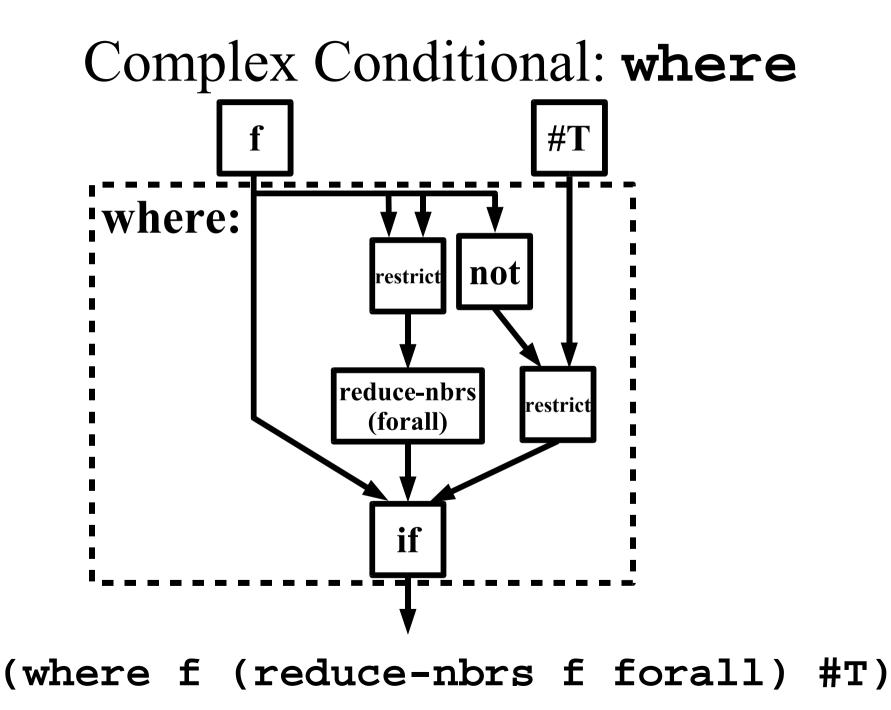


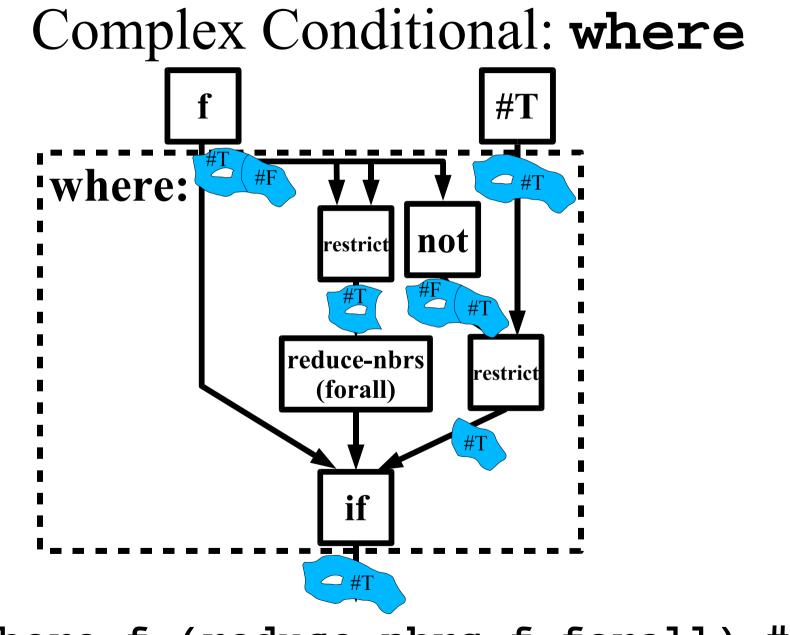


(if f (reduce-nbrs f forall) #T)

#### restrict

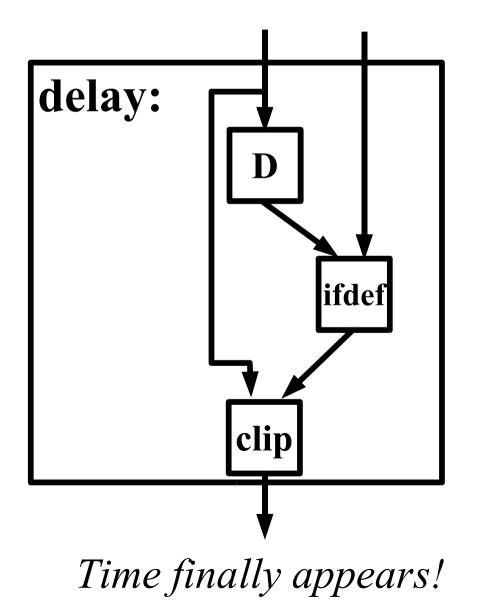


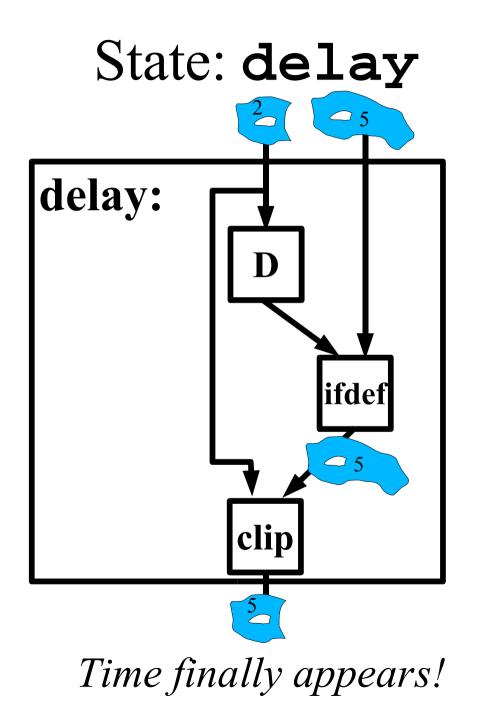


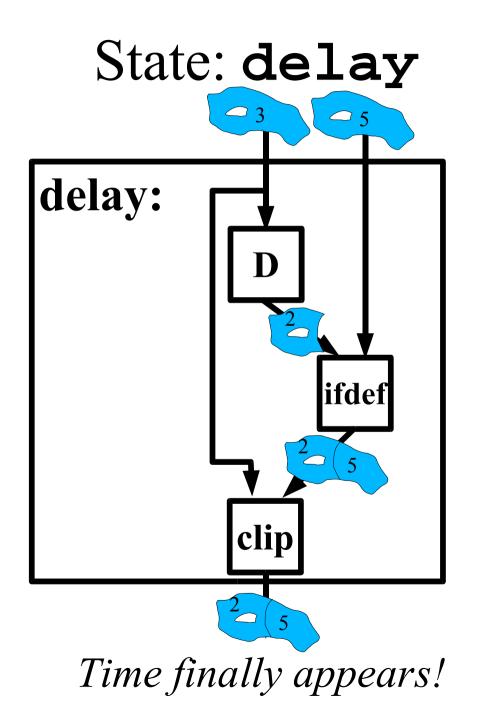


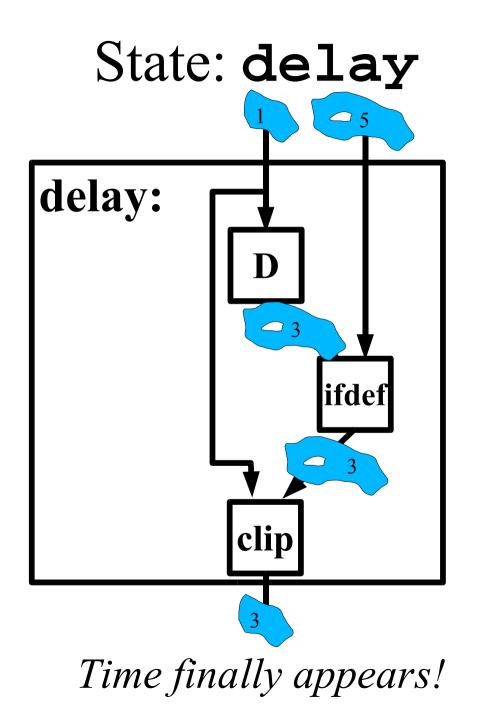
(where f (reduce-nbrs f forall) #T)

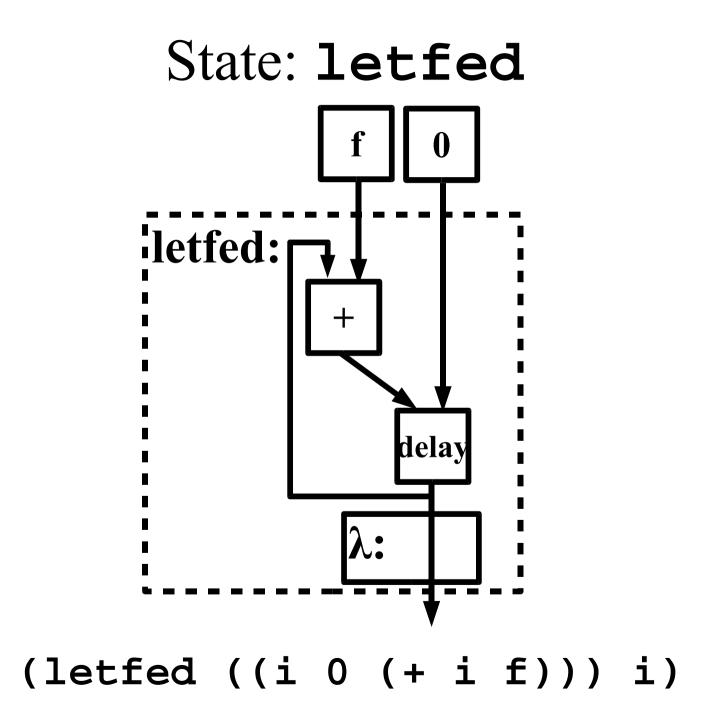
#### State: **delay**

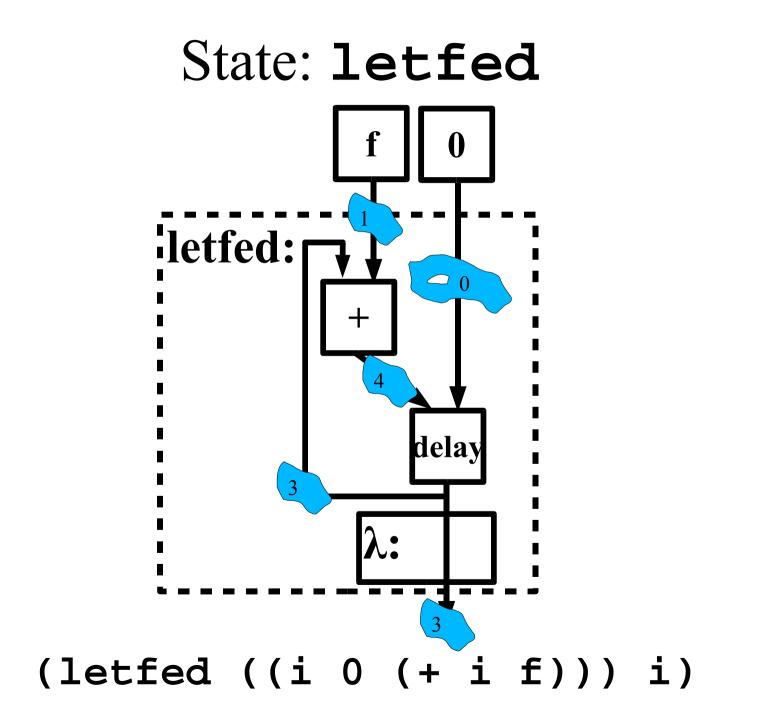




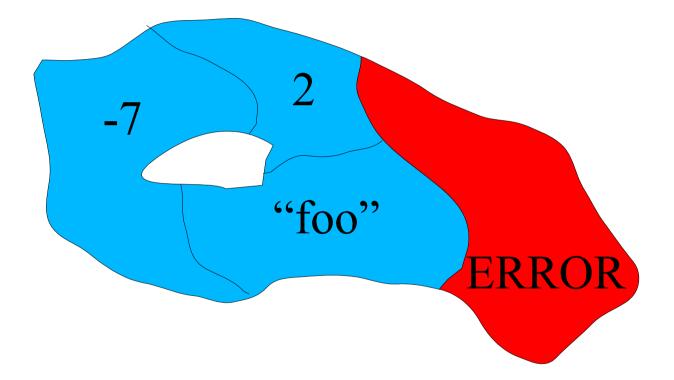








# Error Handling



What happens when an error is localized? *Conditions are values, not flow control.* 

# Putting it all together: gradient

