**Introduction to Phenotyping**

**phenotype** (Greek: phainein = to show) - composition of an organism's observable characteristics

- phenotyping of the plant *Arabidopsis thaliana*:
  - characteristics of the root such as branching points and branch endings are analysed
  - these characteristics can be efficiently described by a skeletal graph representation

**Reeb Graph Based Representation**

Root characteristics described by Reeb graphs (according to height function and geodesic distance):
- Reeb graphs preserve topological information
- nodes in Reeb graphs correspond to critical points (branching points and end points of branches)
- edges in Reeb graphs describe topological persistence [1]
- 2D critical points (nodes in the Reeb graph) are minima, maxima, or saddles [2]
- Reeb graphs are based on Morse theory but have been extended to the discrete domain
- according to Morse theory: for all pairs of distinct critical points \( x_1, x_2 \), \( f(x_1) \neq f(x_2) \) holds true [2]

**Results**

Combination of graph representations through isomorphic subgraphs

distance between two graphs through maximal common subgraph

\[
d(G_1, G_2) = 1 - \frac{G_{max}}{\text{max}(|G_1|, |G_2|)}
\]

Structural equality of graphs

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<th>height function Reeb g</th>
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<th>median axis graph</th>
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based on a dataset of 34 root images

- root17, day 12 is a subgraph of root 17, day 16
- root17, day 16 and root 17, day 20 are isomorphic graphs

**Conclusion**

Reeb graphs:
- are suitable descriptors for root structures
- capture the main characteristics of roots well: branches and branch endings [3]
- branching points and overlaps by projection from 3D can be immediately distinguished (cycle in the Reeb graph) [3]
- the attributes of different graph representations can be combined for isomorphic subgraphs
- normalised representation: efficient comparison of roots of different plants or on different days of growth

References: