SMARTROOT

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

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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
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
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 - 1

- mouse click
- **local threshold**
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Tracing algorithm - 1

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- local threshold

Pixel value

Path

Local threshold
Tracing algorithm - 1

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- local threshold

Path

Pixel value

Local threshold

UCL - Earth & Life Institute
Tracing algorithm - 1

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Tracing algorithm - 1

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

Diagram:
- Path
- Pixel value
- Local threshold
- Path

Diagram highlights:
- Node centering
- Append node

UCL - Earth & Life Institute
Tracing algorithm - 1

- mouse click
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- search path
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- local threshold

- pixel value
- local threshold
- path
Tracing algorithm - 1

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- append node
- local threshold

Pixel value

Local threshold

Path
Tracing algorithm - 1

- Mouse click
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- Node creation
- Node centering
- Search path
- Diameter check
- Node creation
- Node centering
- Append node
- Local threshold

Pixel value

Path

Local threshold
Tracing algorithm - 1

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

(pixel value graph)

local threshold

path
Tracing algorithm - 1

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

Diagram:
- Pixel value graph with local threshold crossing.
- Path indicated with arrows.

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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

Region of Interest

[Image of a diagram with nodes and pathways]
Tracing algorithm - 2

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

**Graph:**
- Frequency axis
- Pixel value axis
- MIN and MAX values
- Region of Interest

**Diagram Components:**
- Green box indicating "local threshold"
- Diagram of node creation and centering processes
- Graph overlaying a threshold curve
Tracing algorithm - 2

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![Graph showing frequency vs. pixel value with MIN and MAX values.](Image)
Tracing algorithm - 2

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- diameter check
- node creation
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- append node

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

**Region of Interest**

**pixel value**

**frequency**

**MIN**

**MAX**

**THRESHOLD**
Tracing algorithm - 3

mouse click
local threshold
node creation
node centering
search path
diameter check
node creation
node centering
append node
Tracing algorithm - 3

- mouse click
- local threshold
- node creation
- node centering
- search path
- diameter check
- node creation
- node centering
- append node
Tracing algorithm - 3

- mouse click
- local threshold
- node creation
- node centering
- search path
- diameter check
- node creation
- node centering
- append node
Tracing algorithm - 3

- mouse click
- local threshold
- node creation
- node centering
- search path
- diameter check
- node creation
- node centering
- append node
Tracing algorithm - 3

- mouse click
- local threshold
- node creation
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- search path
- diameter check
- node creation
- node centering
- append node
Tracing algorithm - 3

- mouse click
- local threshold
- node creation
- node centering
- 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
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

![Diagram of tracing algorithm steps]
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
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
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- diameter check
- local threshold
- search path
- 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

Nodes as individual objects

Root as individual object

Topology

Individual actions

[move, crop, append]
Vector based
Vector based

Coordinates in the pixel space

\[ [x, y] \]
Vector based

Vector coordinates

[root, pos]

Coordinates in the pixel space

[x, y]
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
- 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

\[
growth = f(\text{type, age, position})
\]

rhizotron, apex tracking

\[
\text{[contrast - , resolution + ]}
\]

\[
\text{root tracing}
\]

\[
\text{mark positioning}
\]

\[
\text{[growth = f(type, age, position)]}
\]
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 - ]

\[ \text{trace the primary} \]

\[ \text{automatic lateral tracing} \]

\[ \text{diameters, root length, interbranch, angles} \]
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
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[fnrs logo]