



EARTH & LIFE INSTITUTE

# SMARTROOT

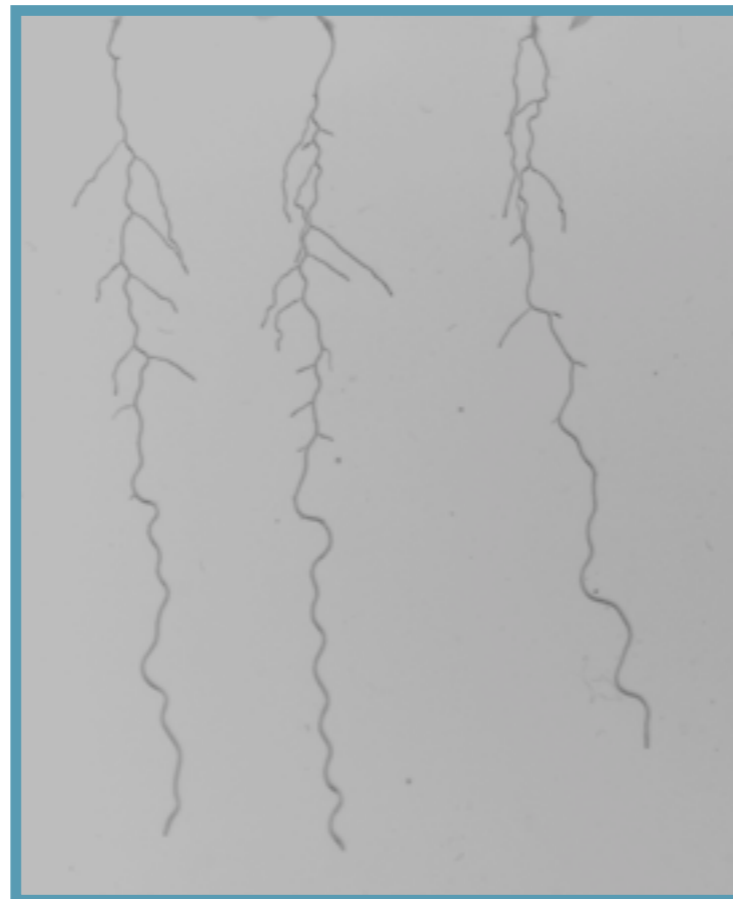
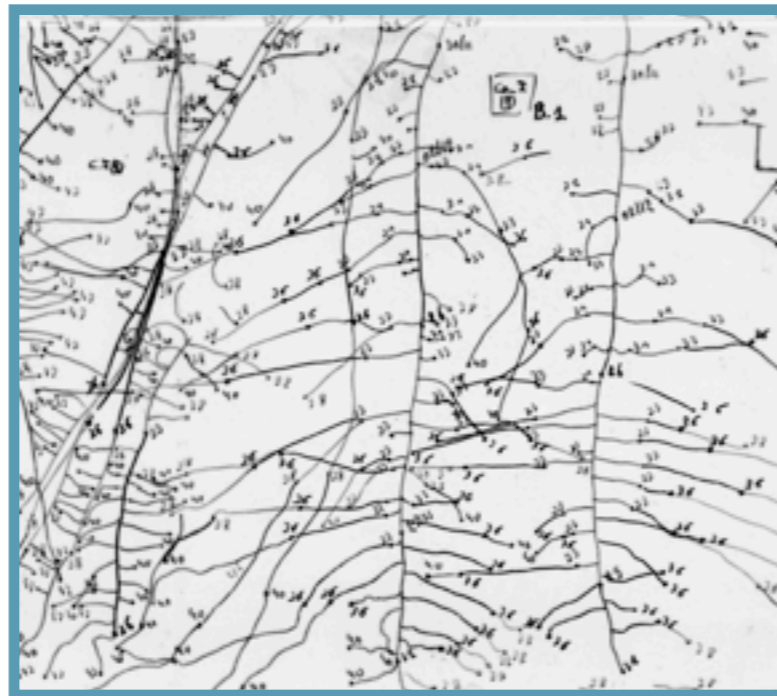
A novel image analysis toolbox  
enabling quantitative analysis  
of root system architecture

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Guillaume Lobet, Loïc Pagès and Xavier Draye

6th of September 2012

# What we do in our lab



# What is SmartRoot?



- Semi-automated
- Root tracing software
- Morphology, topology
- Wide range of image

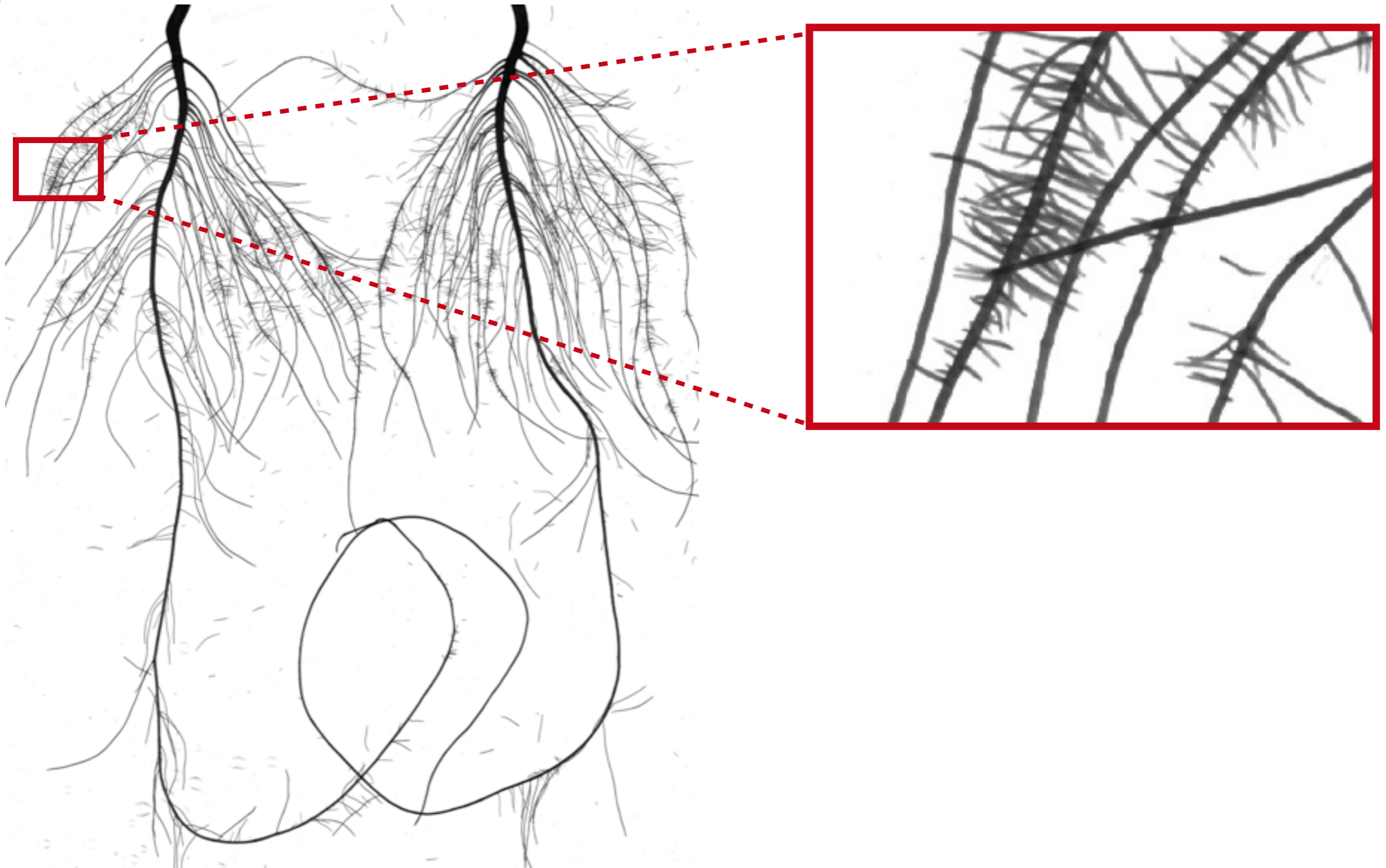


# Why semi-automated?

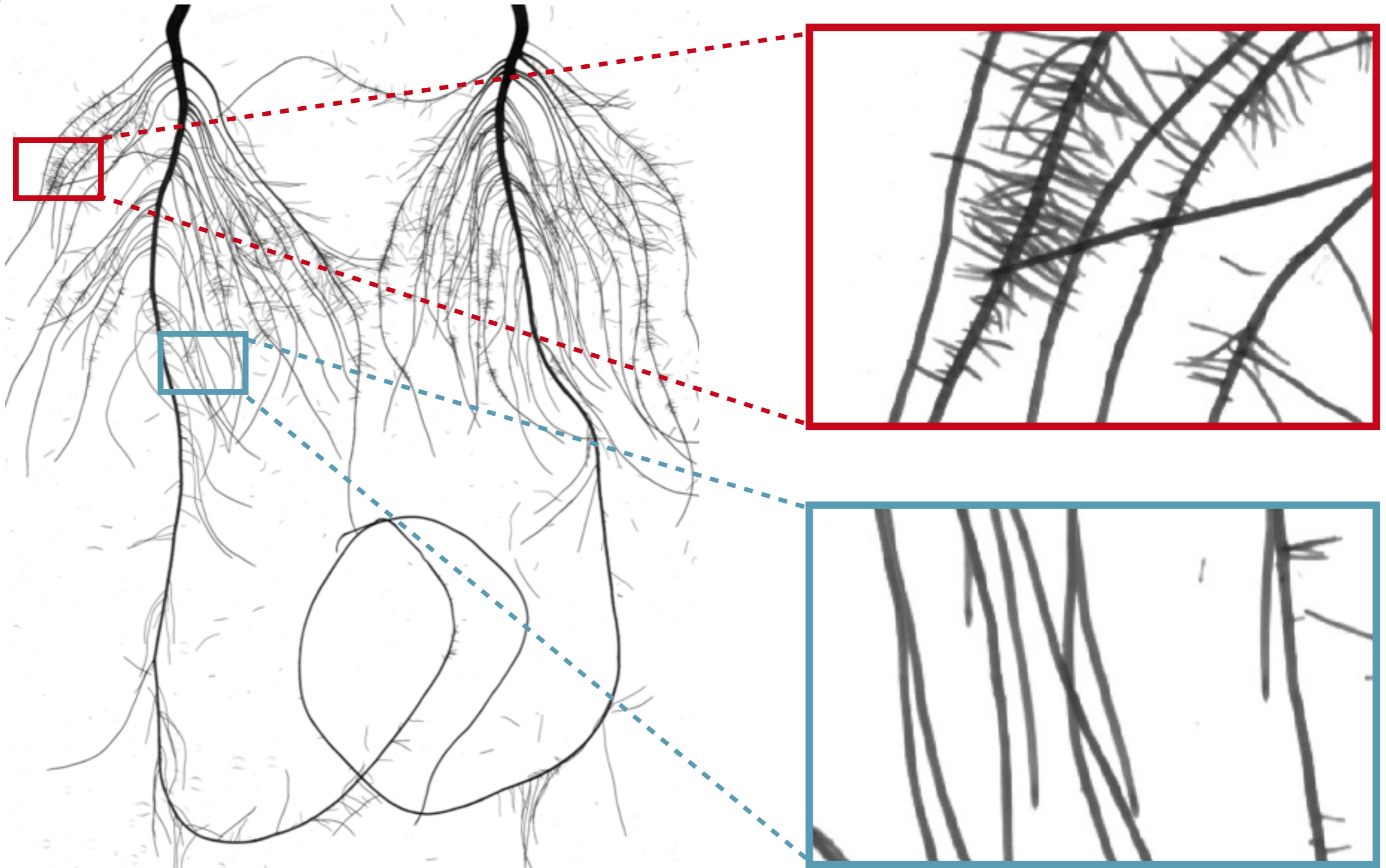




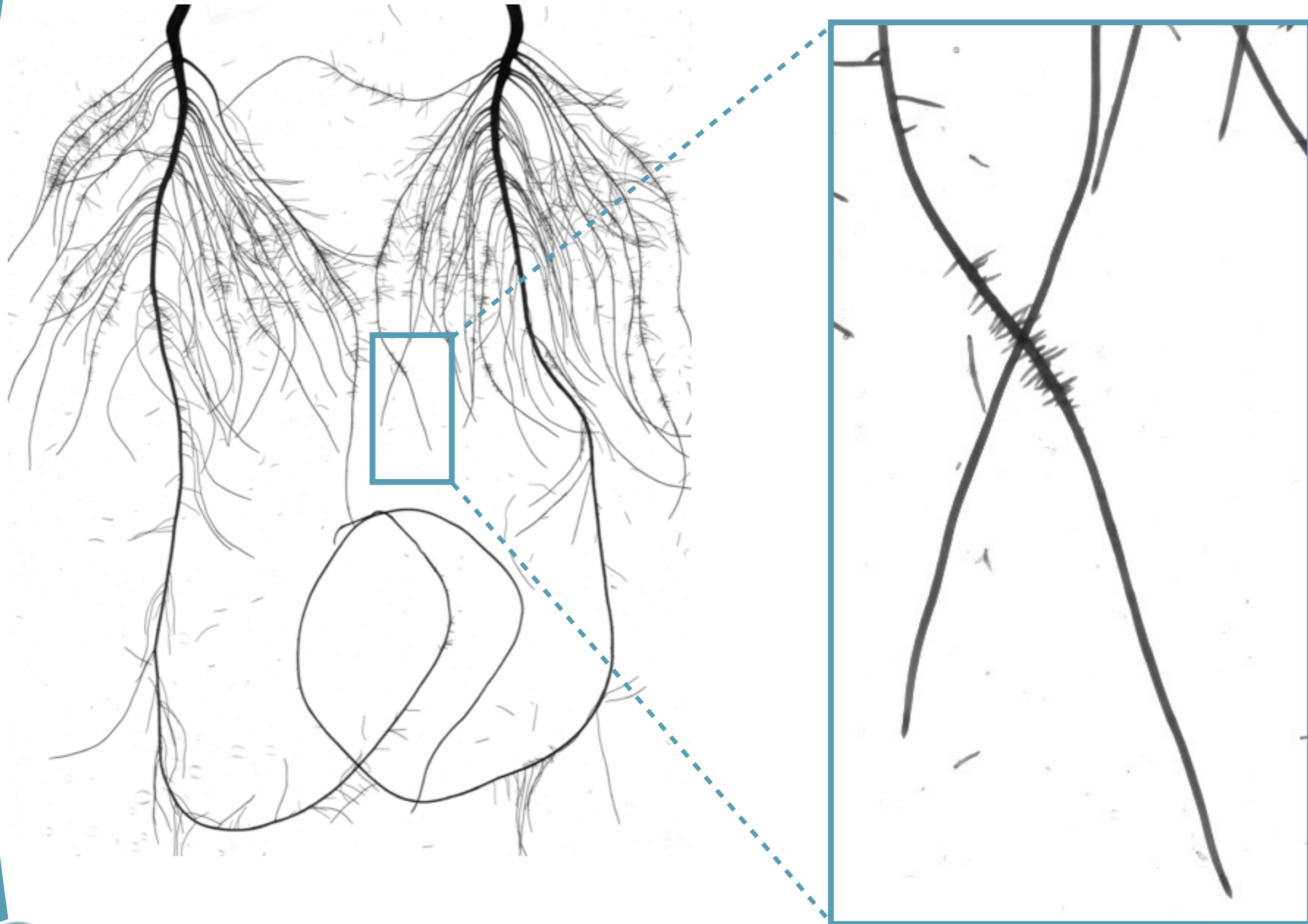
# Heterogenous image



# Heterogenous image

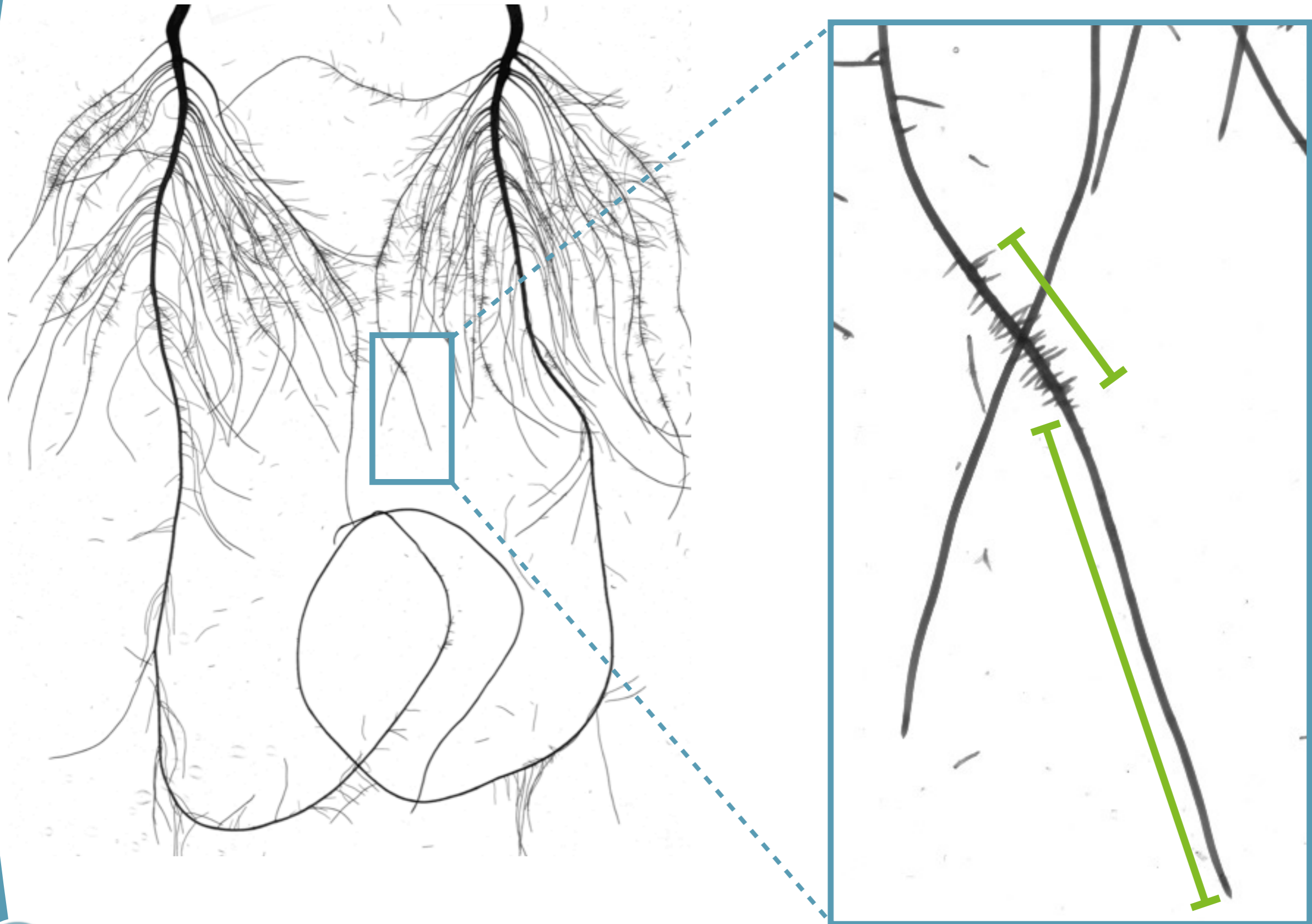


# Local information



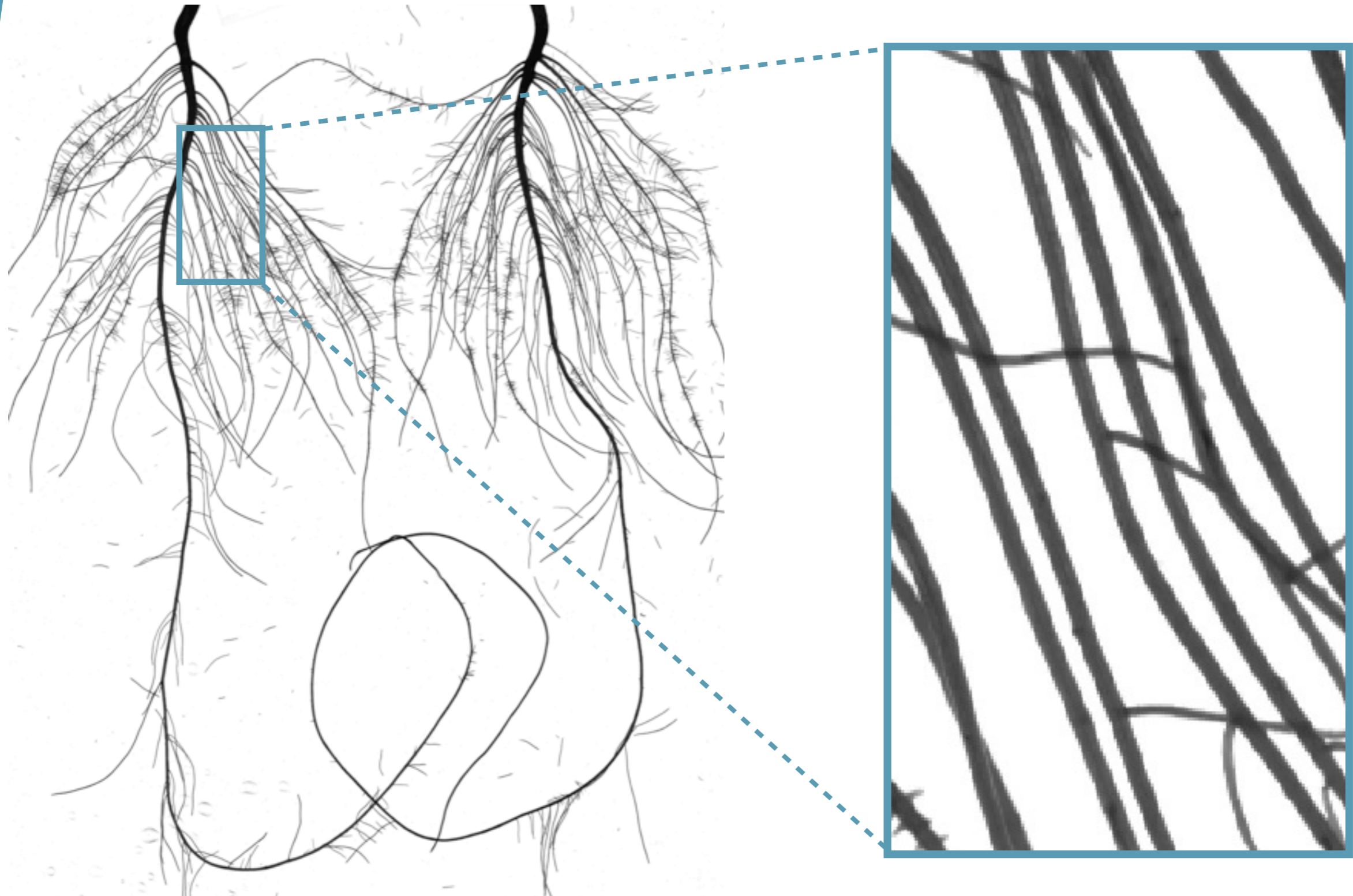


# Local information

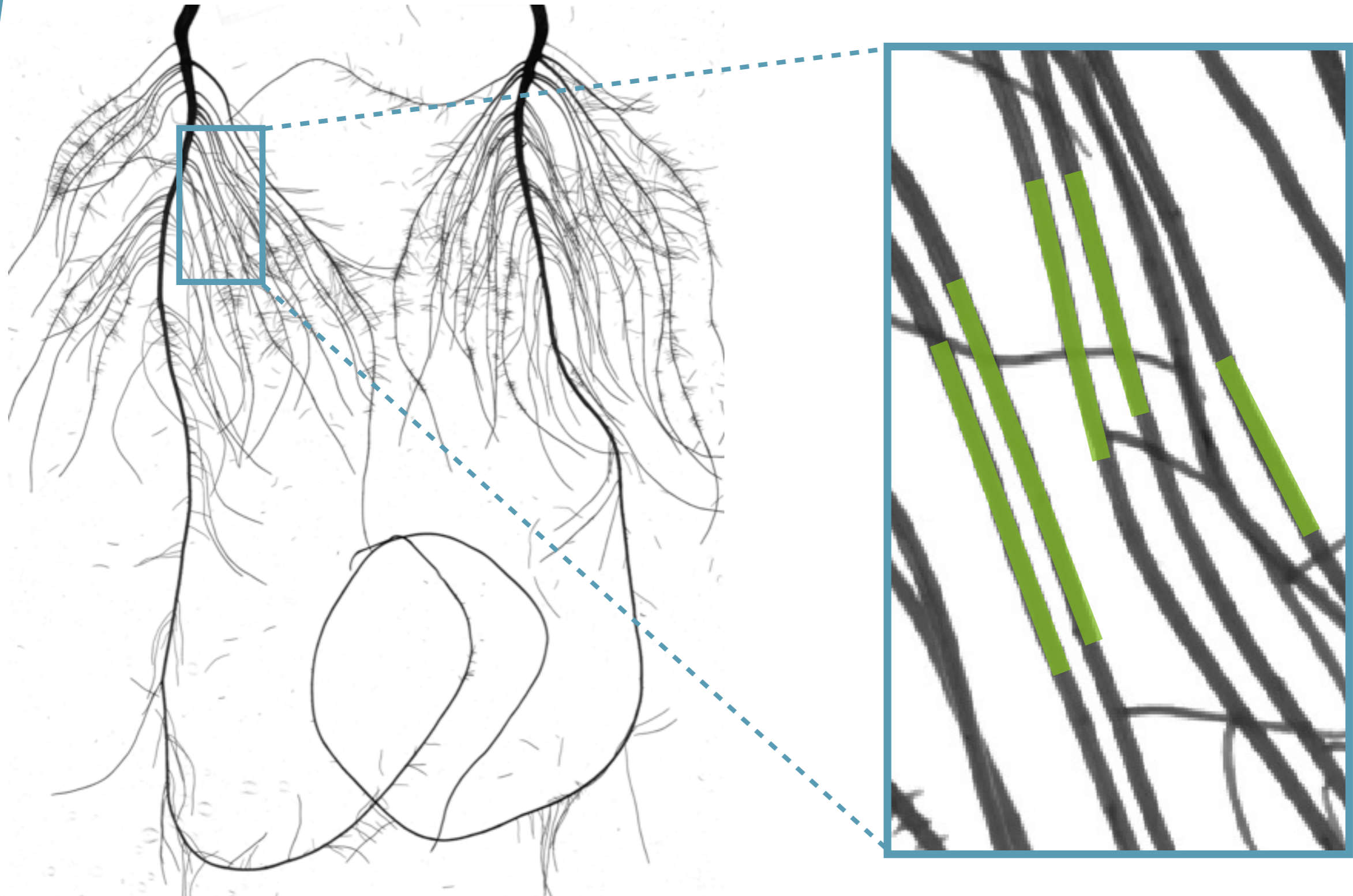




# Root system as a population



# Root system as a population



# Why semi-automated?



- Local information is needed
- Sample the root system
- Sample the image





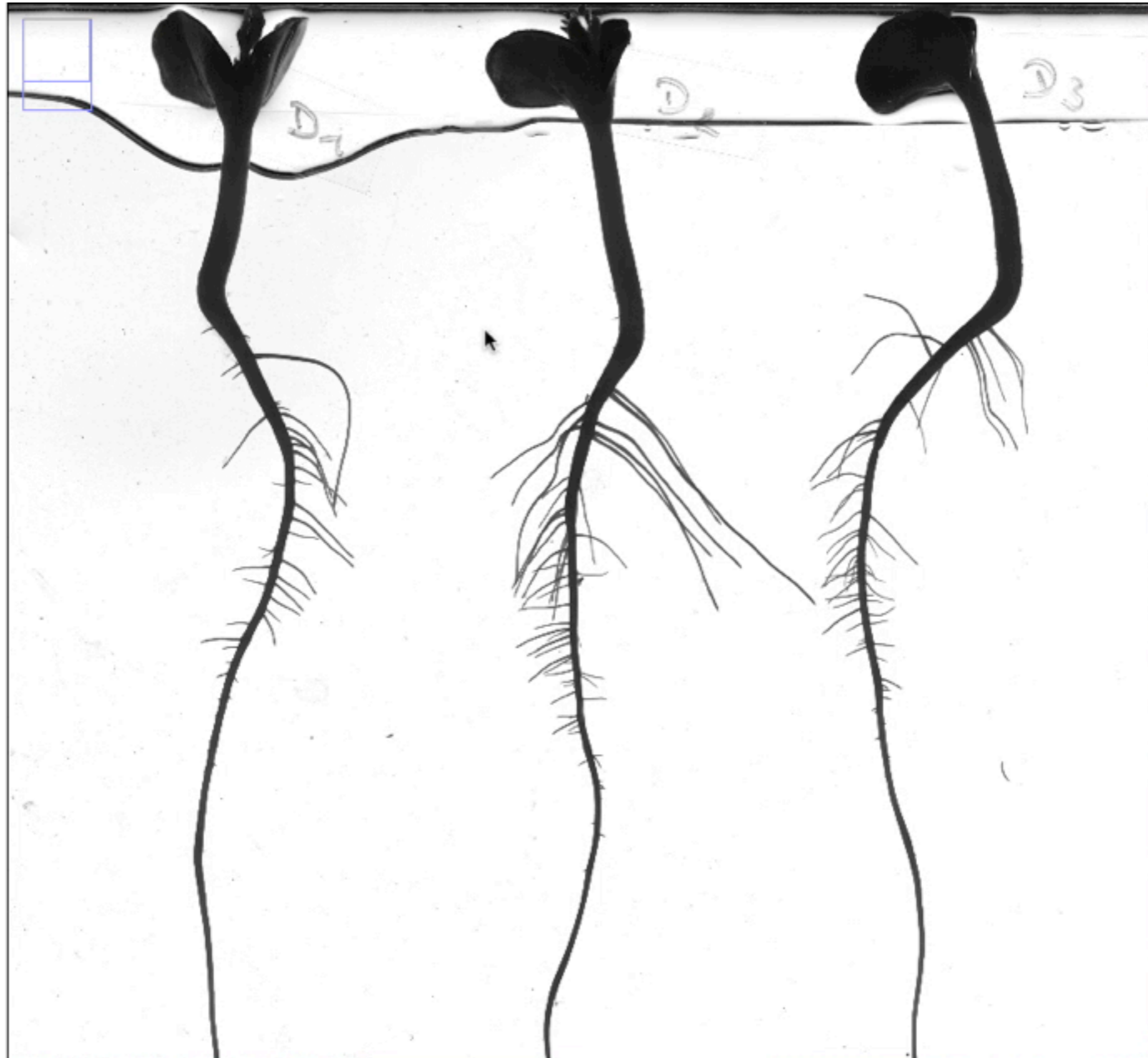
# How does it work?



# Quick root tracing overview



# Quick root tracing overview





# Tracing algorithm - 1

- mouse click
- local threshold
- node creation
- node centering
- search path
- diameter check
- node creation
- node centering
- append node
- local threshold



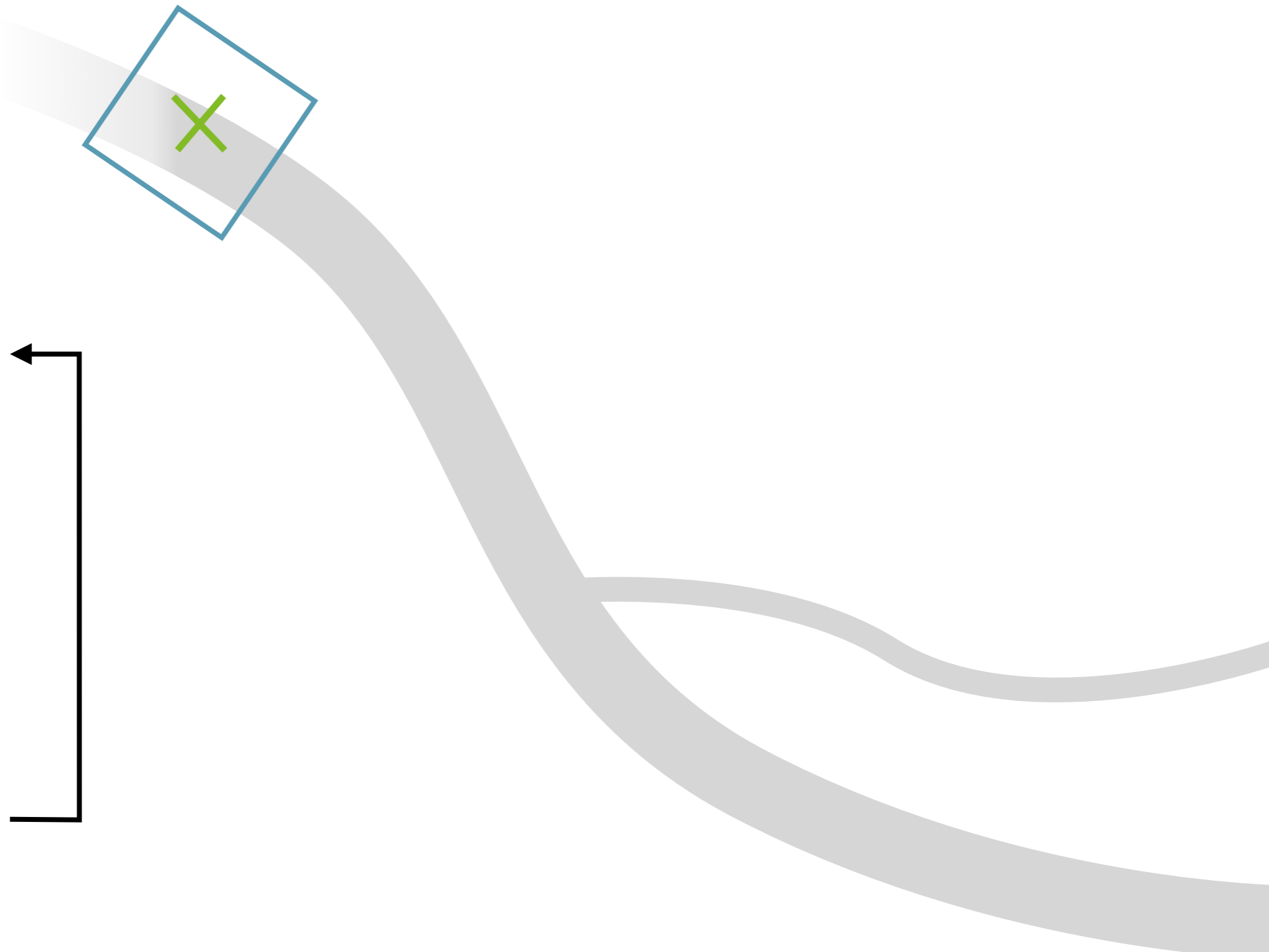
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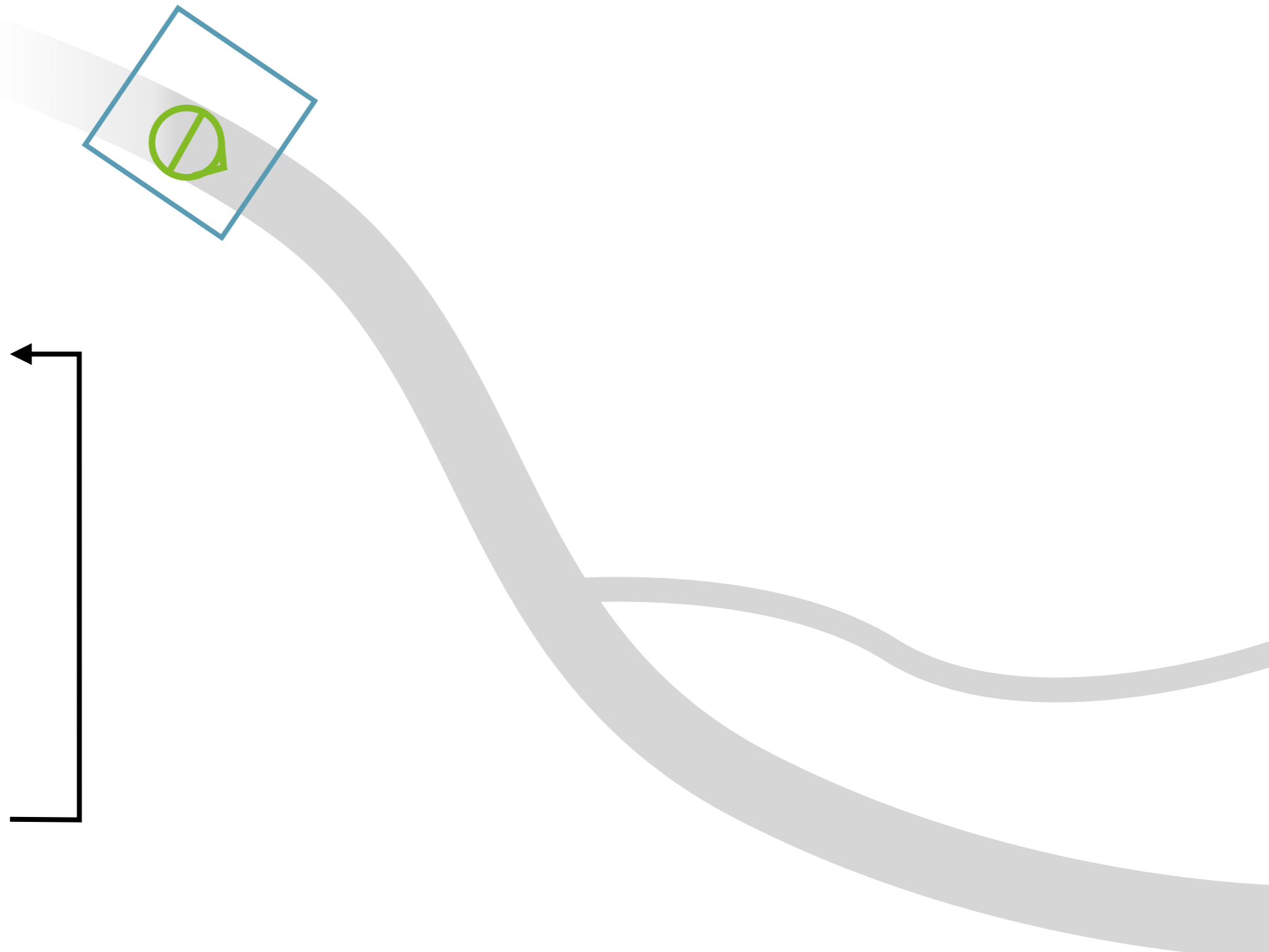
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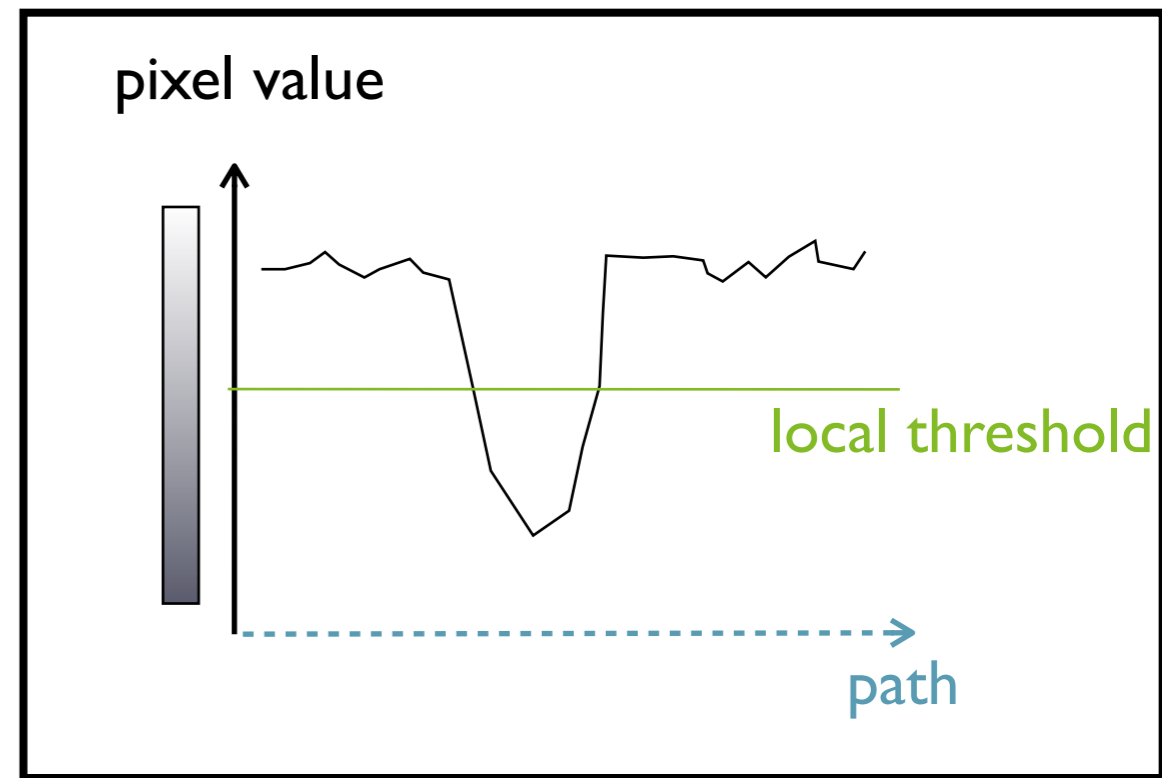
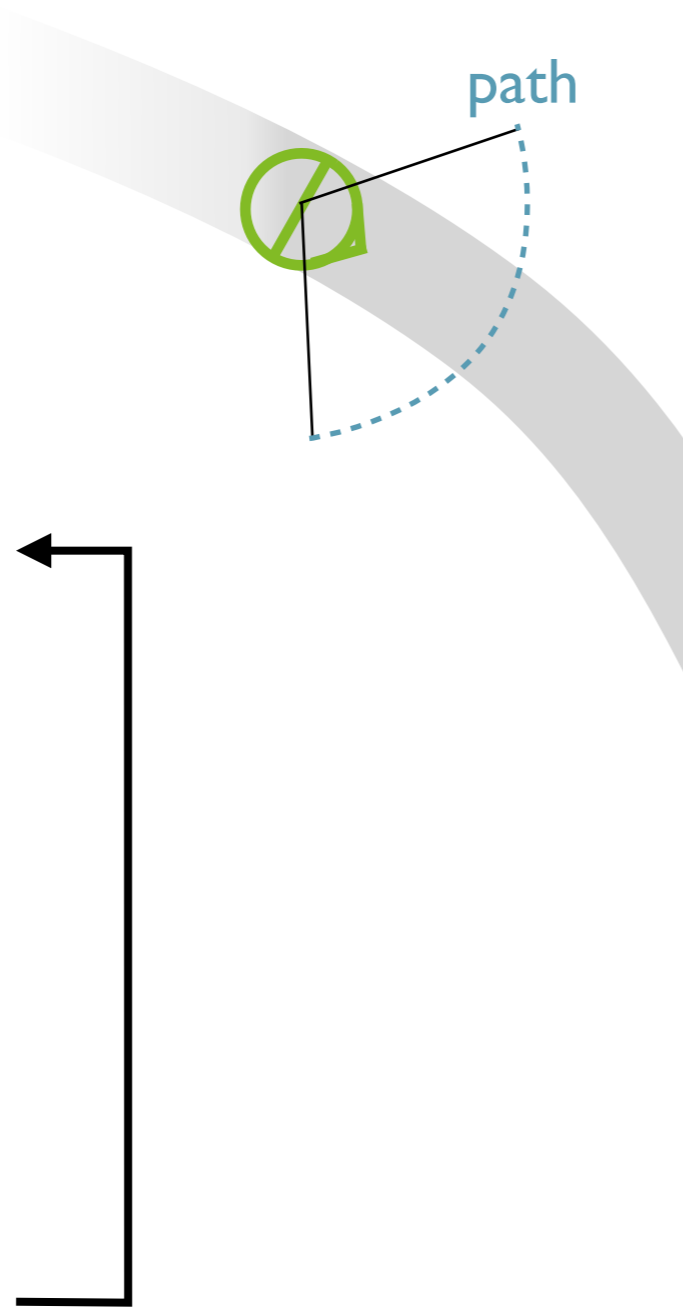
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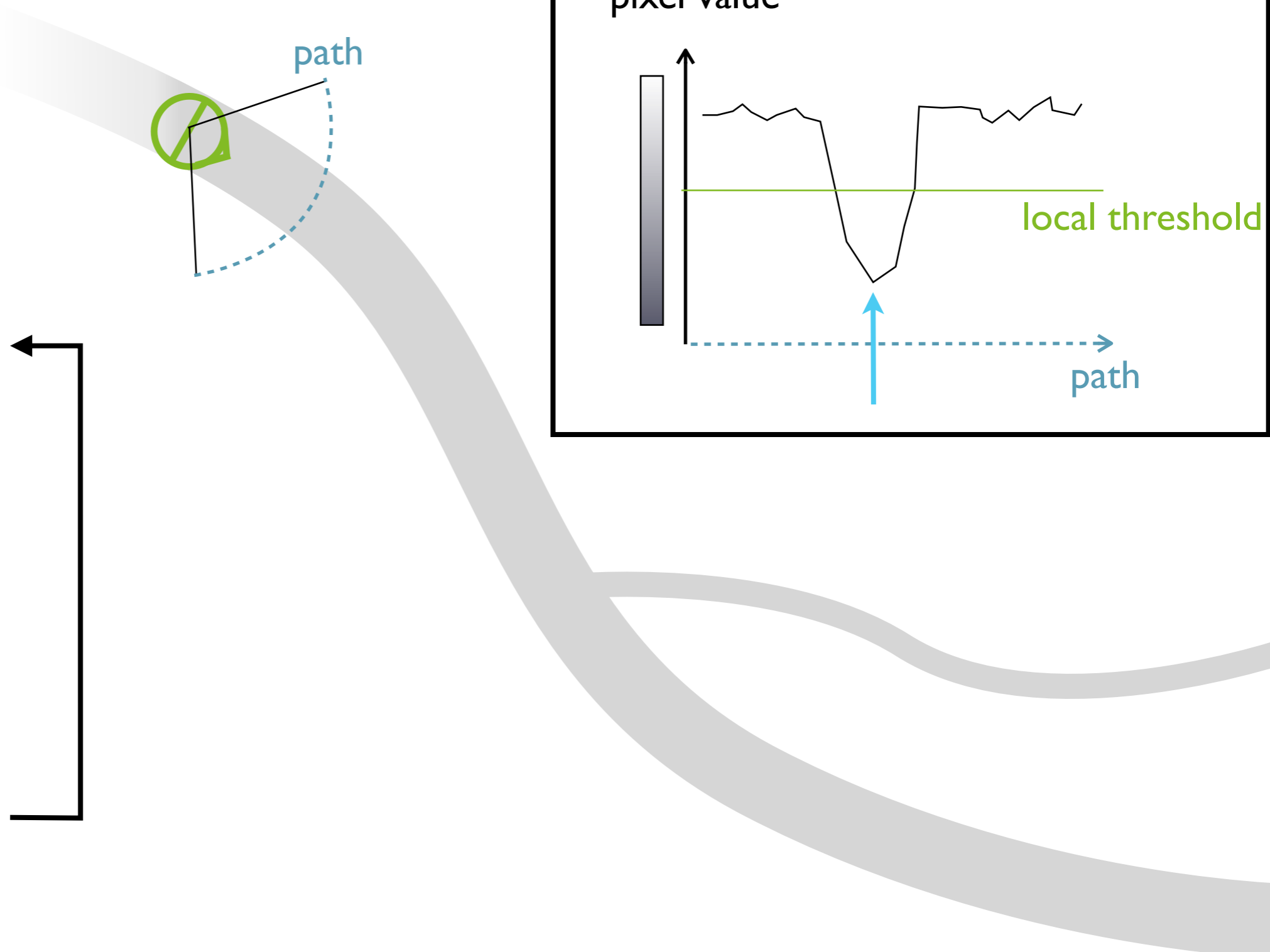
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# Tracing algorithm - 1

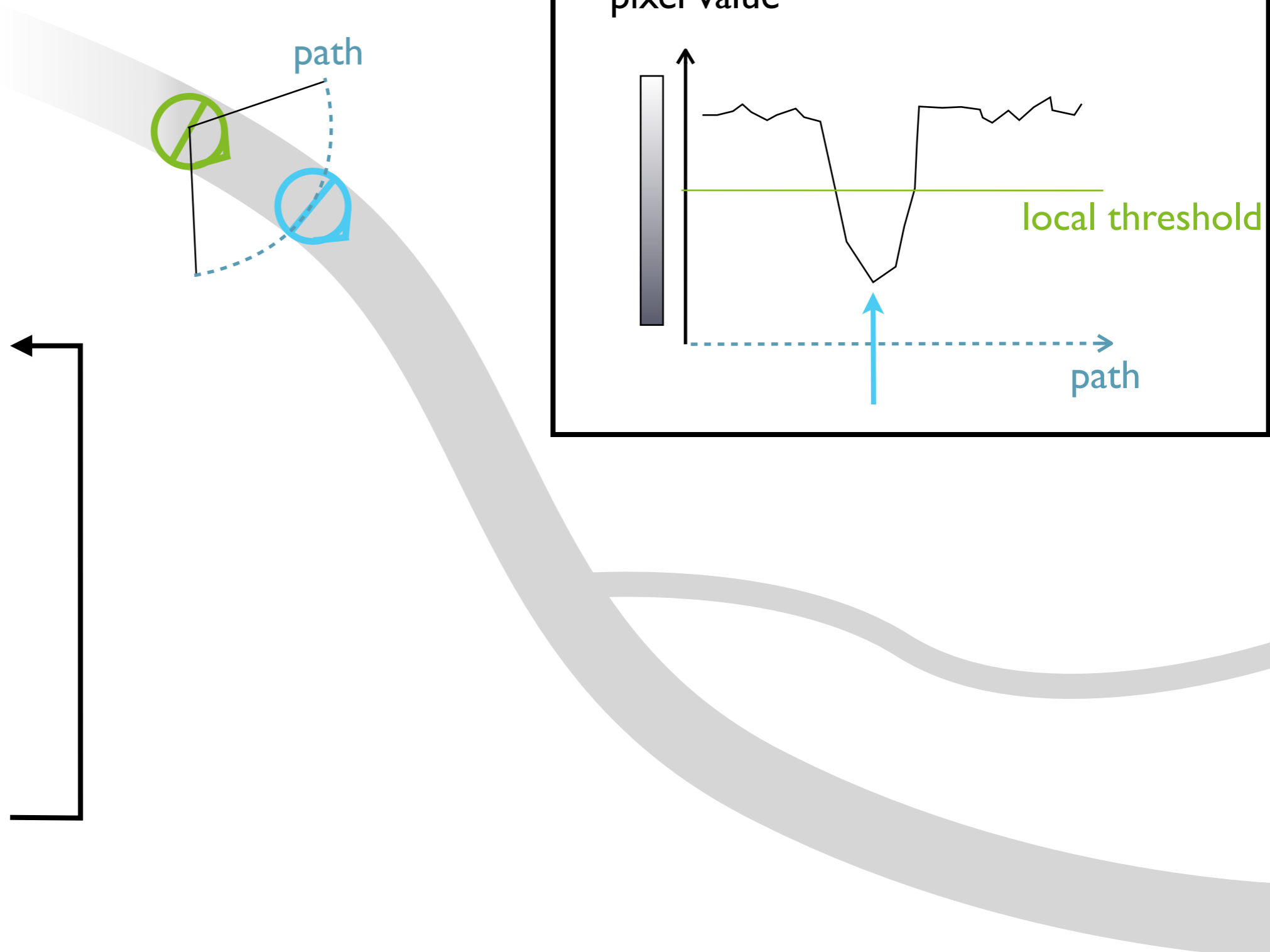
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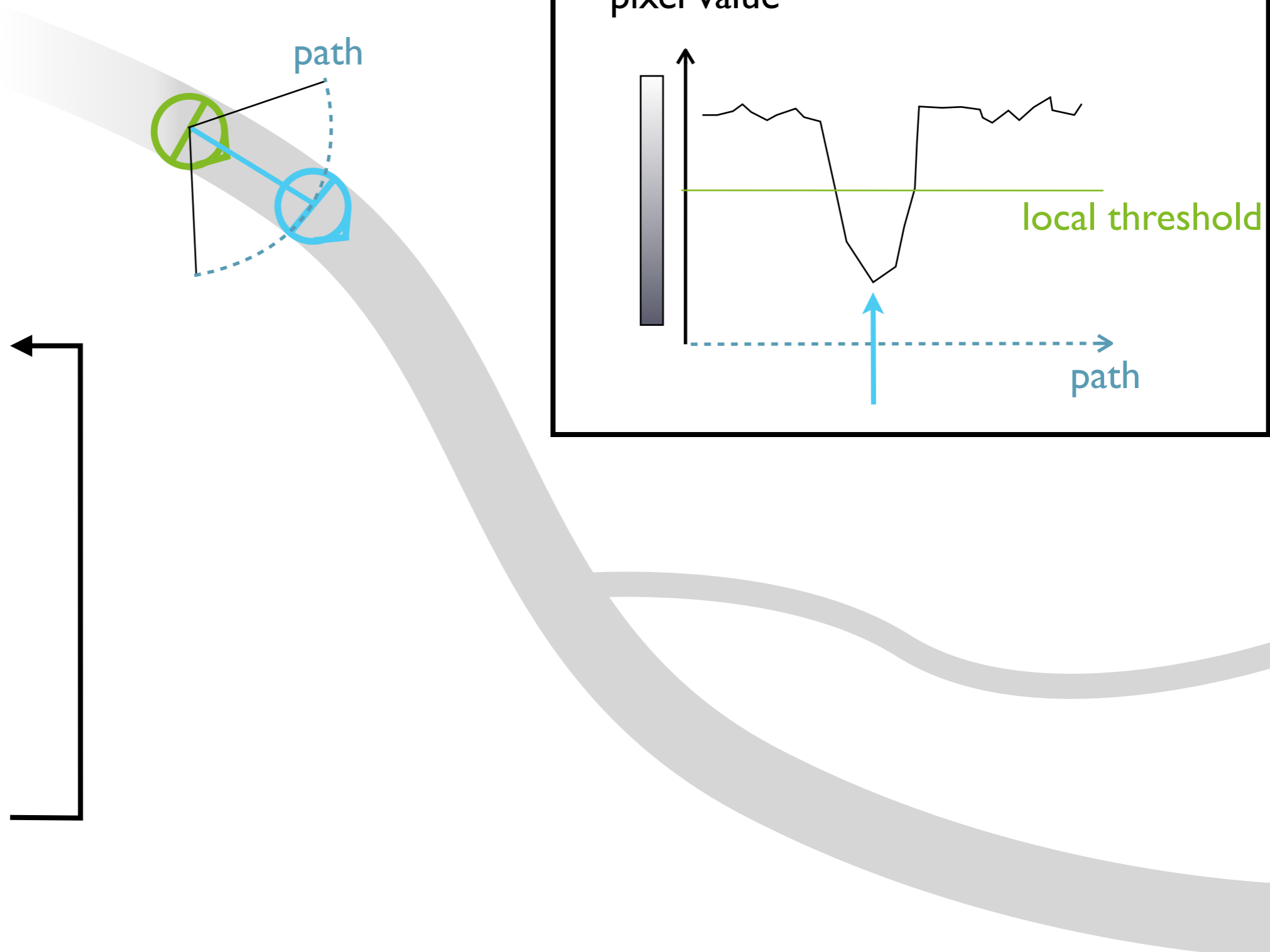
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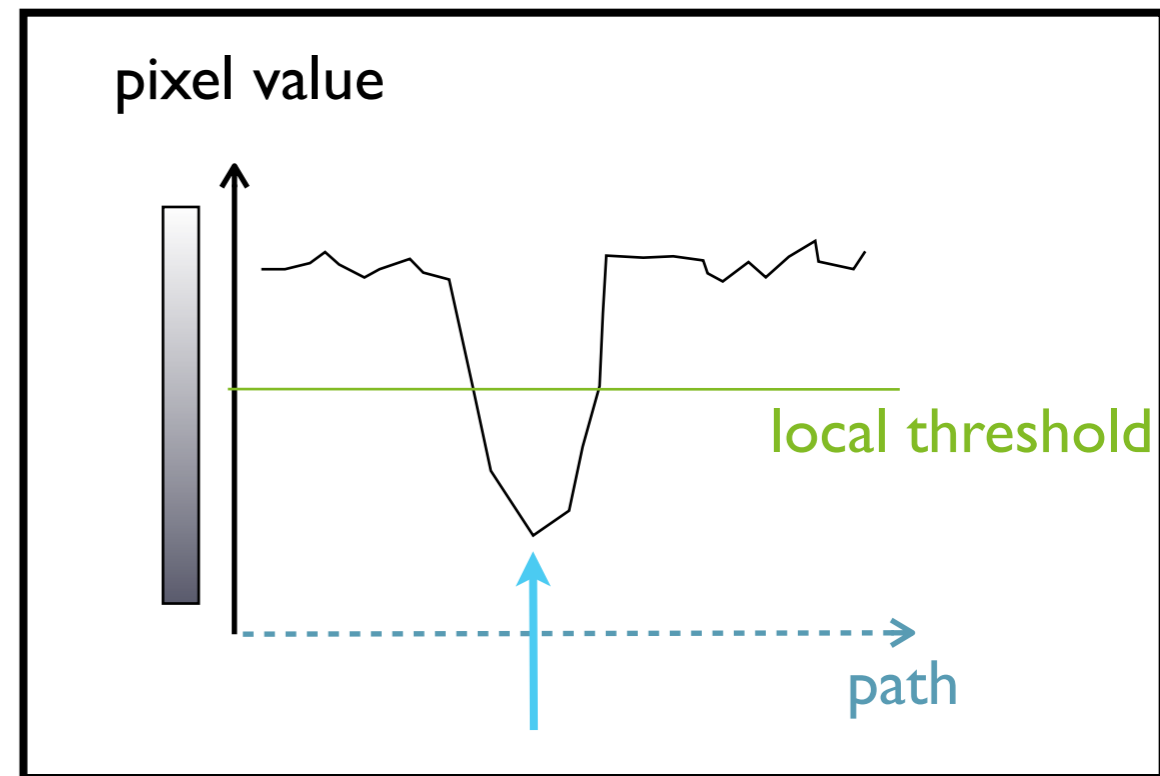
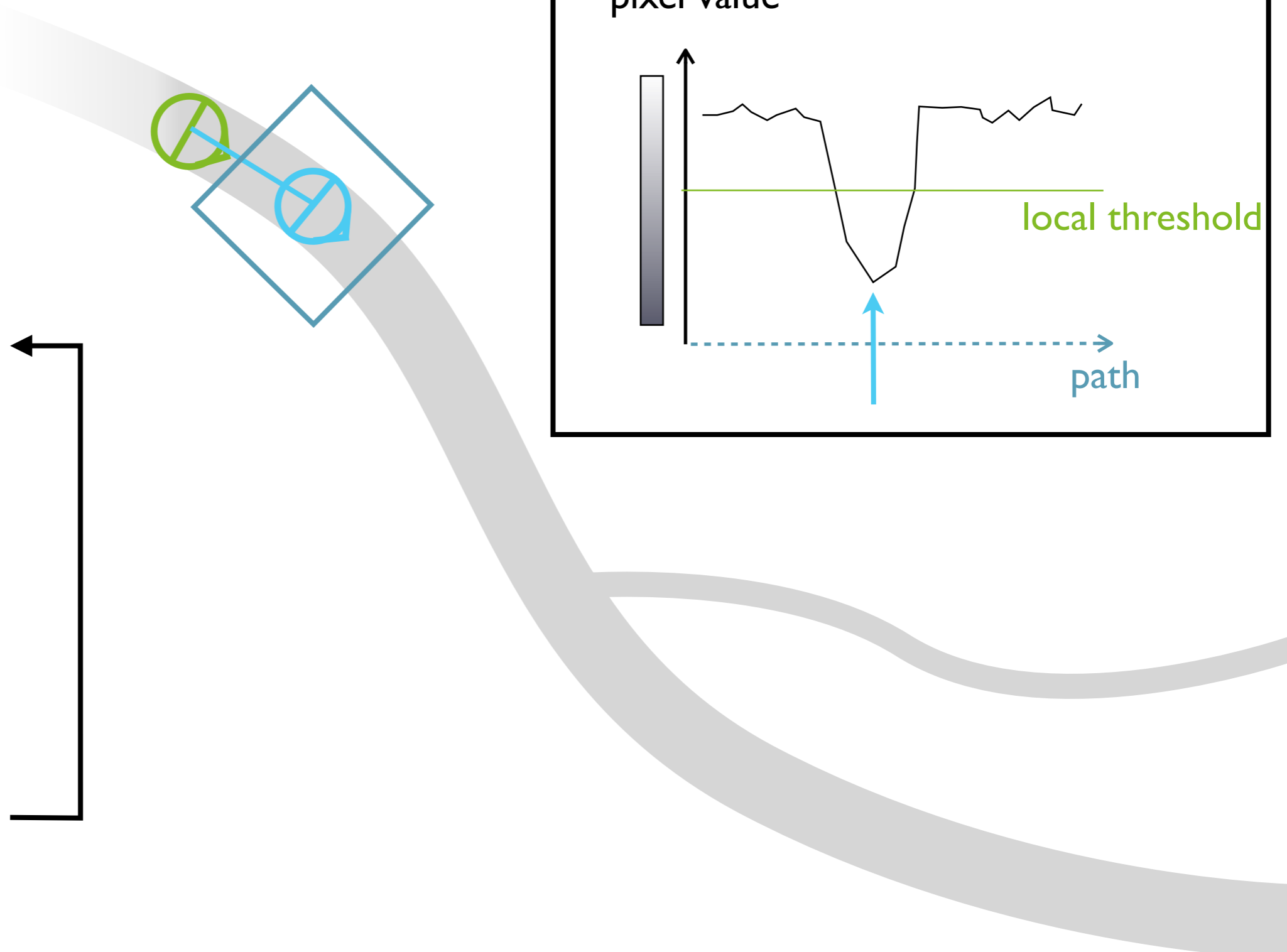
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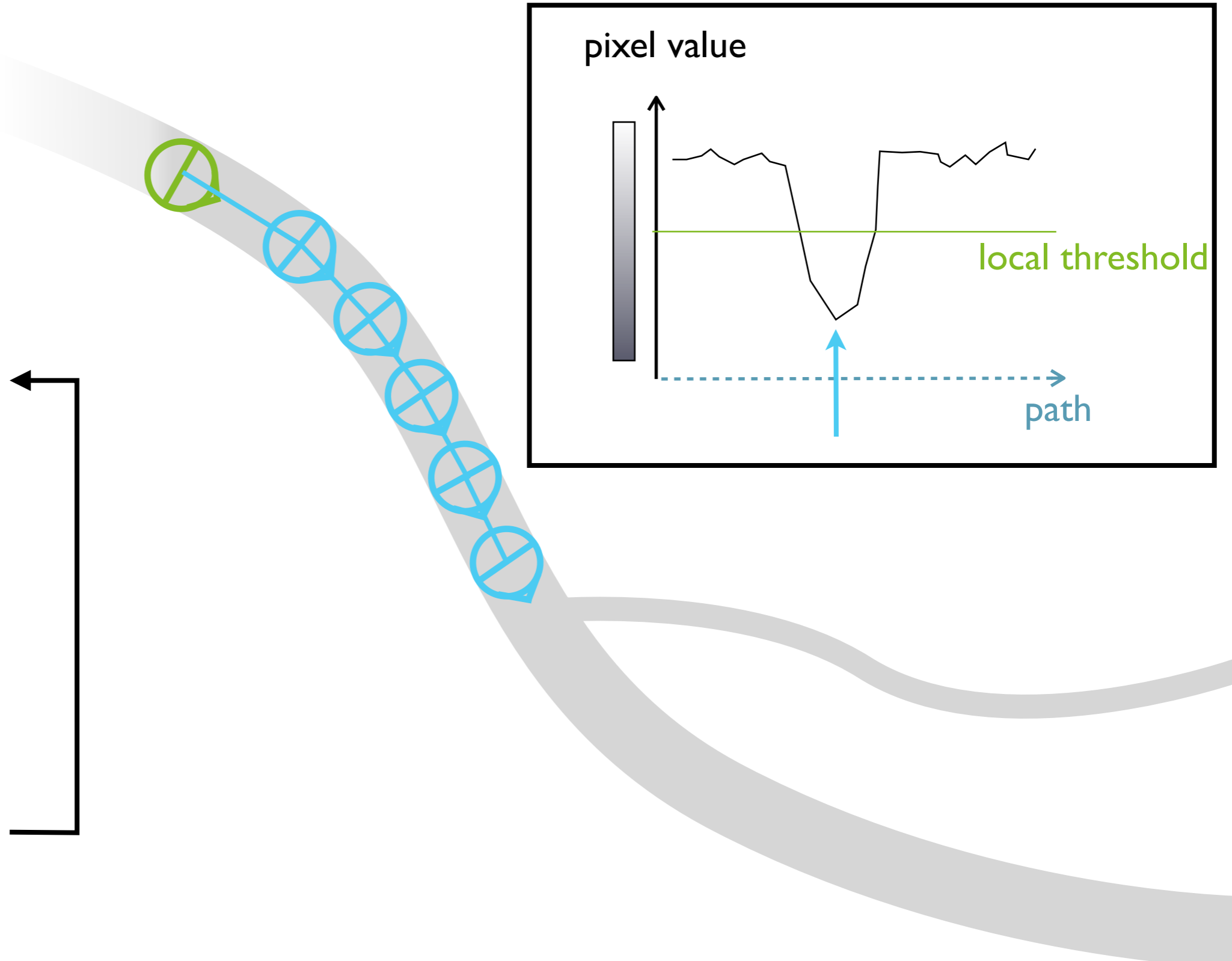
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# Tracing algorithm - 1

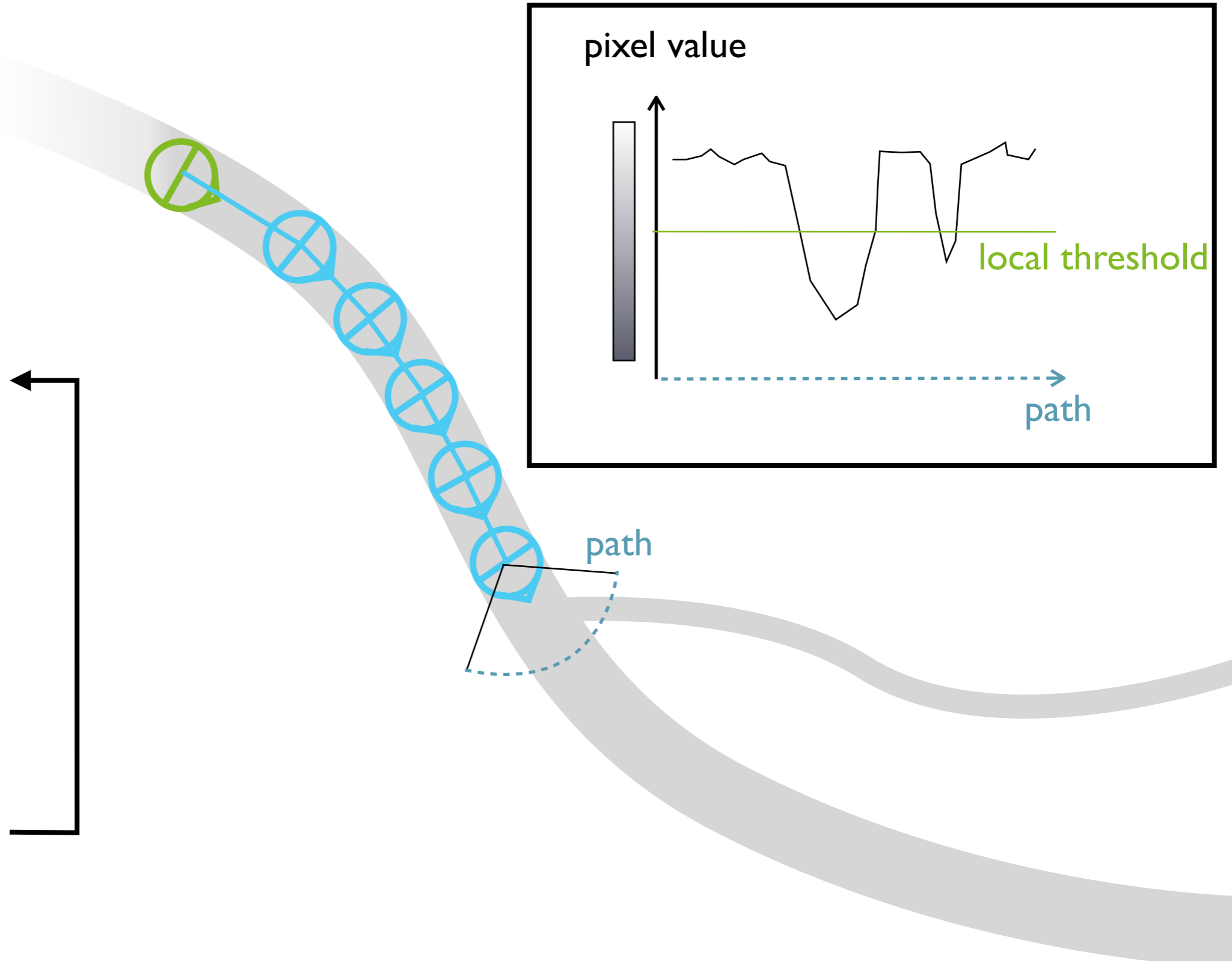
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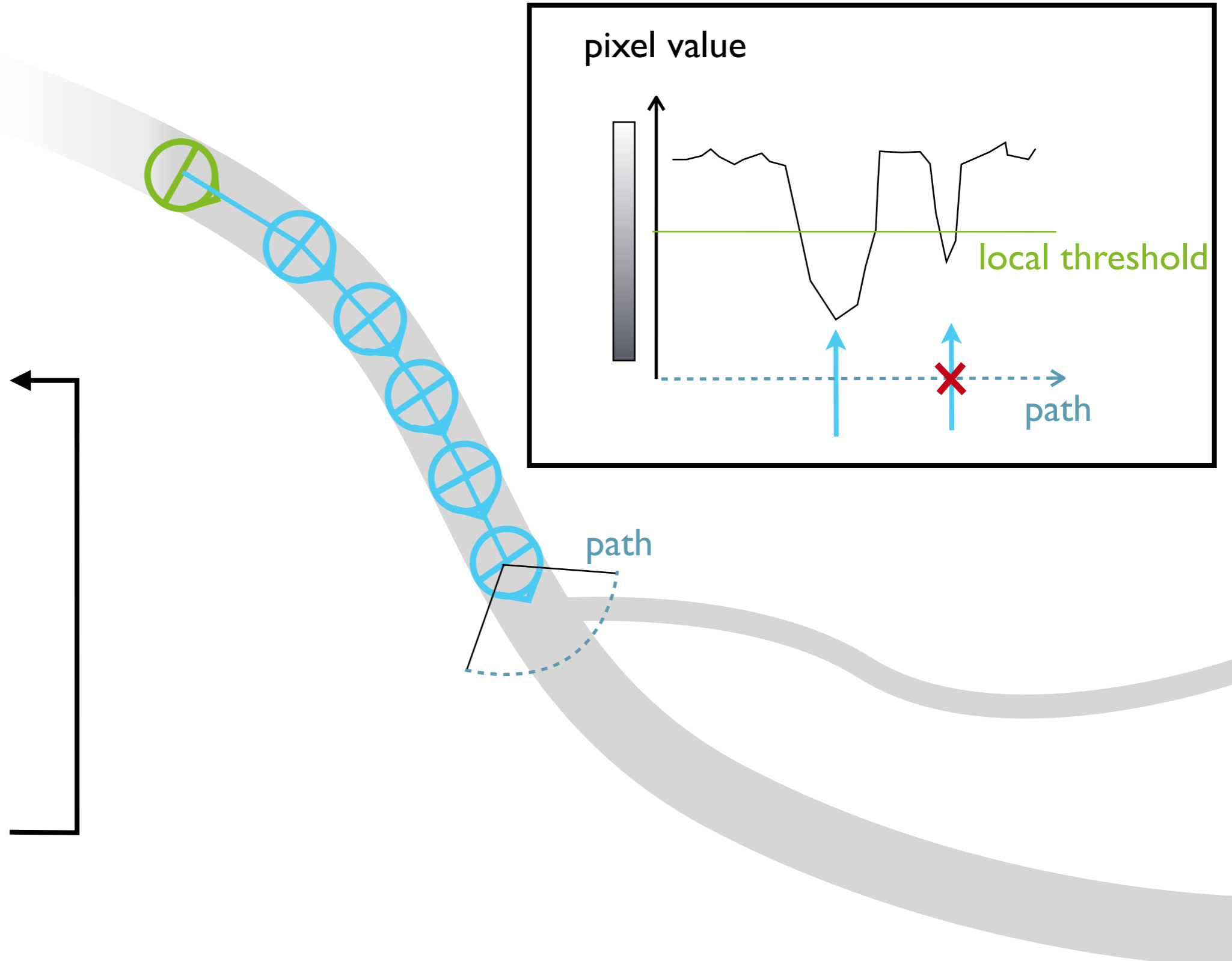
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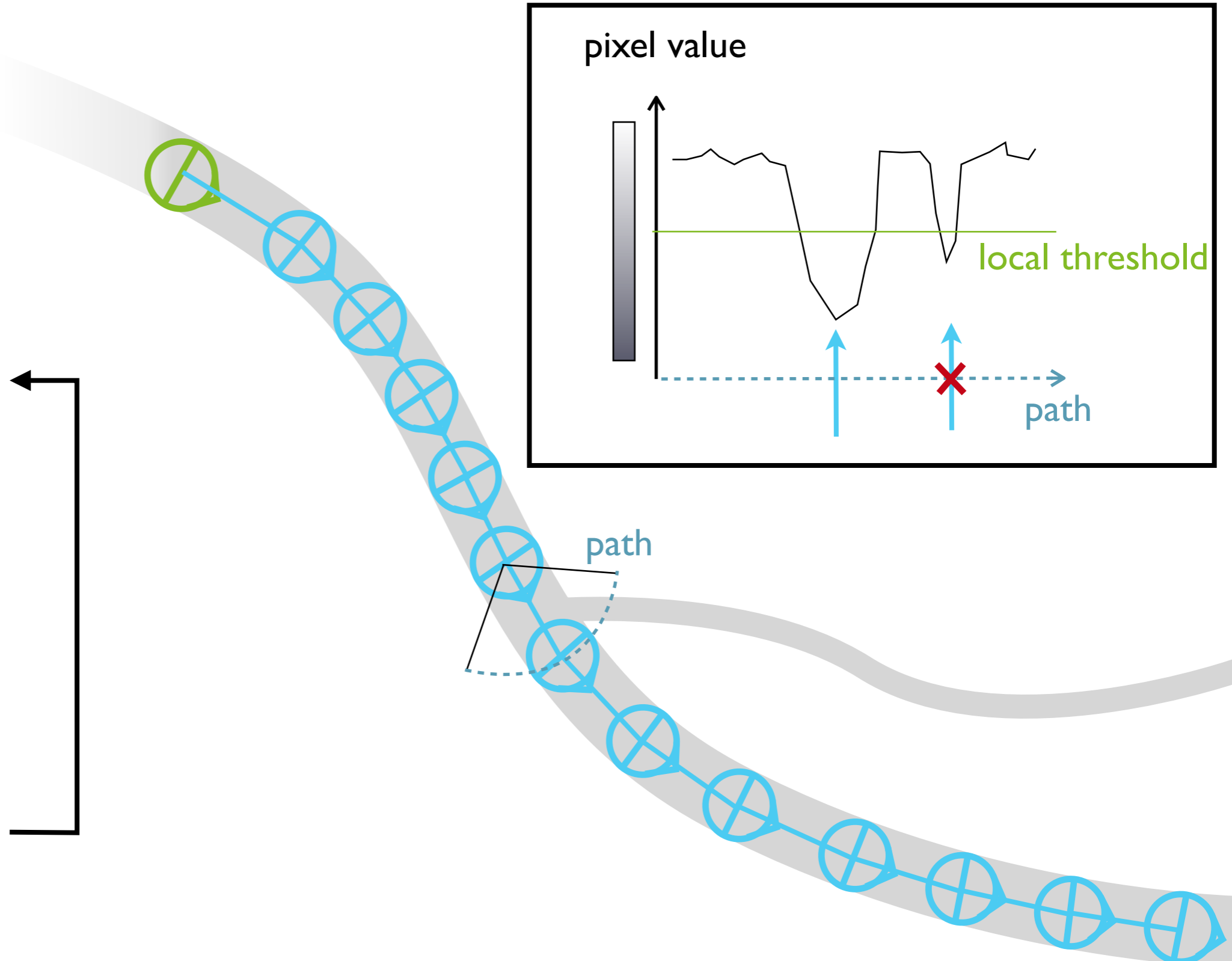
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# Tracing algorithm - 1

- mouse click
- local threshold
- node creation
- node centering
- search path
- diameter check
- node creation
- node centering
- append node
- local threshold**



# Tracing algorithm - 2

mouse click

**local threshold**

node creation

node centering

local threshold

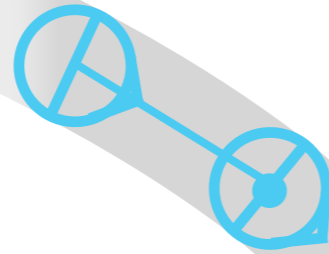
search path

diameter check

node creation

node centering

append node





# Tracing algorithm - 2

mouse click

**local threshold**

node creation

node centering

local threshold

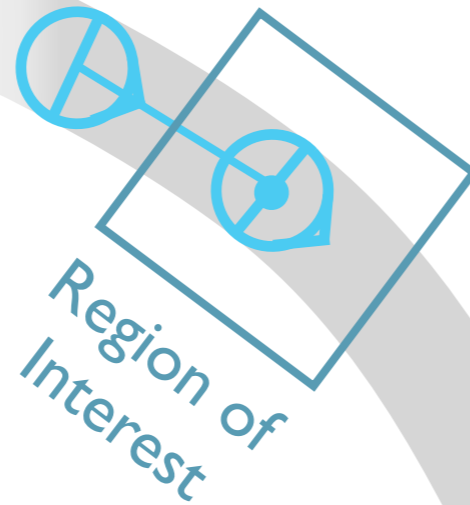
search path

diameter check

node creation

node centering

append node



# Tracing algorithm - 2

mouse click

**local threshold**

node creation

node centering

local threshold

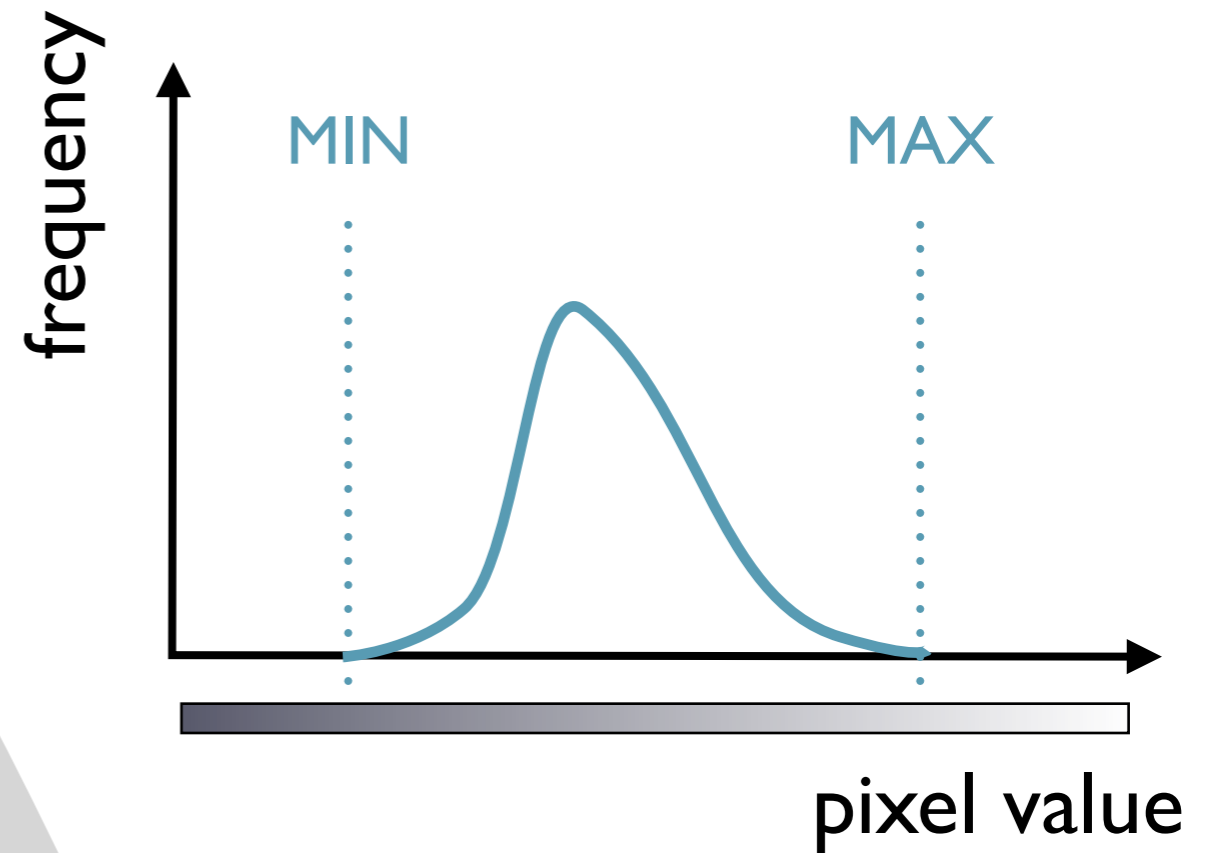
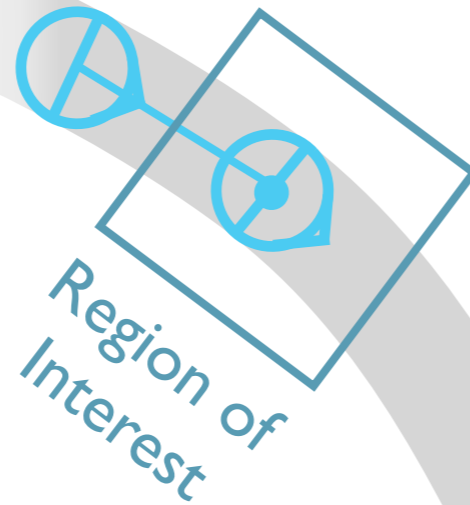
search path

diameter check

node creation

node centering

append node



# Tracing algorithm - 2

mouse click

**local threshold**

node creation

node centering

local threshold

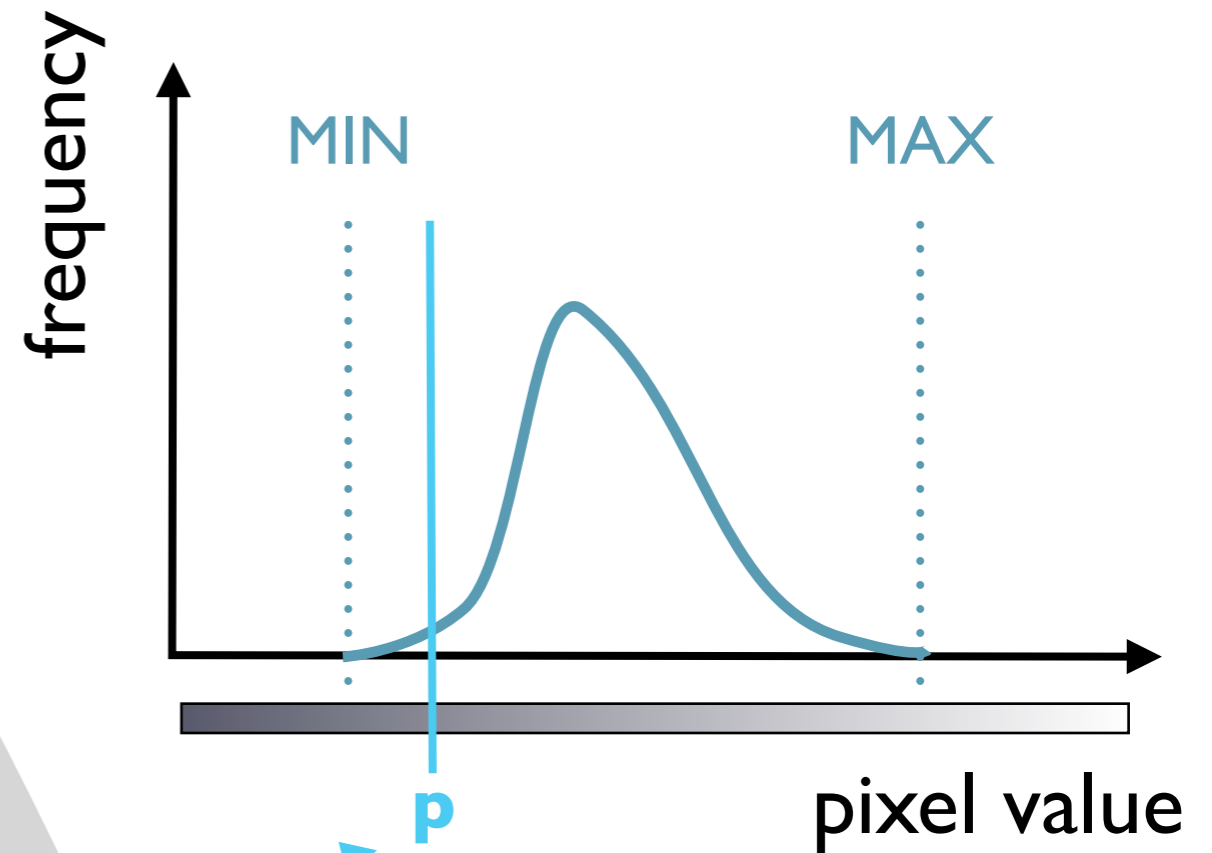
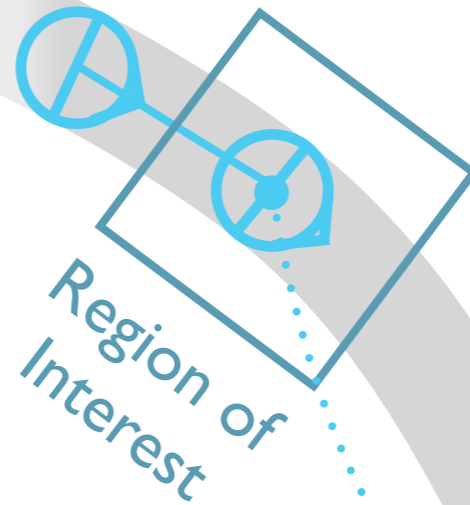
search path

diameter check

node creation

node centering

append node



# Tracing algorithm - 2

mouse click

**local threshold**

node creation

node centering

local threshold

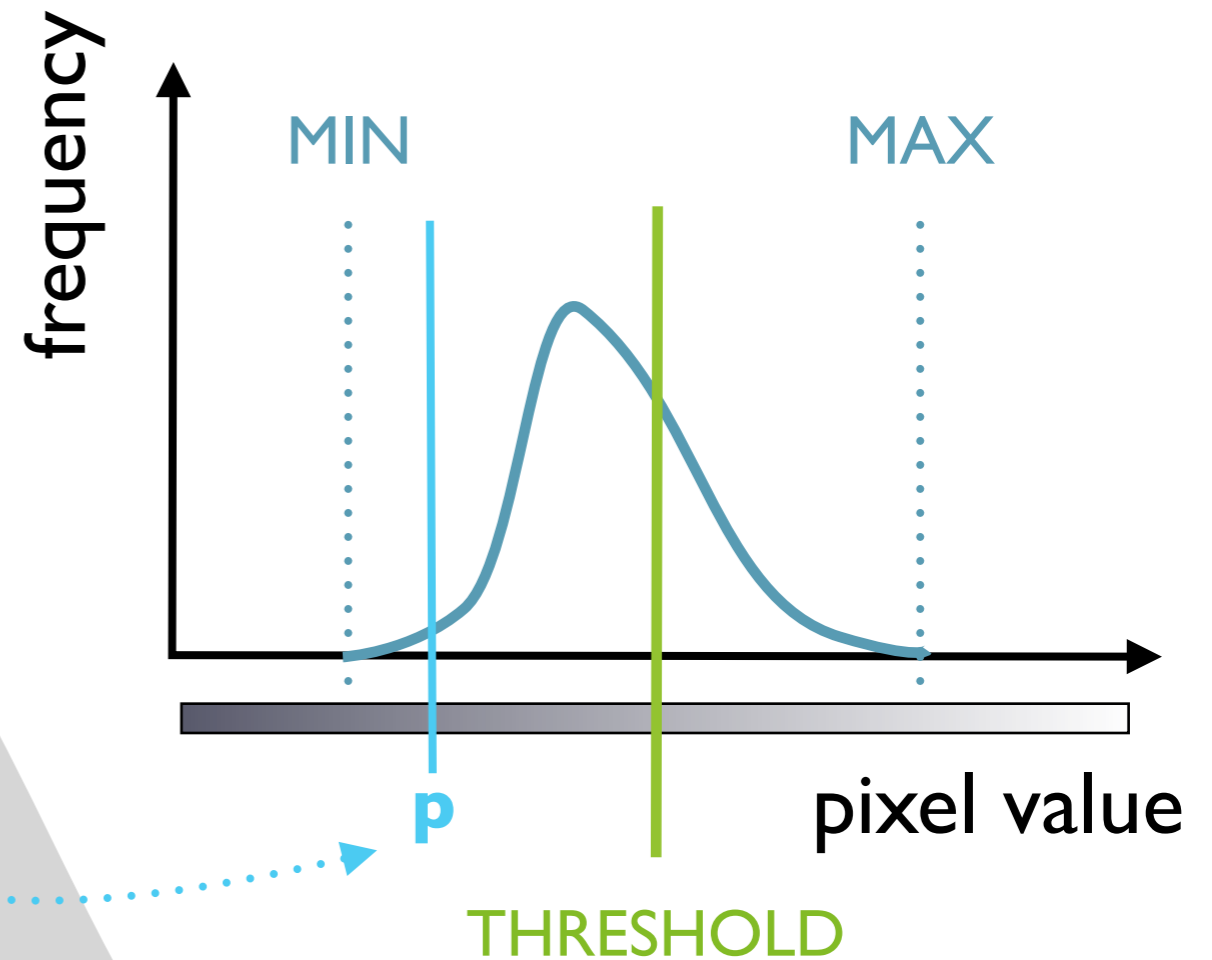
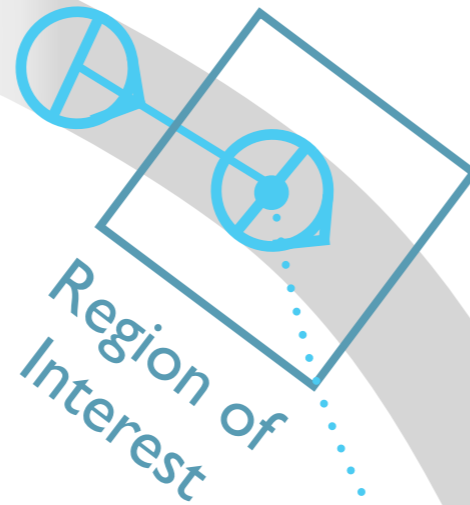
search path

diameter check

node creation

node centering

append node



$$T = \frac{\frac{p + \text{MIN}}{2} + \text{MAX}}{2}$$





# Tracing algorithm - 3

mouse click

local threshold

node creation

**node centering**

local threshold

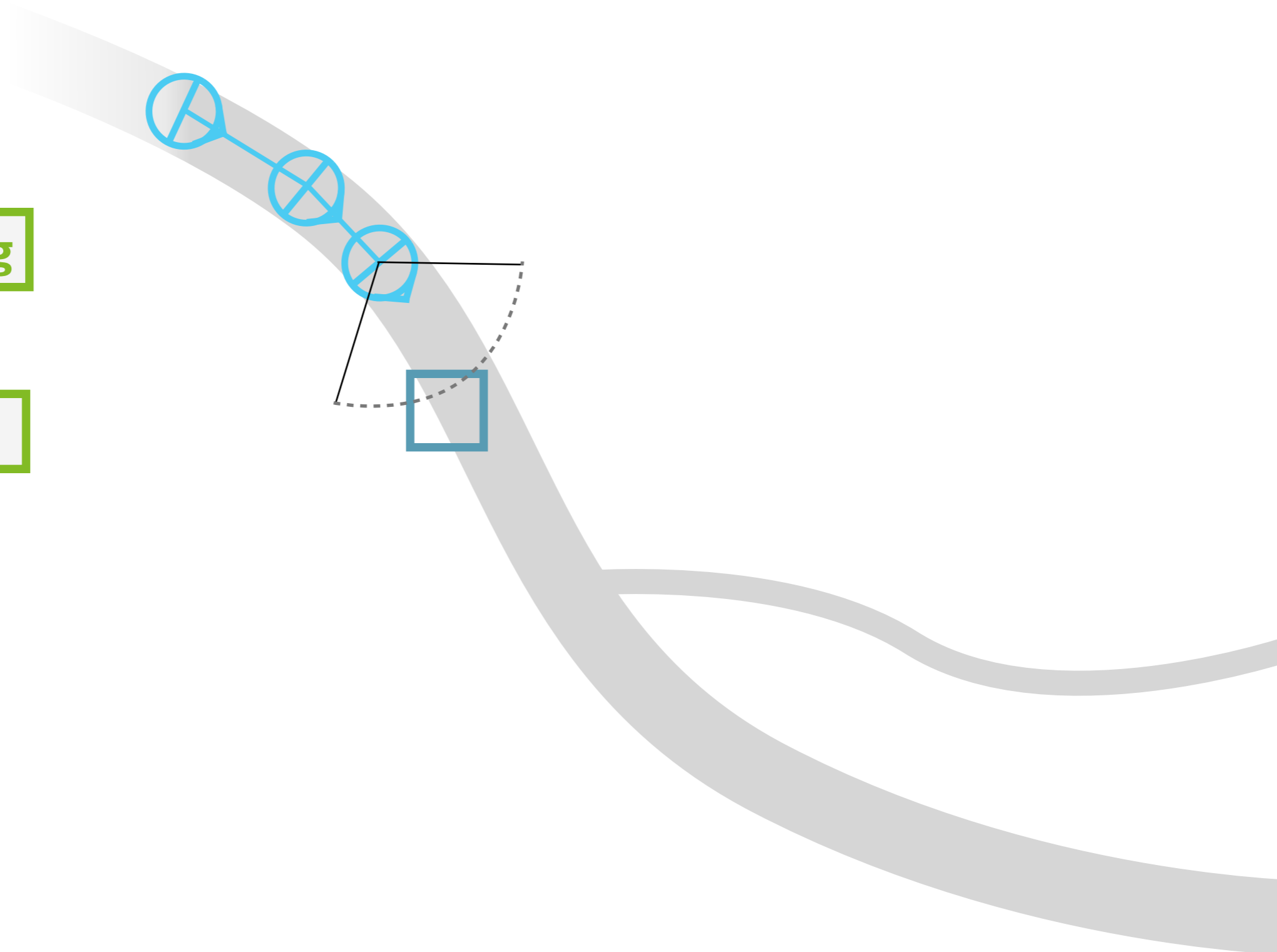
**search path**

diameter check

node creation

node centering

append node



# Tracing algorithm - 3

mouse click

local threshold

node creation

**node centering**

local threshold

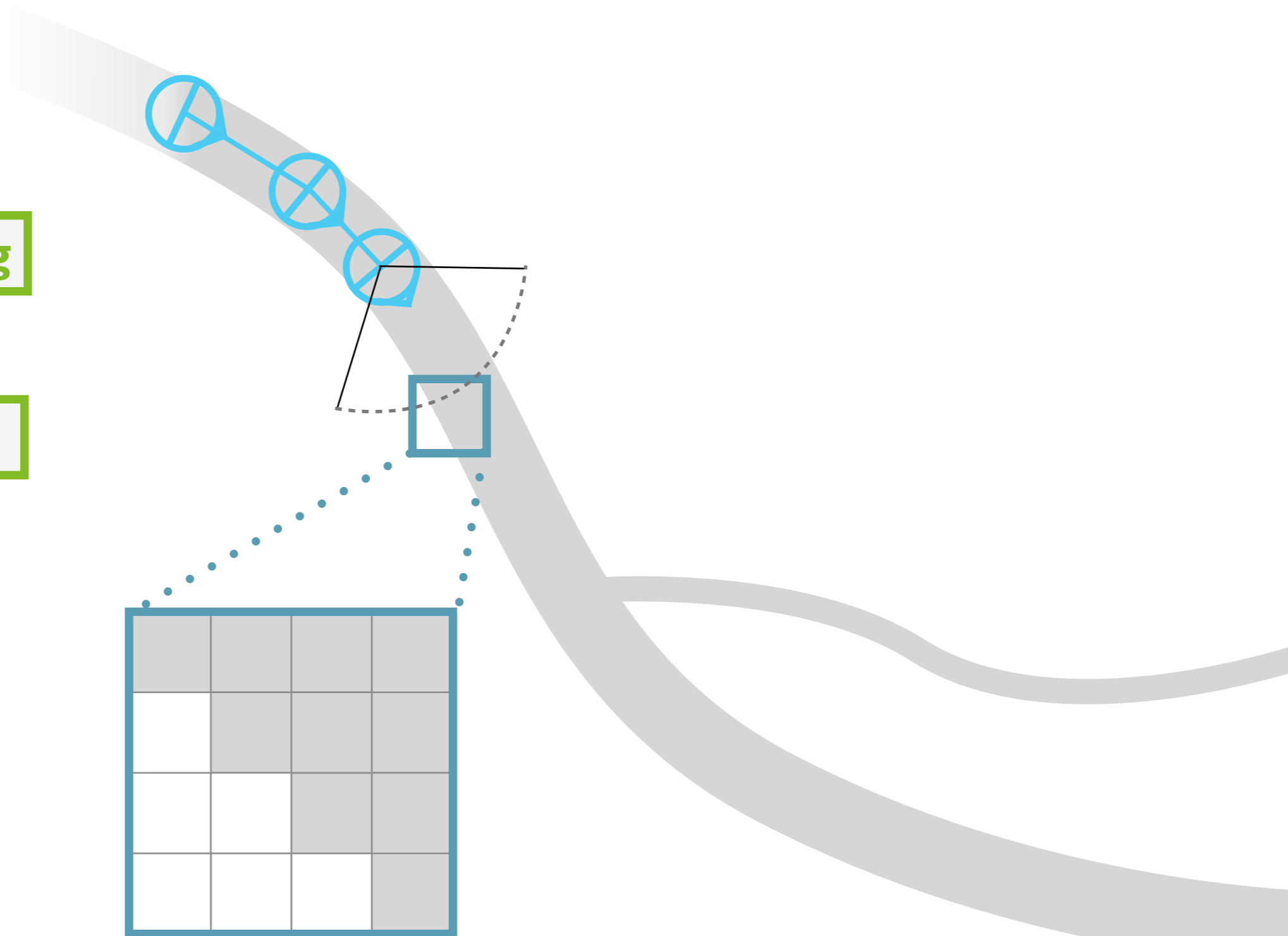
**search path**

diameter check

node creation

node centering

append node



# Tracing algorithm - 3

mouse click

local threshold

node creation

**node centering**

local threshold

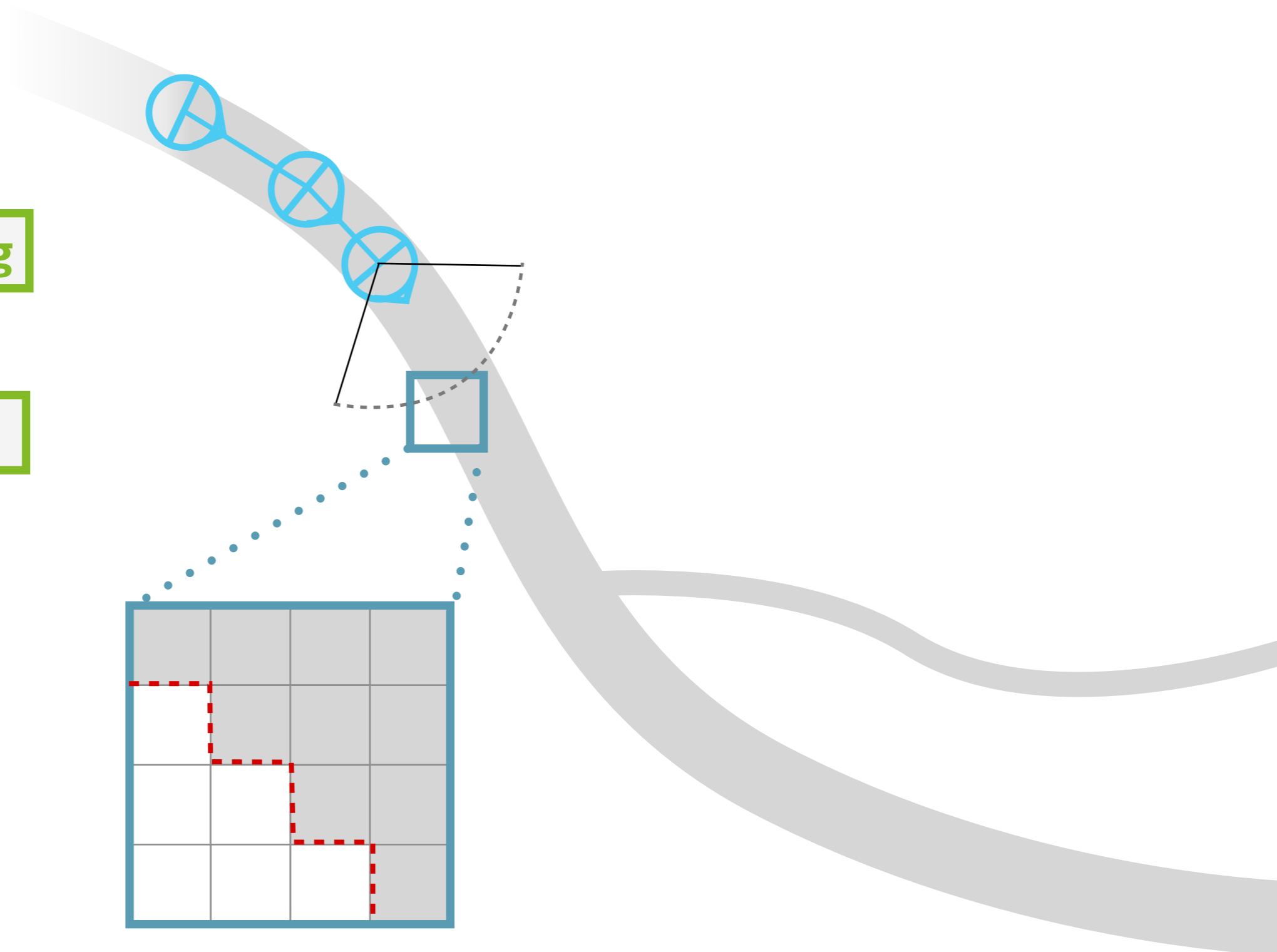
**search path**

diameter check

node creation

node centering

append node



# Tracing algorithm - 3

mouse click

local threshold

node creation

**node centering**

local threshold

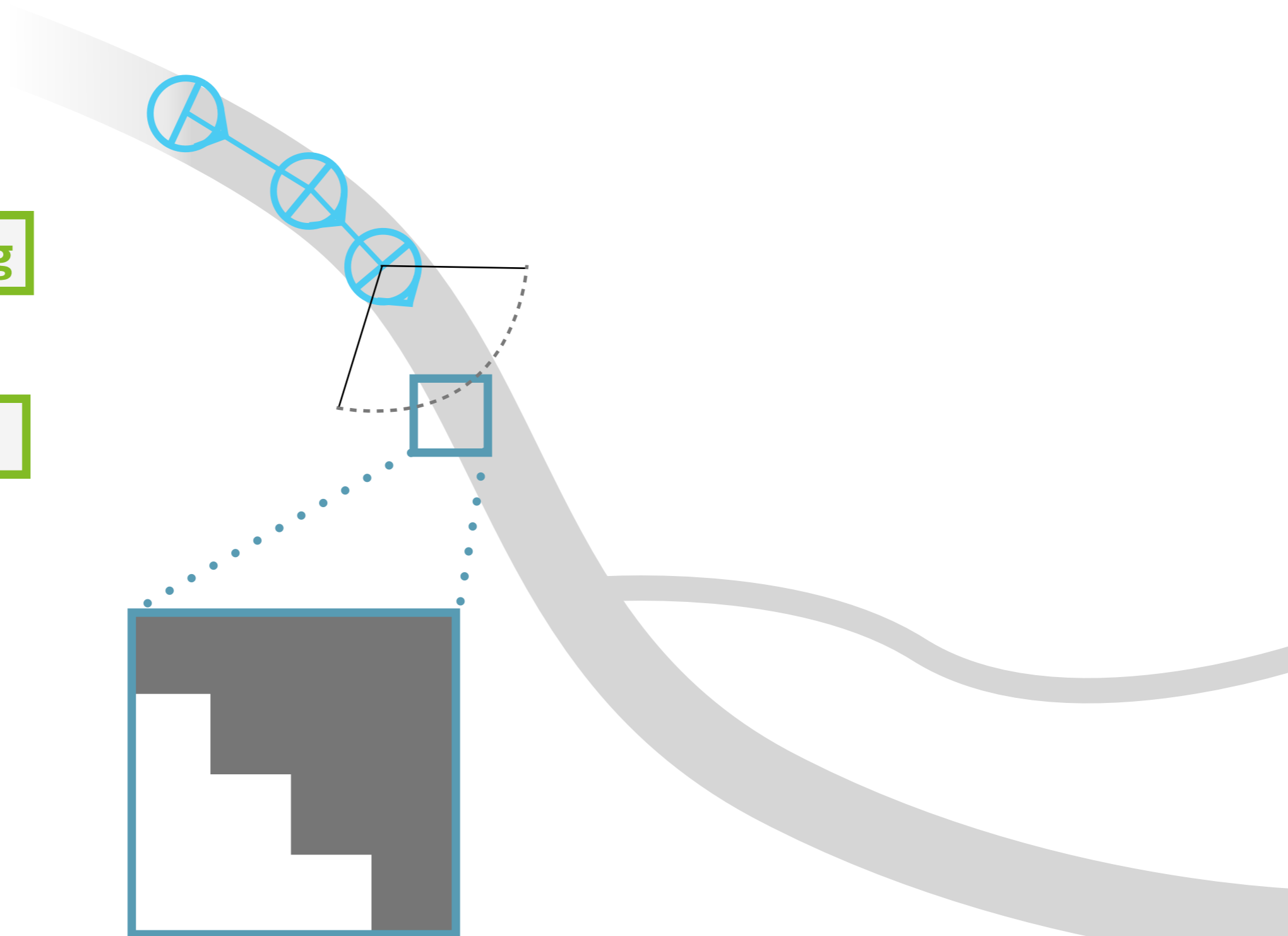
**search path**

diameter check

node creation

node centering

append node



# Tracing algorithm - 3

mouse click

local threshold

node creation

**node centering**

local threshold

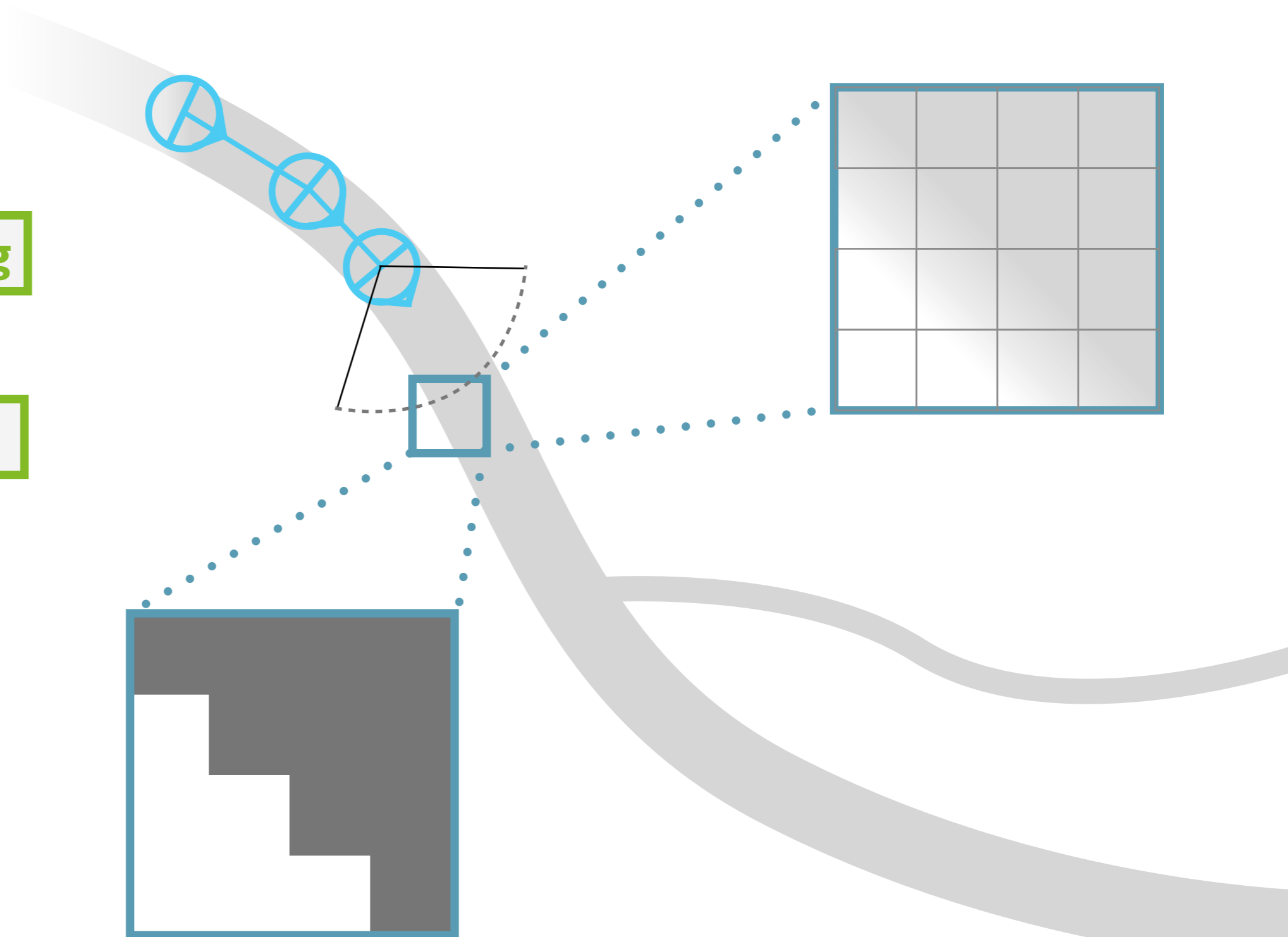
**search path**

diameter check

node creation

node centering

append node



# Tracing algorithm - 3

mouse click

local threshold

node creation

**node centering**

local threshold

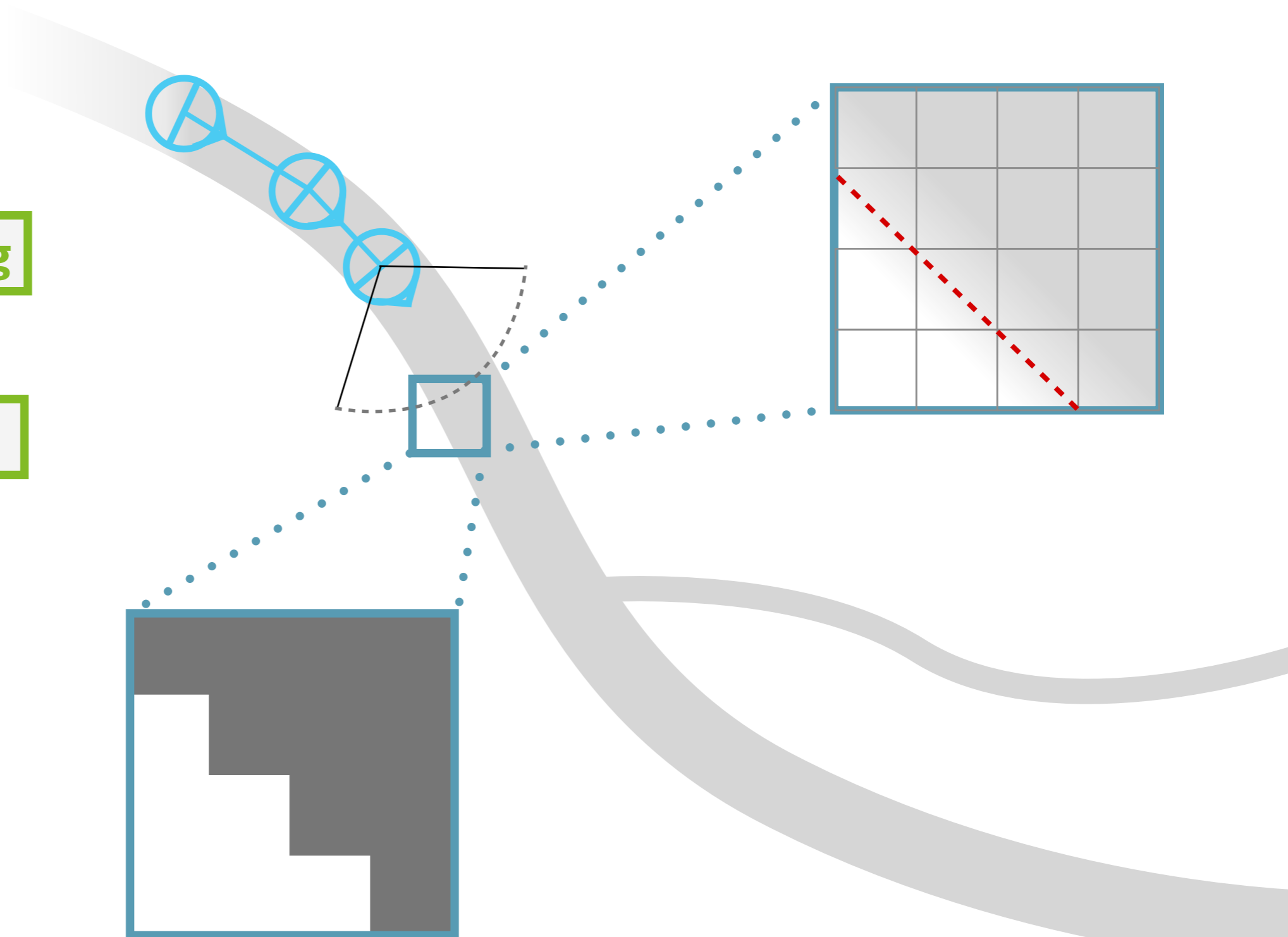
**search path**

diameter check

node creation

node centering

append node





# Tracing algorithm - 3

mouse click

local threshold

node creation

**node centering**

local threshold

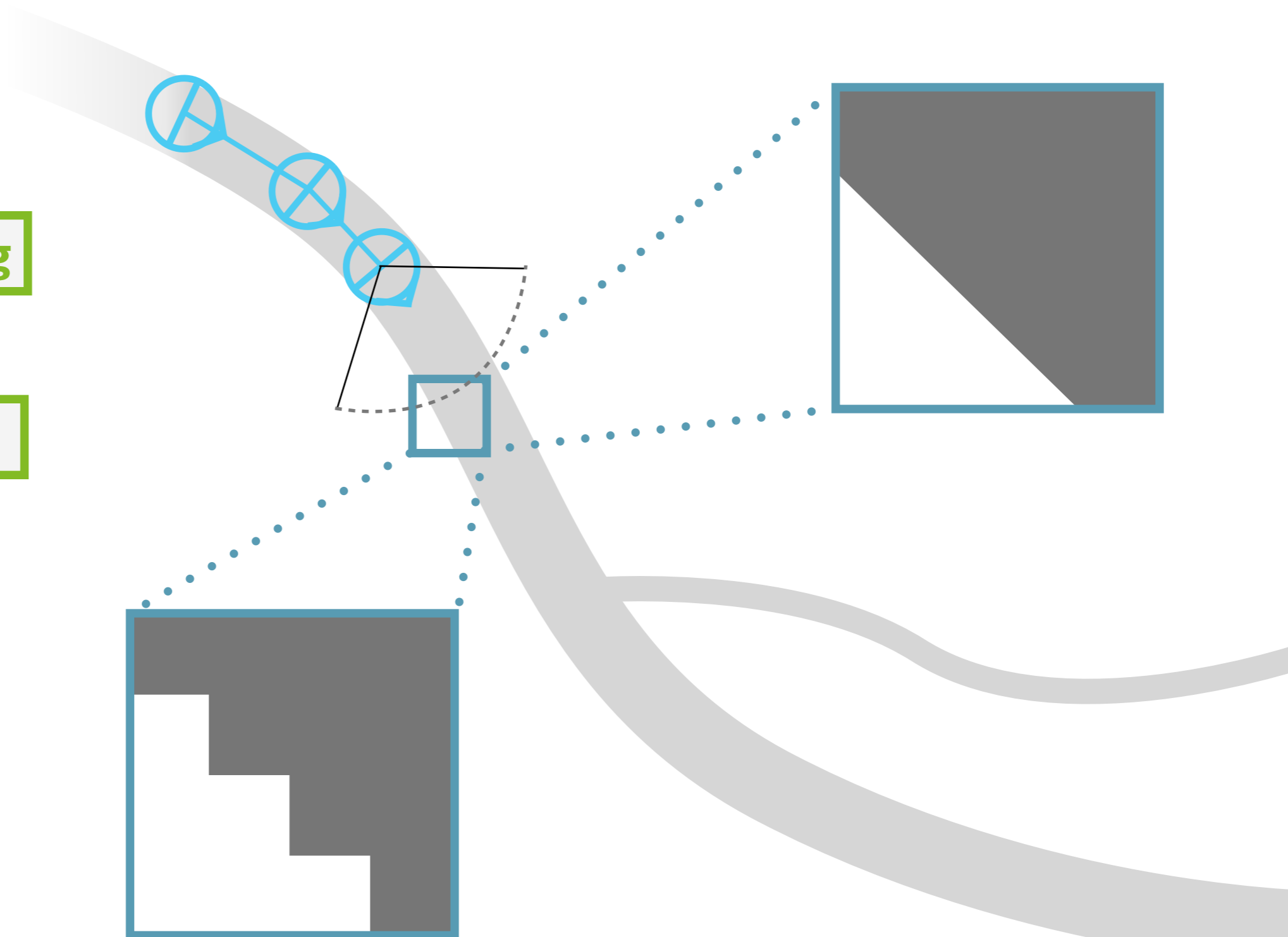
**search path**

diameter check

node creation

node centering

append node



# Tracing algorithm - 4

mouse click

local threshold

node creation

**node centering**

local threshold

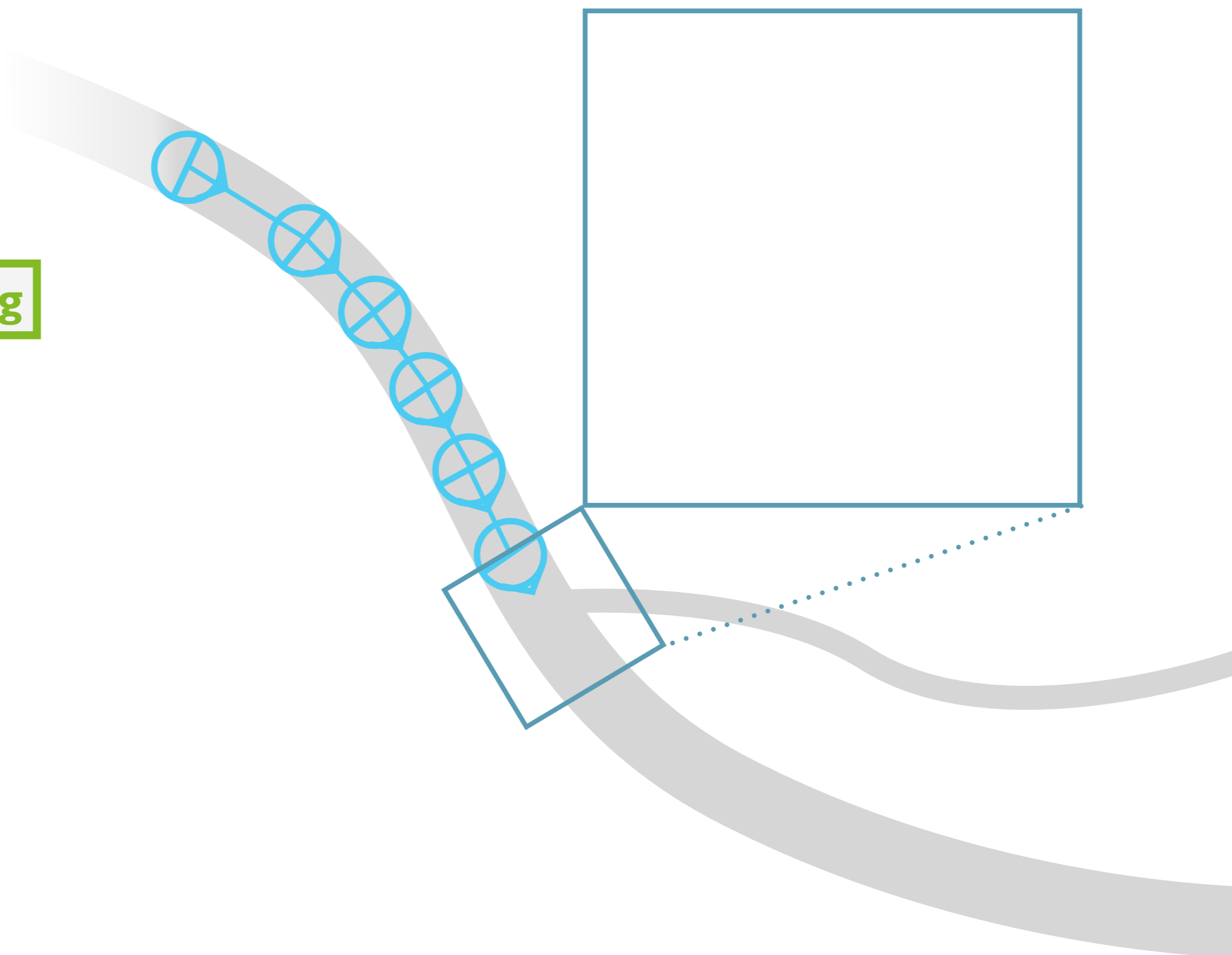
search path

diameter check

node creation

node centering

append node



# Tracing algorithm - 4

mouse click

local threshold

node creation

**node centering**

local threshold

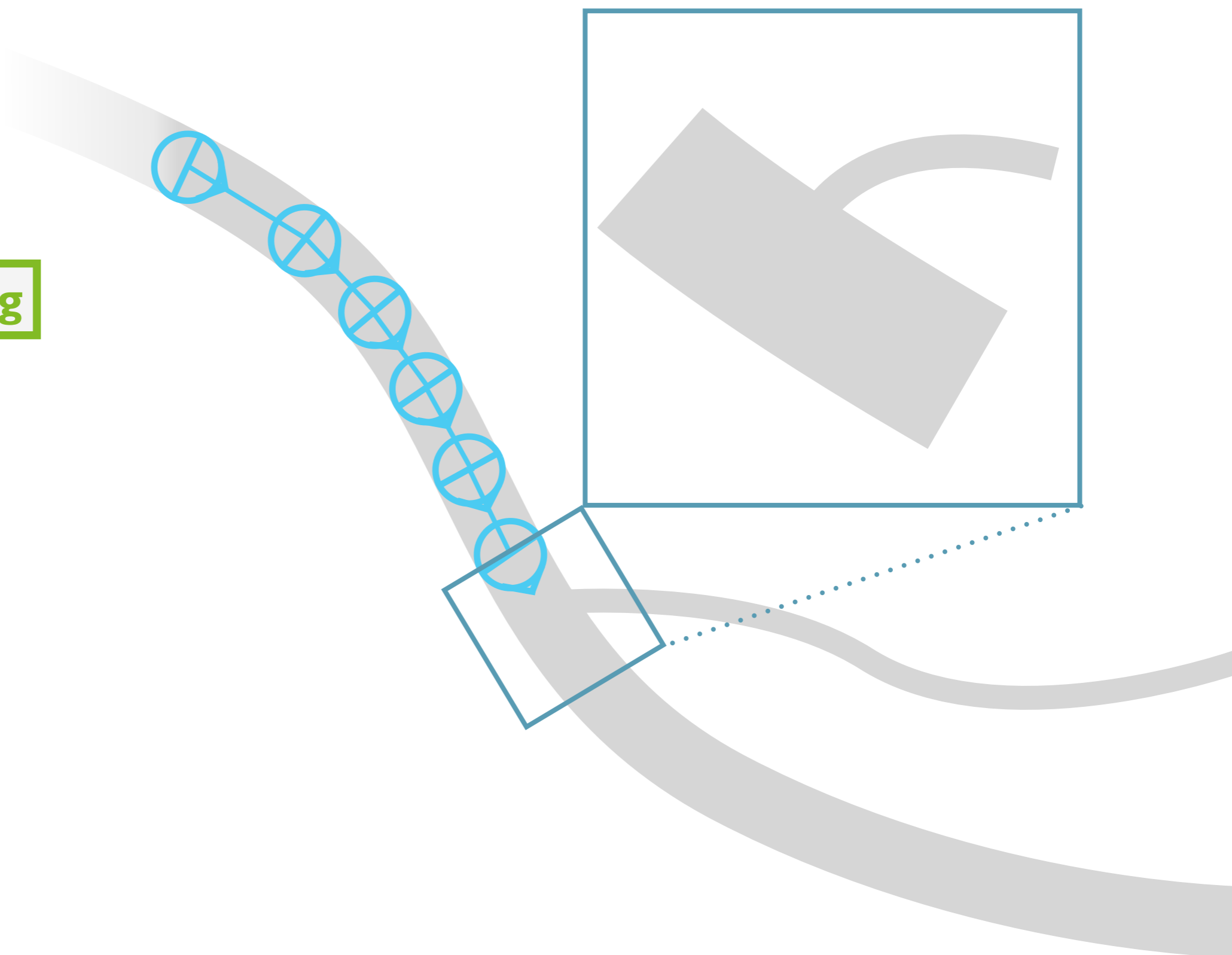
search path

diameter check

node creation

node centering

append node



# Tracing algorithm - 4

mouse click

local threshold

node creation

**node centering**

local threshold

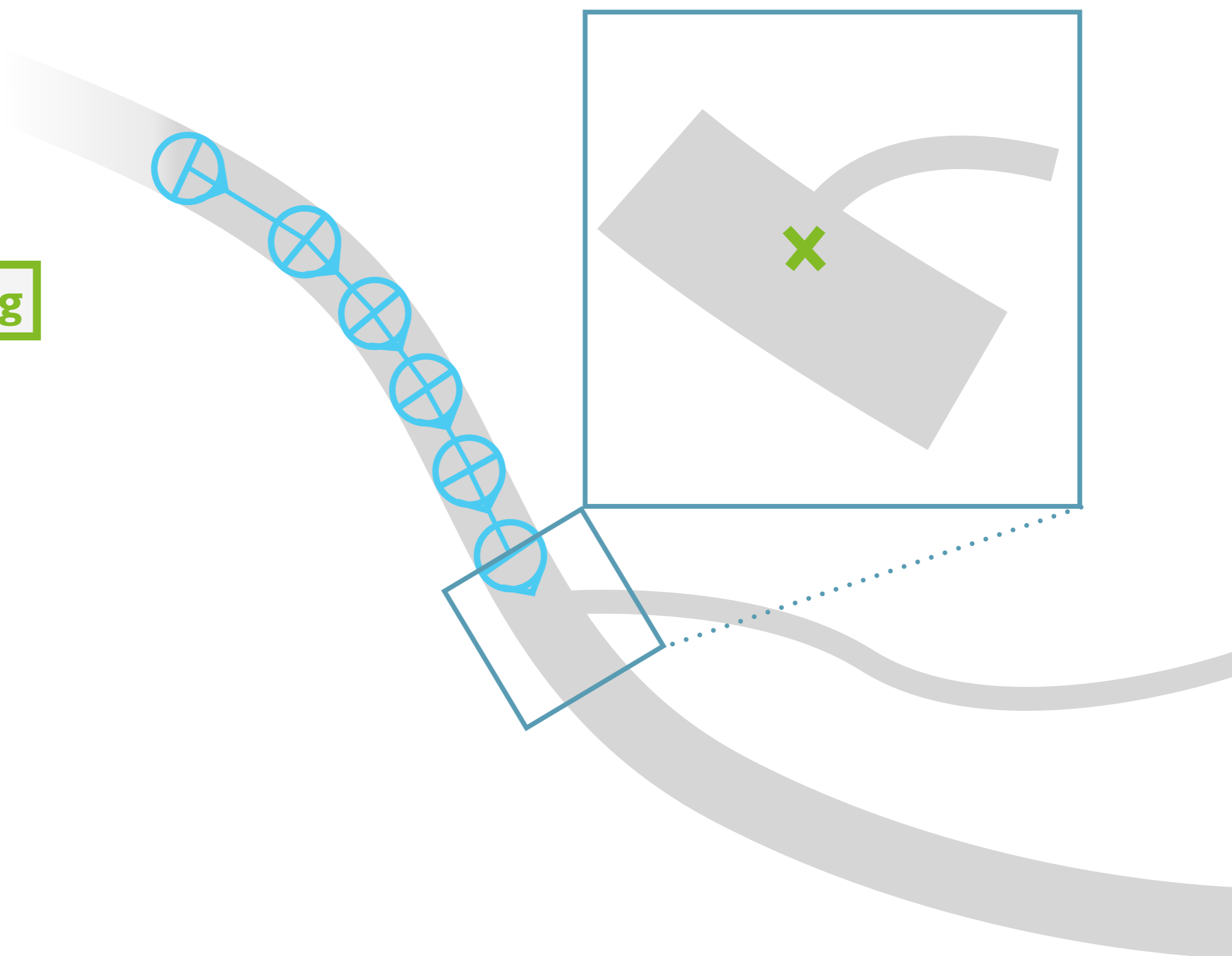
search path

diameter check

node creation

node centering

append node



# Tracing algorithm - 4

mouse click

local threshold

node creation

**node centering**

local threshold

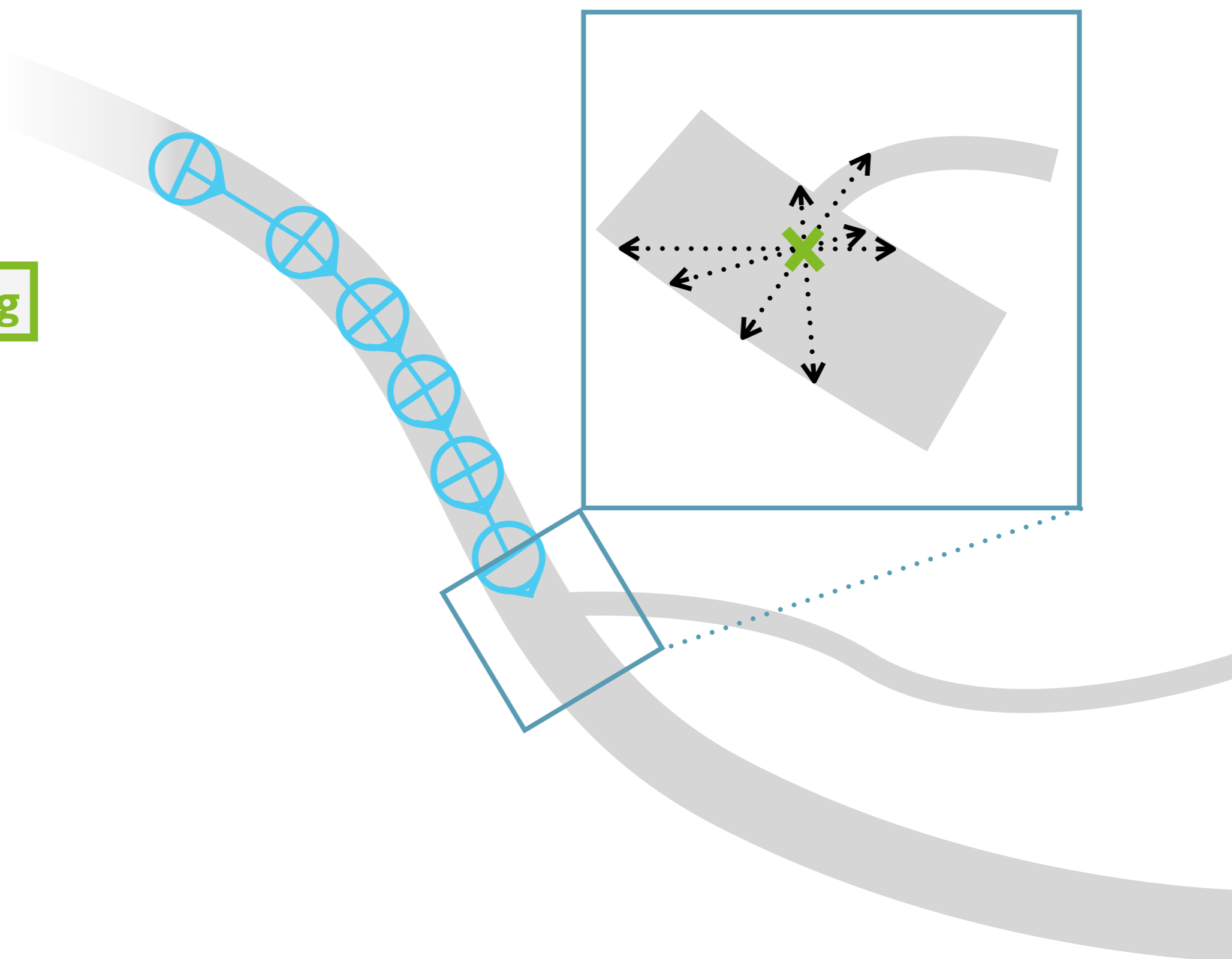
search path

diameter check

node creation

node centering

append node



# Tracing algorithm - 4

mouse click

local threshold

node creation

**node centering**

local threshold

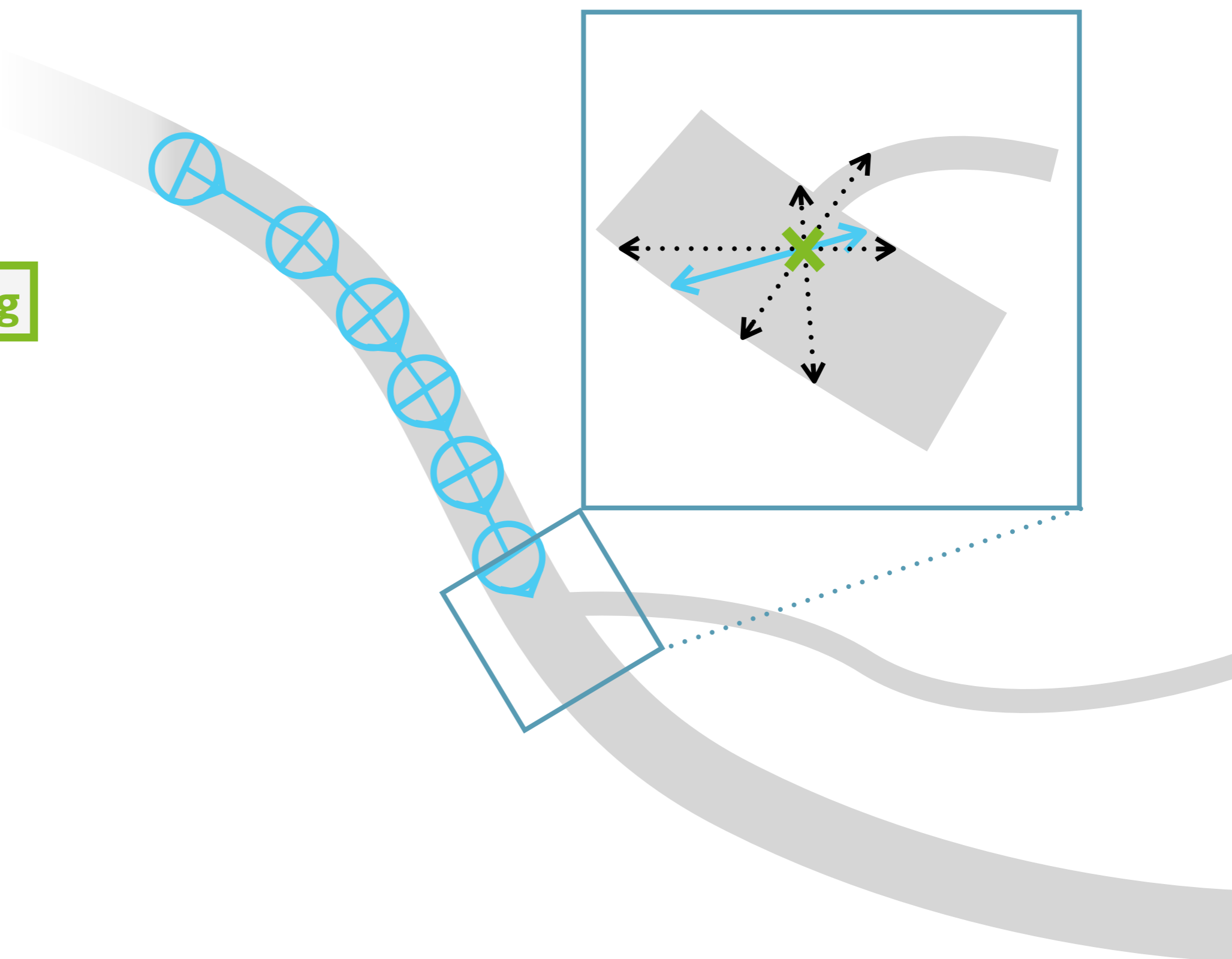
search path

diameter check

node creation

node centering

append node





# Tracing algorithm - 4

mouse click

local threshold

node creation

**node centering**

local threshold

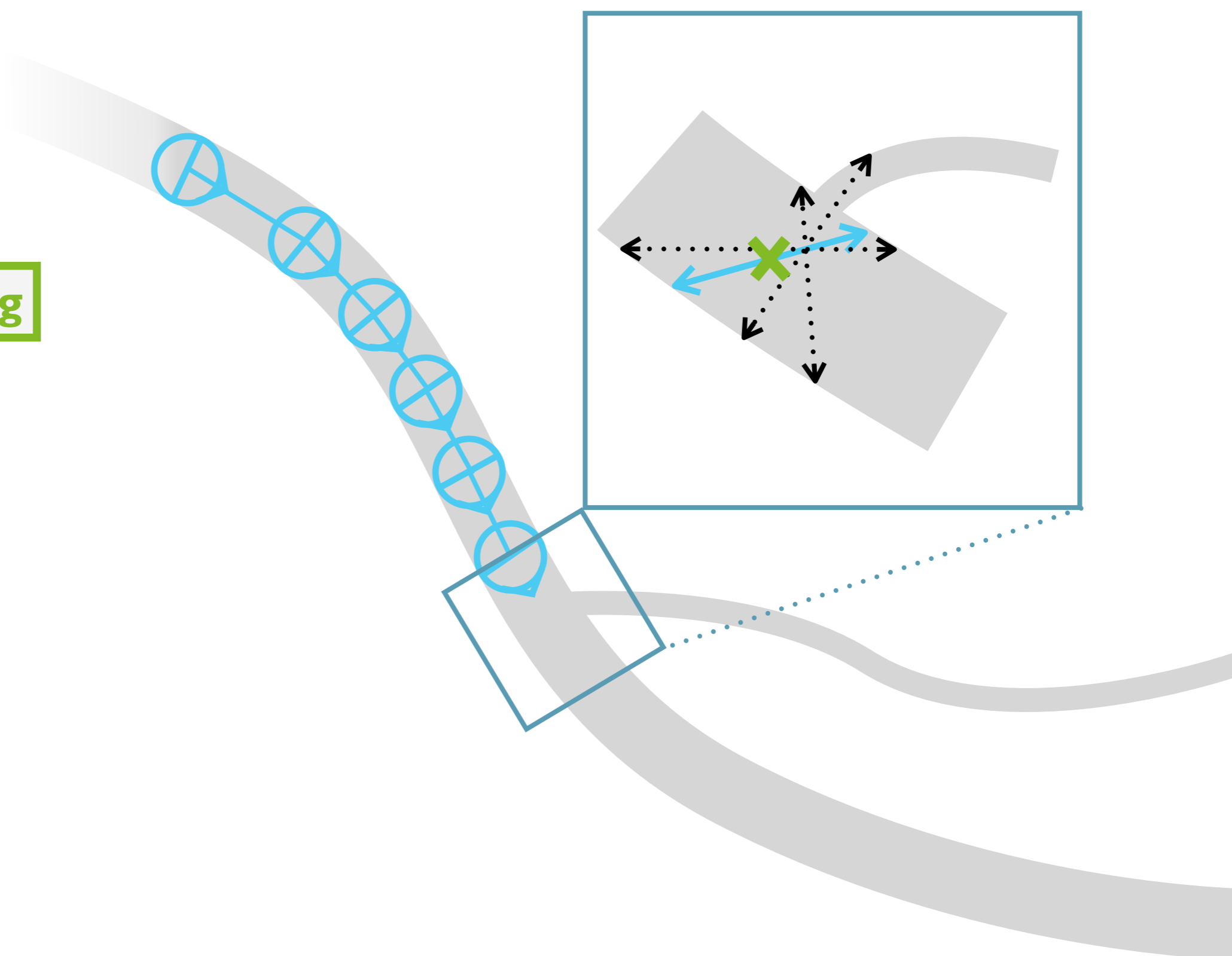
search path

diameter check

node creation

node centering

append node



# Tracing algorithm - 4

mouse click

local threshold

node creation

**node centering**

local threshold

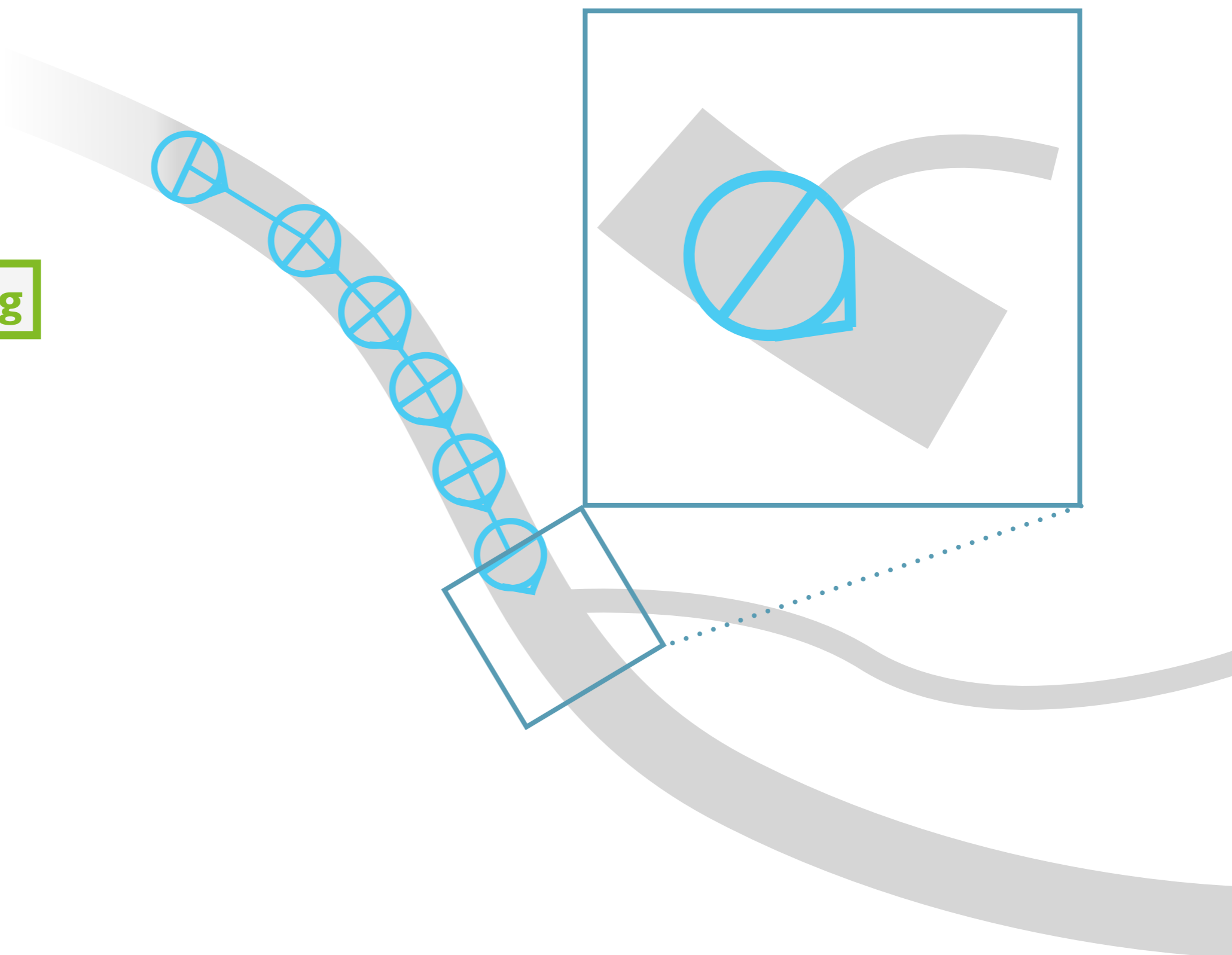
search path

diameter check

node creation

node centering

append node



# Tracing algorithm - 5

mouse click

local threshold

node creation

**node centering**

local threshold

search path

**diameter check**

node creation

node centering

append node



# Tracing algorithm - 5

mouse click

local threshold

node creation

**node centering**

local threshold

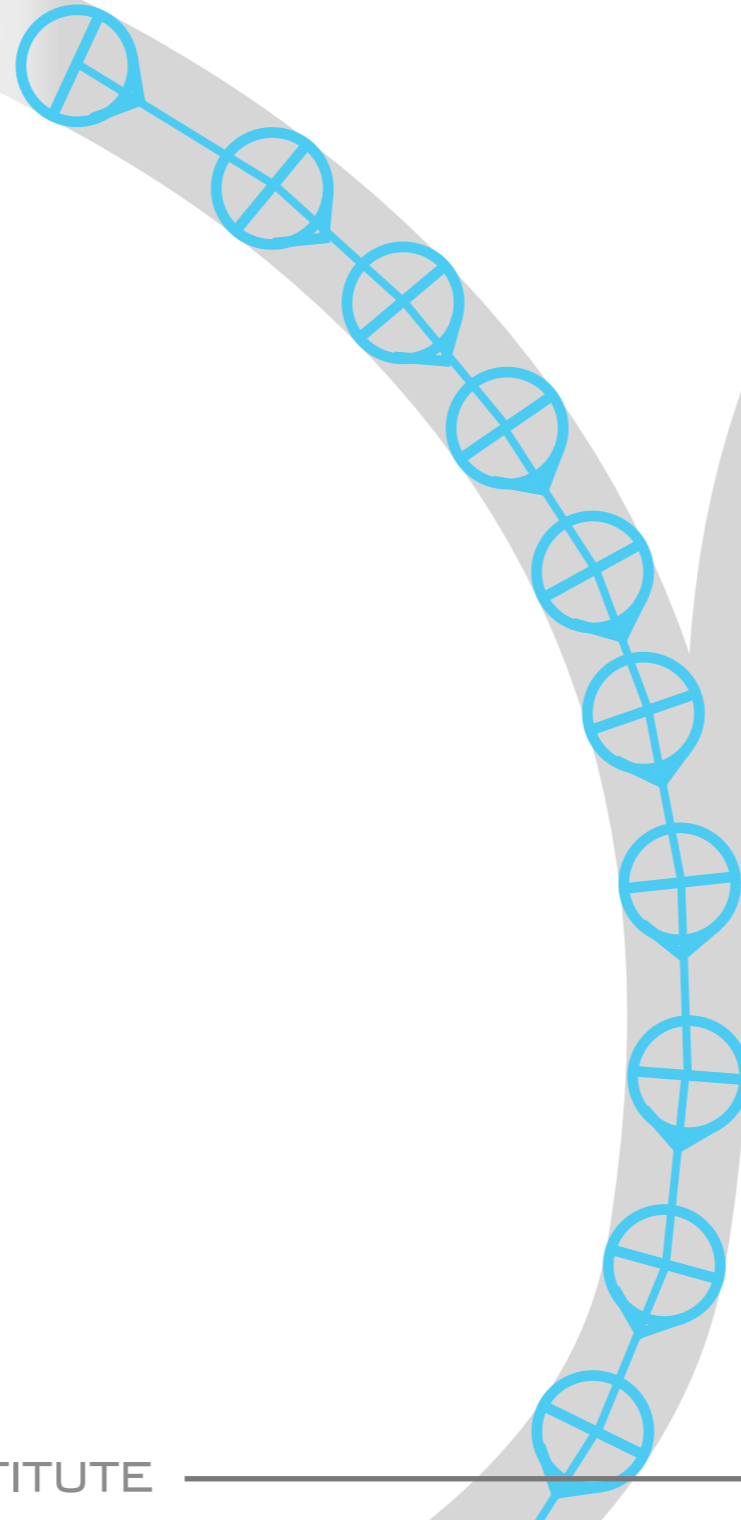
search path

**diameter check**

node creation

node centering

append node



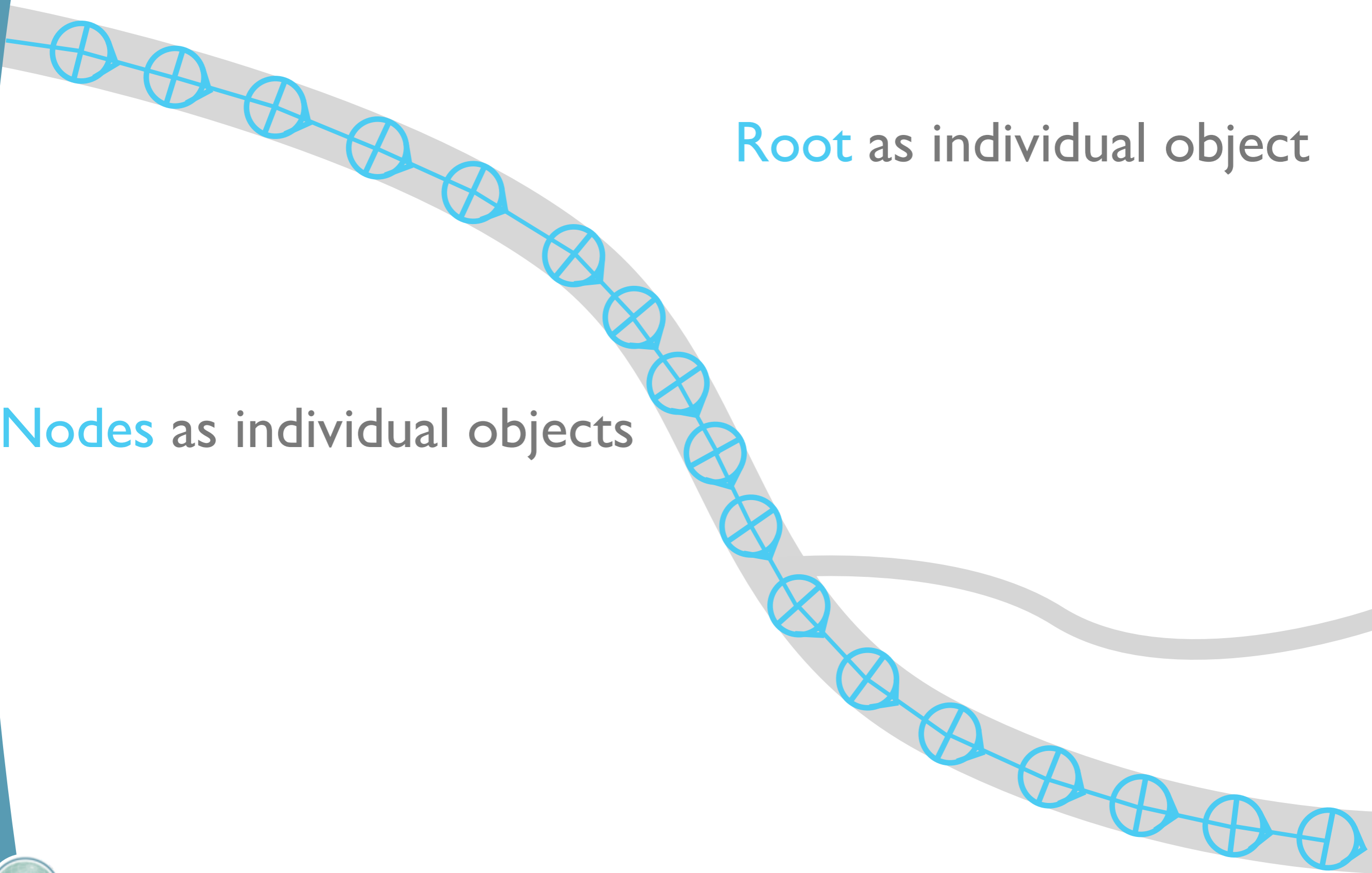
**Diameter freeze**



# Object oriented

Root as individual object

Nodes as individual objects



# Object oriented

Root as individual object

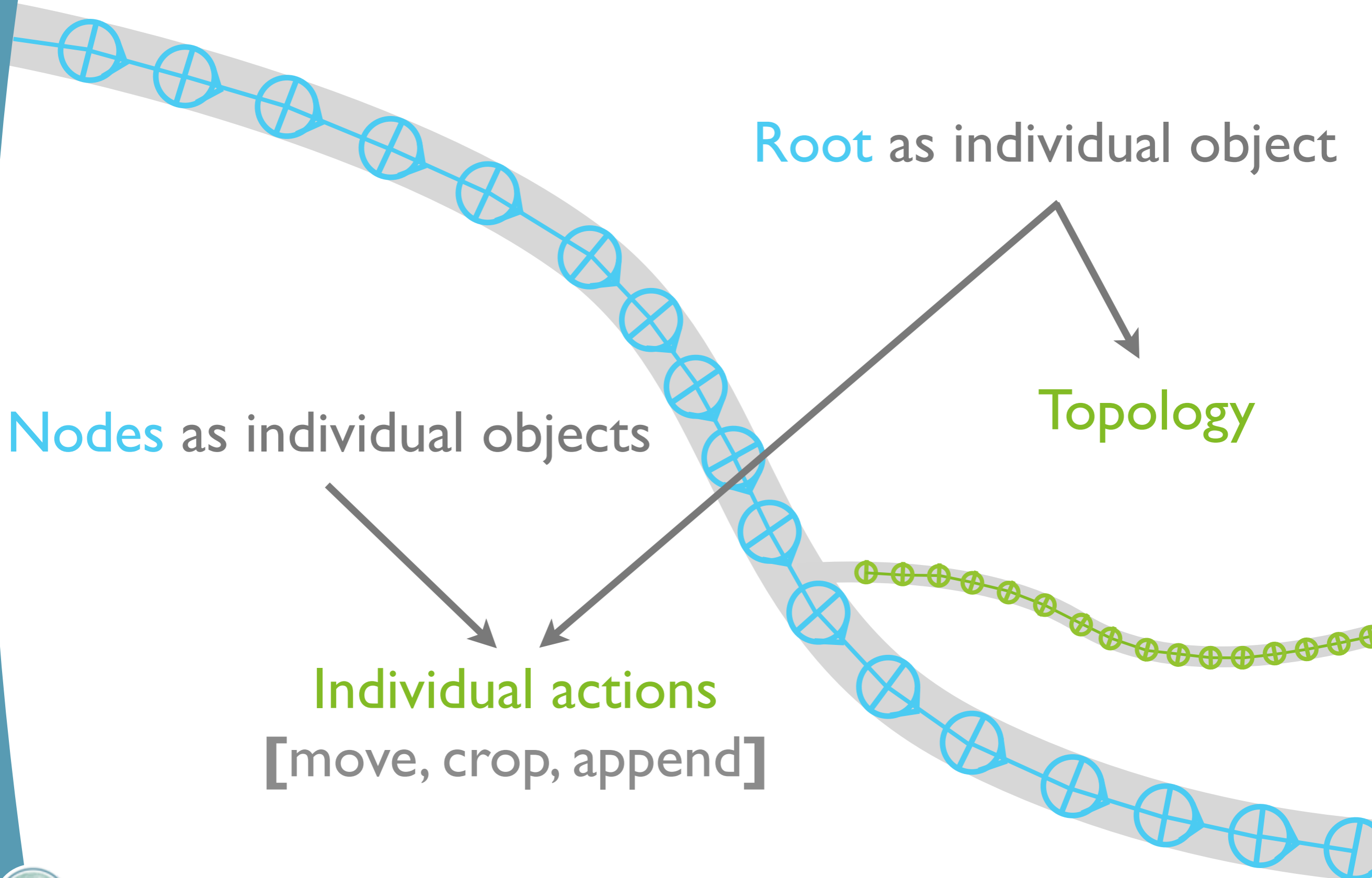
Nodes as individual objects

Individual actions  
[move, crop, append]





# Object oriented



Root as individual object

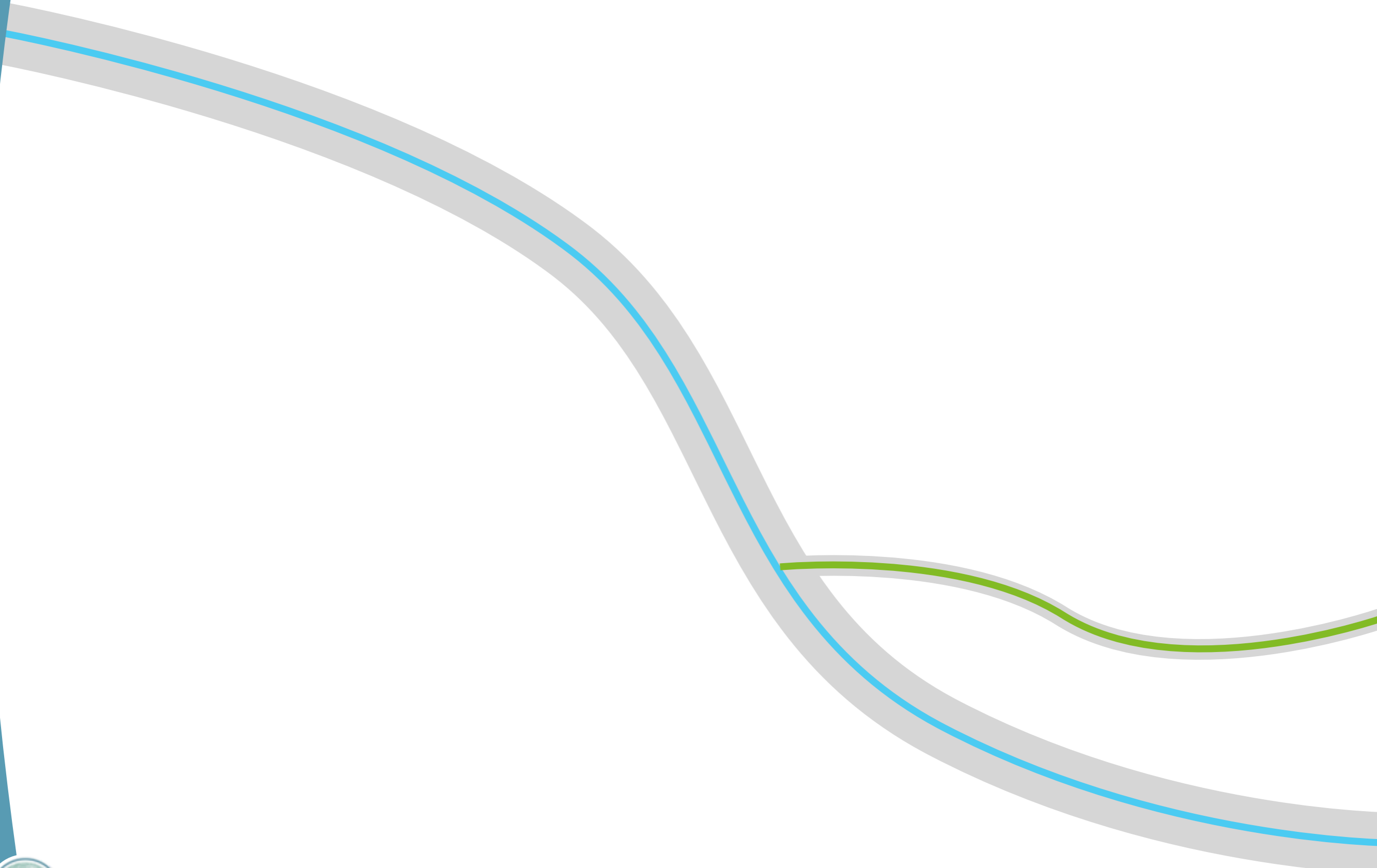
Topology

Nodes as individual objects

Individual actions  
[move, crop, append]

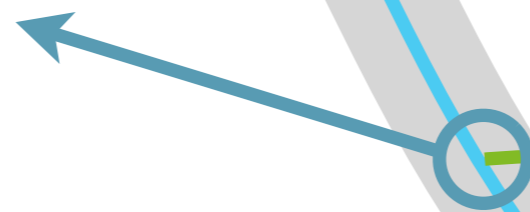


# Vector based



# Vector based

Coordinates in  
the pixel space  
 $[x, y]$



# Vector based

Coordinates in  
the pixel space  
 $[x, y]$

Vector coordinates  
 $[\text{root}, \text{pos}]$





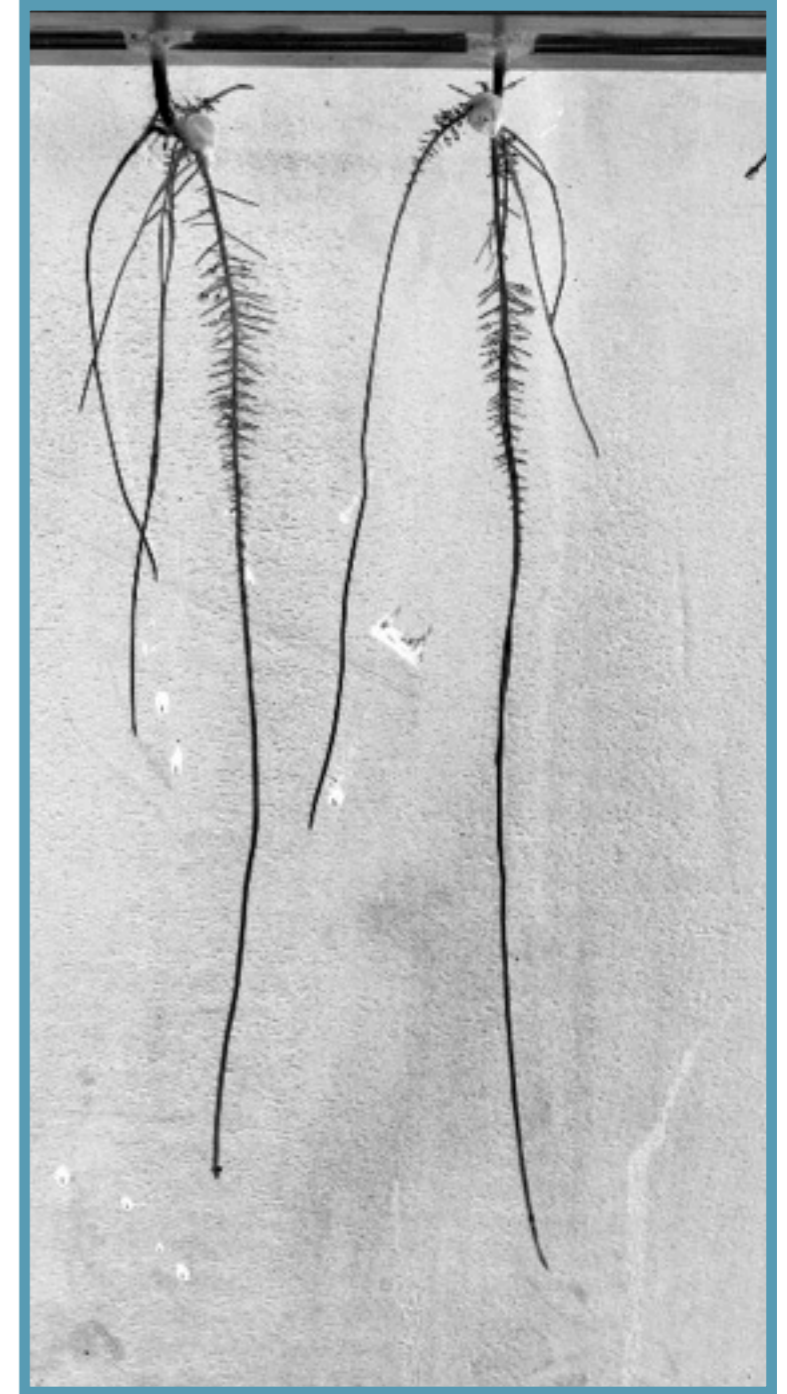
# Working with real images?



# Real life examples

Lupin proteoid root

Maize root architecture



Potato root growth





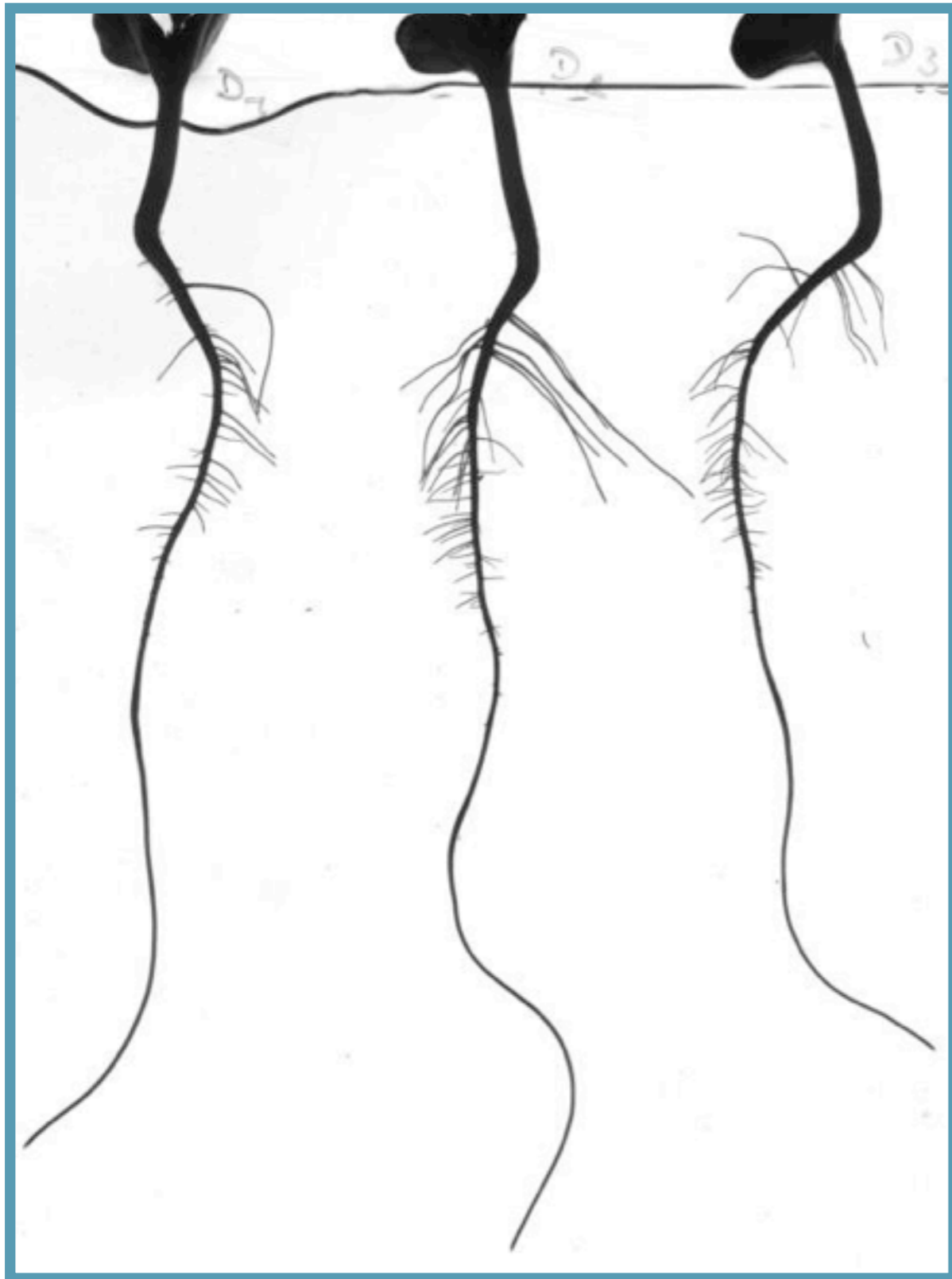
# Lupin proteoid roots

aeroponic, time lapse

[contrast + , resolution + ]



# Lupin proteoid roots



aeroponic, time lapse  
[contrast + , resolution + ]



# Lupin proteoid roots

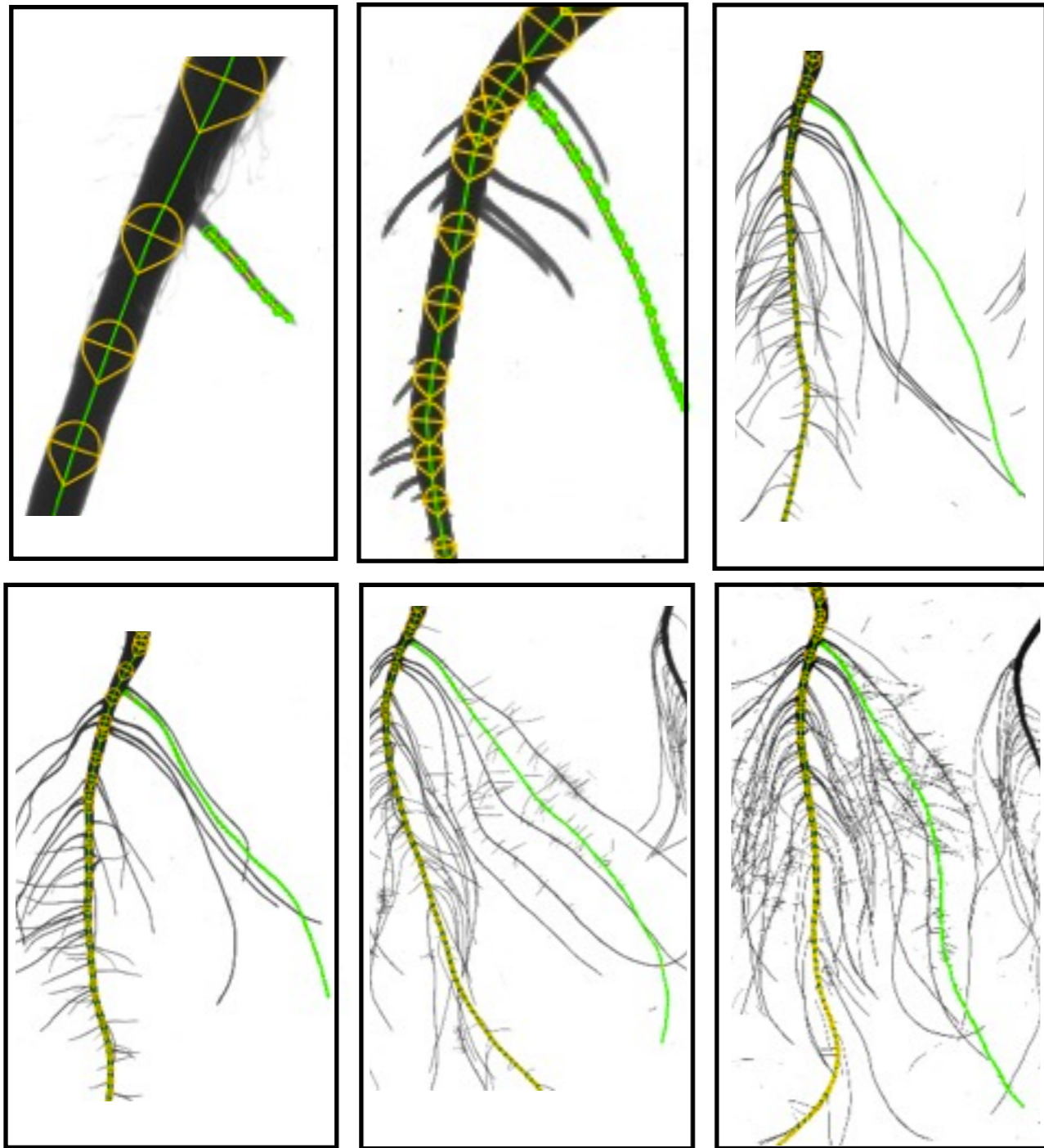


aeroponic, time lapse  
[contrast + , resolution + ]



primary root tracing

# Lupin proteoid roots



aeroponic, time lapse

[contrast + , resolution + ]

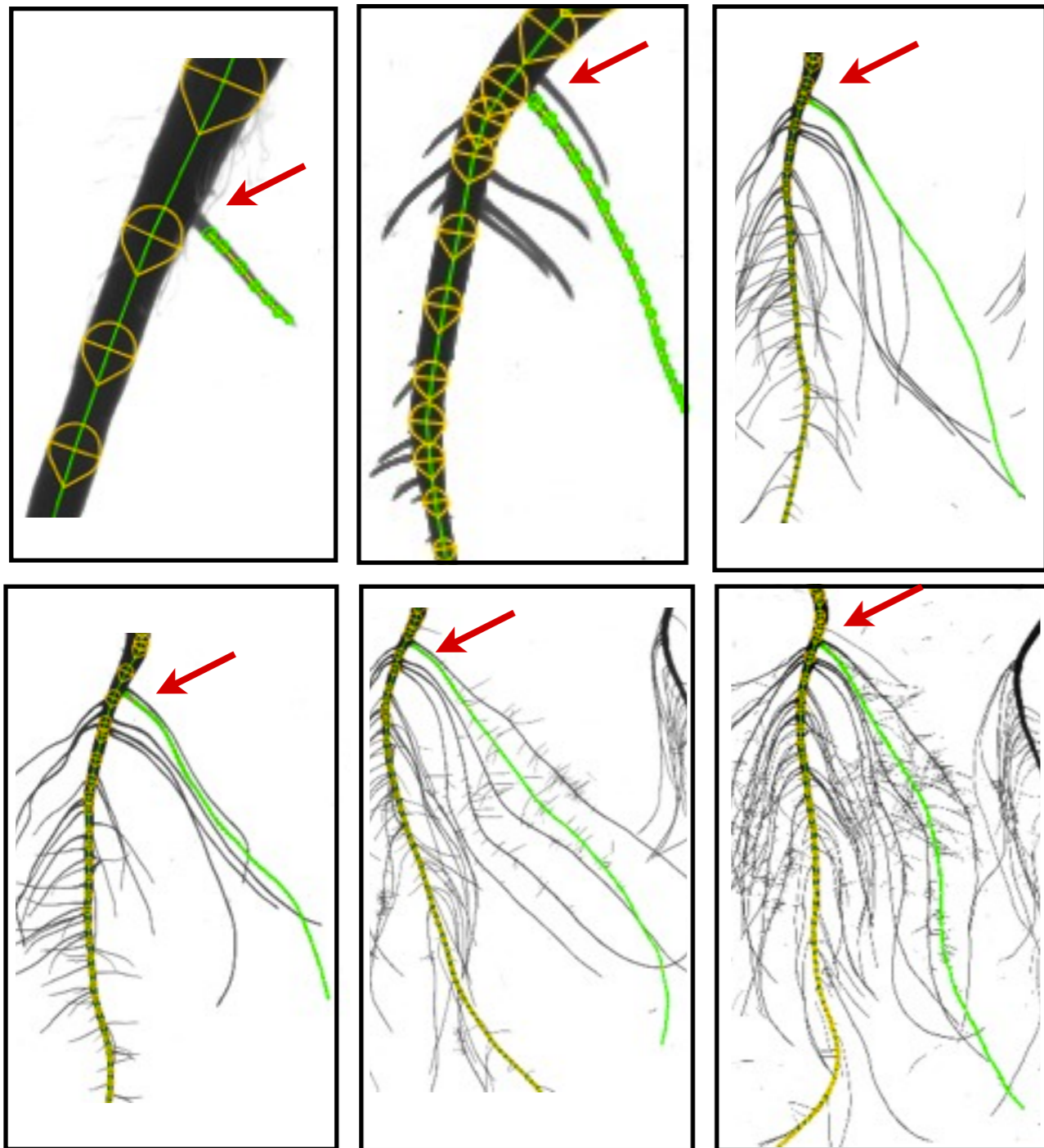


primary root tracing



identify proteoid LR of interest across images

# Lupin proteoid roots



aeroponic, time lapse

[contrast + , resolution + ]



primary root tracing



identify proteoid LR of interest across images



# Lupin proteoid roots

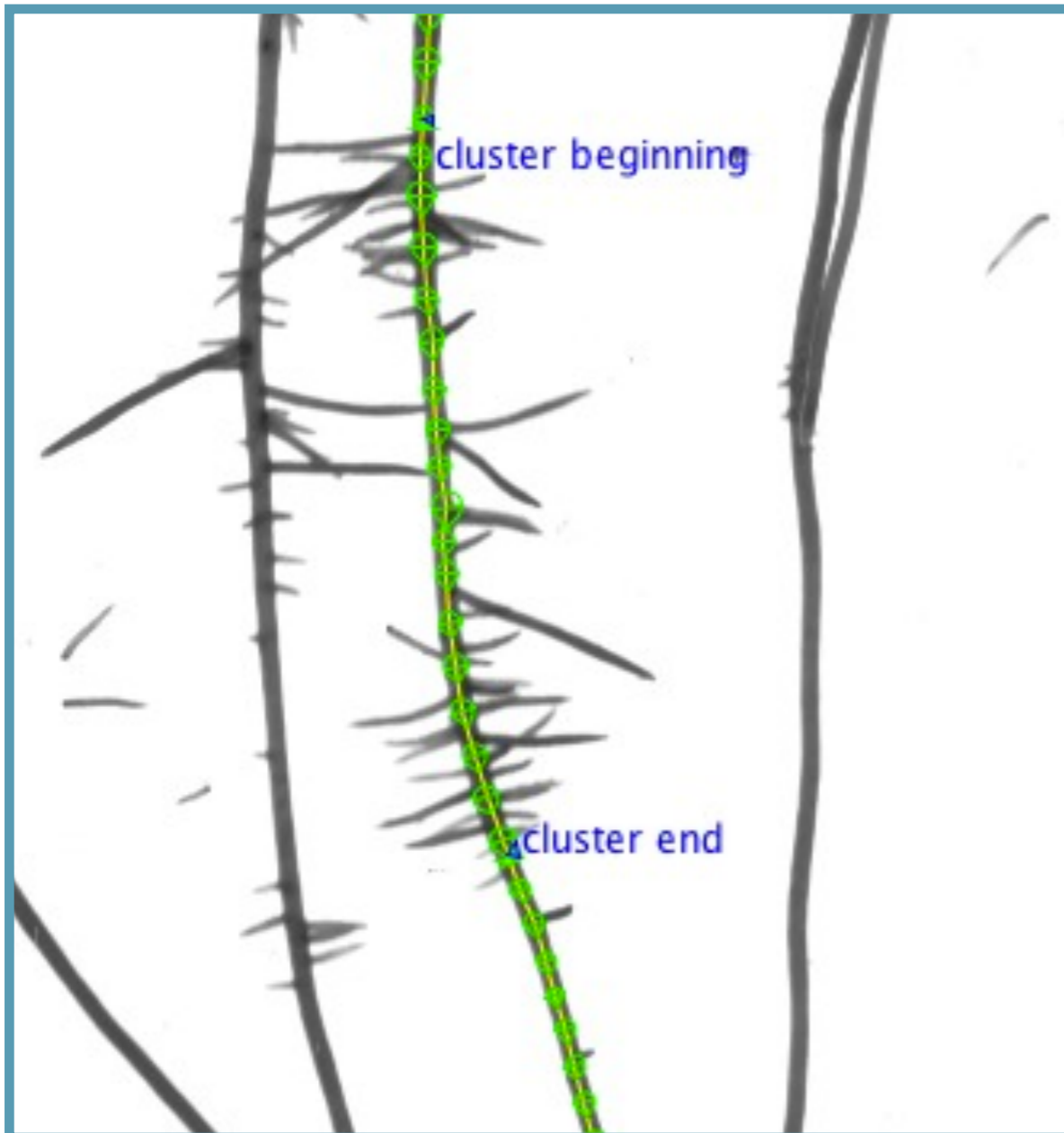
aeroponic, time lapse

[contrast + , resolution + ]

primary root tracing

identify proteoid LR of interest across images

annotate cluster position



# Lupin proteoid roots

aeroponic, time lapse

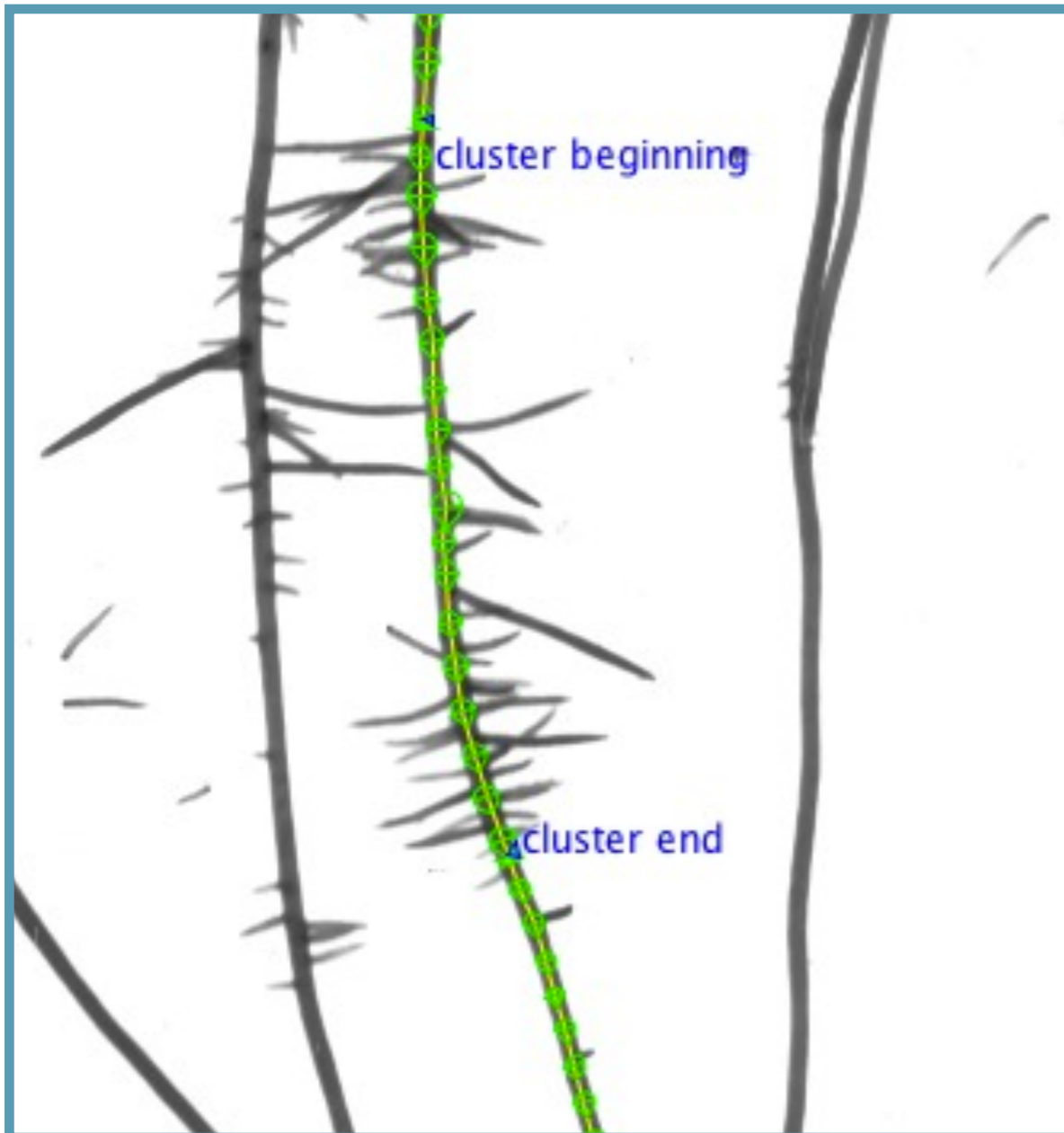
[contrast + , resolution + ]

primary root tracing

identify proteoid LR of interest across images

annotate cluster position

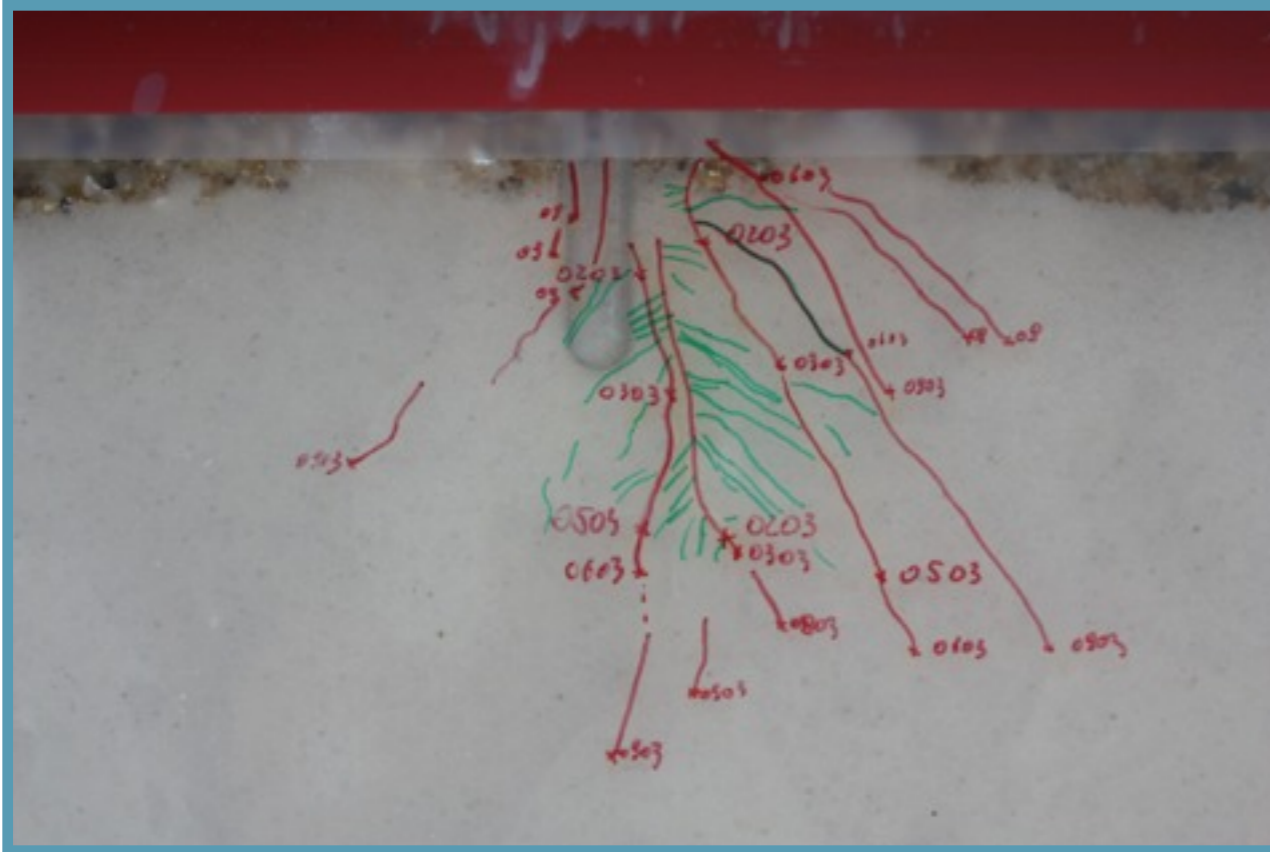
[ spatial and temporal root development dynamics ]





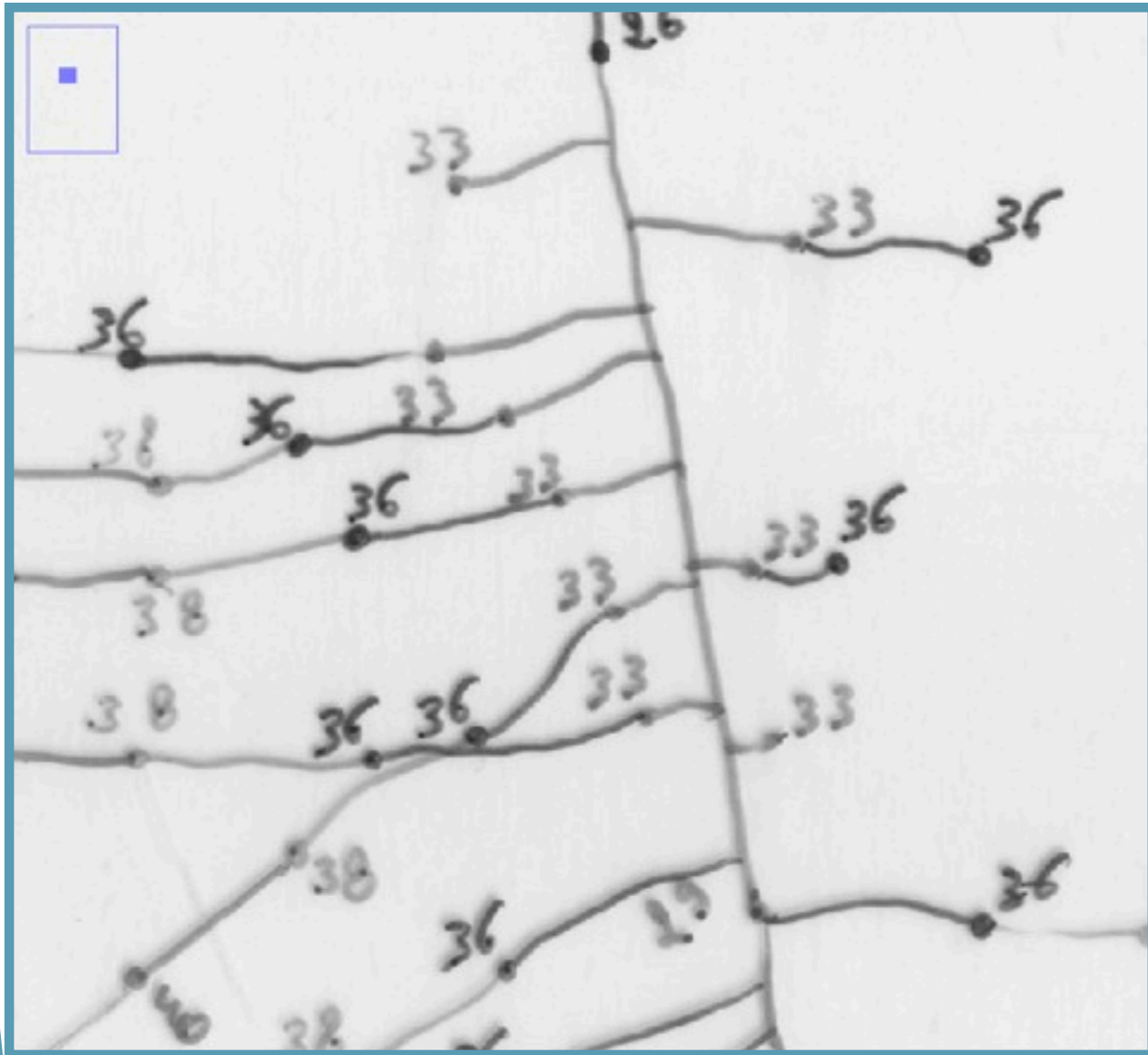
# Root growth in rhizotrons

rhizotron, apex tracking  
[contrast - , resolution + ]



# Root growth in rhizotrons

rhizotron, apex tracking  
[contrast - , resolution + ]

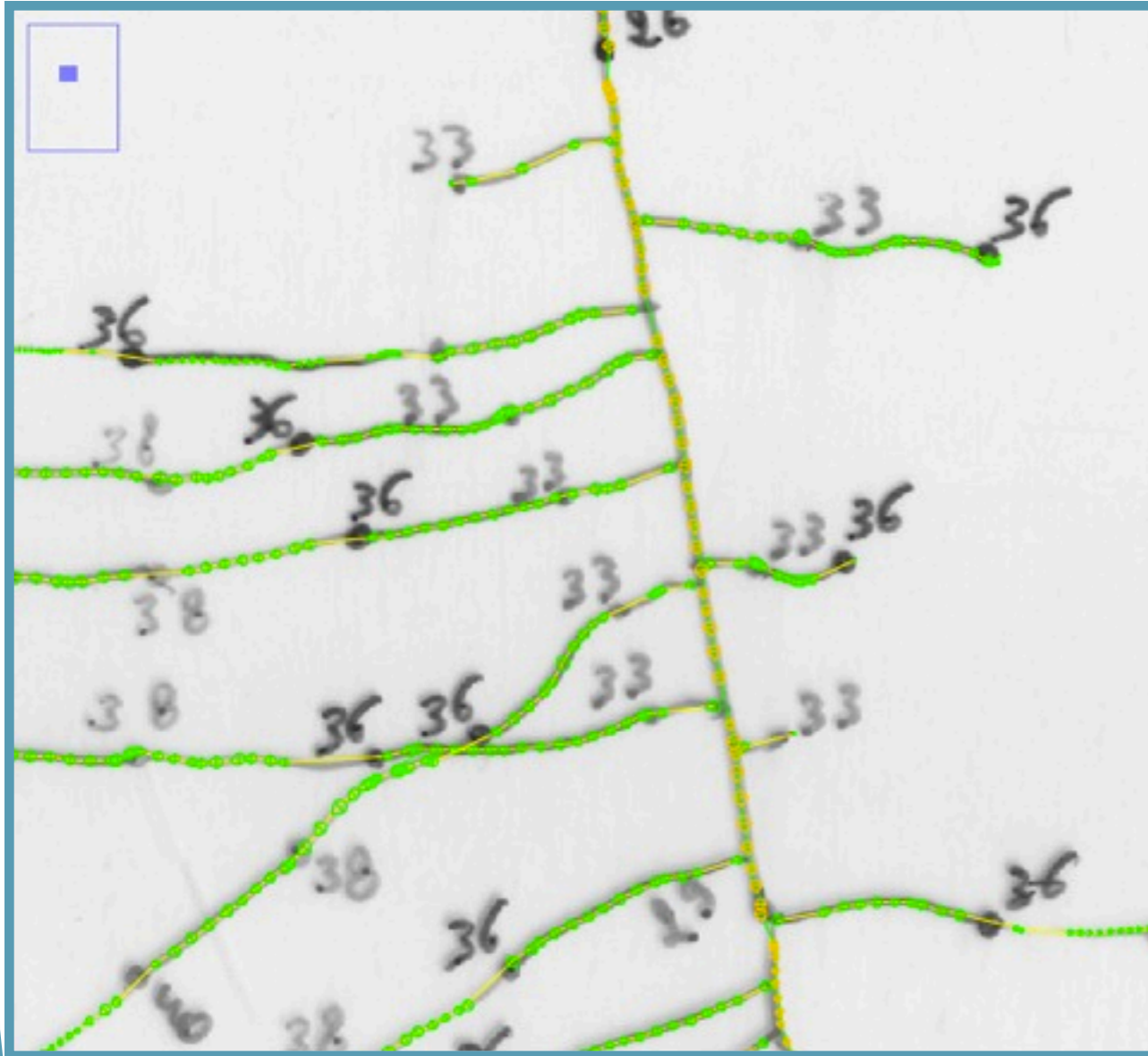


# Root growth in rhizotrons

rhizotron, apex tracking  
[contrast - , resolution + ]



root tracing



# Root growth in rhizotrons

rhizotron, apex tracking  
[contrast -, resolution +]



↓  
root tracing

↓  
mark positioning



# Root growth in rhizotrons

rhizotron, apex tracking

[contrast - , resolution + ]



root tracing



mark positioning



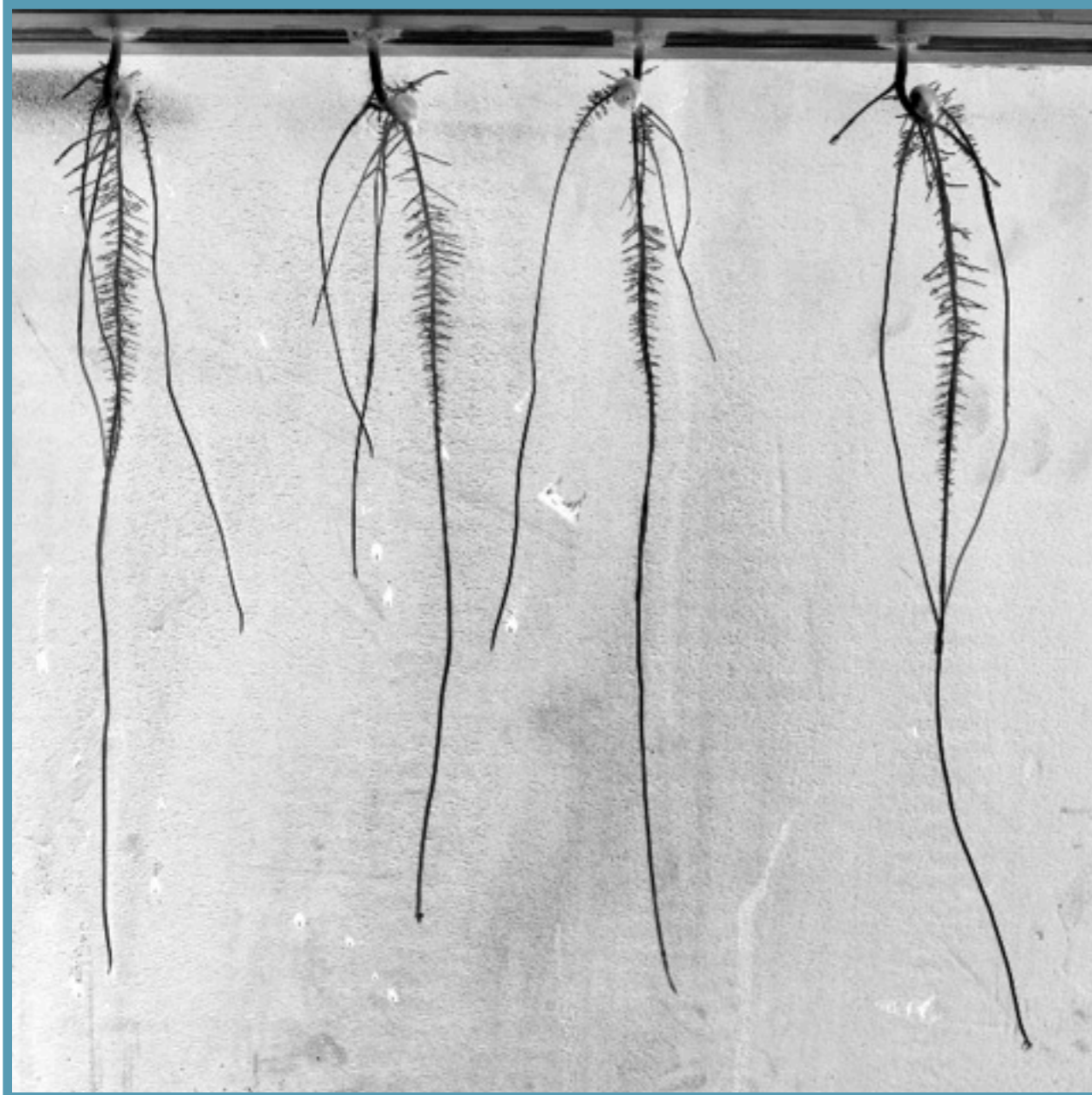
[growth = f(type, age, position)]



# Maize root architecture

aeroponic

[contrast - , resolution - ]



# Maize root architecture



aeroponic

[contrast - , resolution - ]



trace the primary



# Maize root architecture



aeroponic

[contrast - , resolution - ]



trace the primary



automatic lateral tracing

# Maize root architecture



aeroponic

[contrast - , resolution - ]



trace the primary



automatic lateral tracing



[diameters, root length  
interbranch, angles ]





# Take home message

- Morphology, topology
- Wide range of:
  - image quality
  - plant species
  - biological questions
- Vector based and object-oriented
- Annotation tool
- User interface, data export, ....

[www.uclouvain.be/smartroot](http://www.uclouvain.be/smartroot)



# Acknowledgments

## Beta testers

- Tristan Lavigne
- Geoffrey Berguet
- H el ene Cordonnier
- Chantal Lemari e

## Funding



