Artificial Pruning-Aware Procedural Modeling of Shrub Roses

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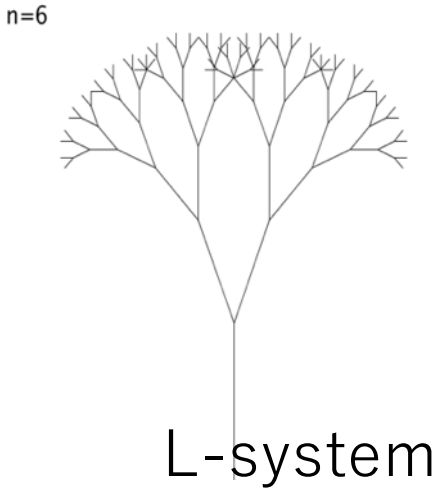
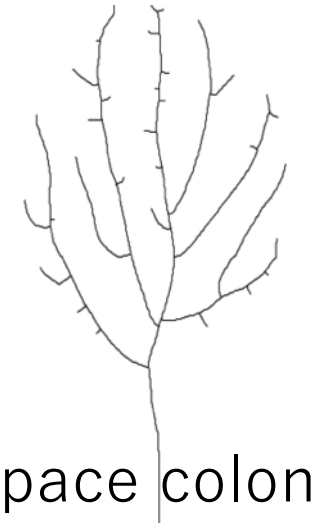
Background

- Plant models in computer graphics
  - Manual creation with labor intensive process
- Procedural techniques
  - Representing a botanical structure as a set of mathematical expressions or structural rules
  - L-system [Prusinkiewiczy 1996]
  - Space colonization method [Runions 2007]
  - Self-organization tree model [Palubicki 2009]
- Only for untended wild plants in grassland and forest



L-system



Space colonization method

Artificial Care for Rose

- Conventional procedural techniques do not fully consider artificially maintained plants. e.g. Rose

- Artificial cares
  - Pruning trunks and stems
  - Eliminating damaged stems
  - Trimming redundant buds
  - Removing wilted blooms

Research Purpose

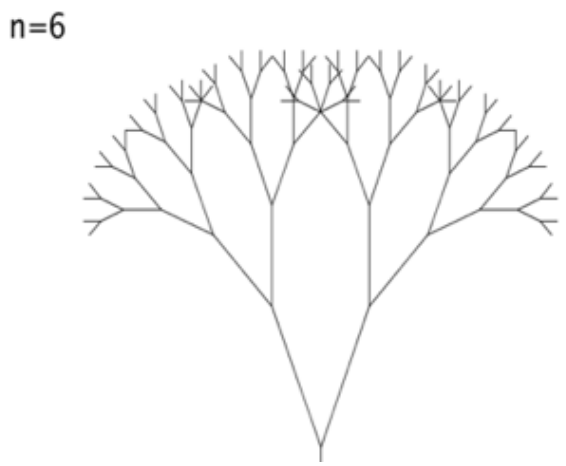
- Procedural system for designing 3D models of well-maintained roses, particularly Shrub Roses

- Considerations
  - Pruning trunks and stems
  - Eliminating damaged stems
  - Trimming redundant buds
  - Removing wilted blooms

Generated branching structure

Related Work

- Conventional methods do not take into account artificial cares and require special knowledge

	L-System	Space Colonization Algorithm
Feature	Using a formal grammar	Suitable for natural trees
Example branching		
Artificial Cares	**Require knowledge**	**Cannot consider**

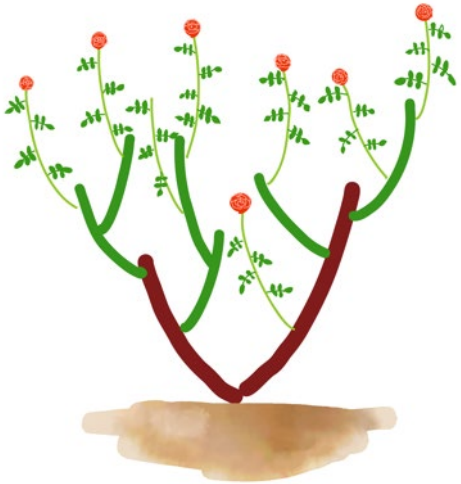
Preliminary

Terminology about the rose structure

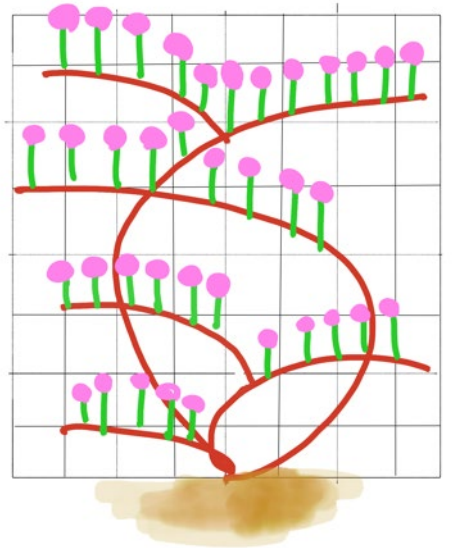
Typical pruning procedure in actual cultivation

Terminology: Shrub & Climbing Roses

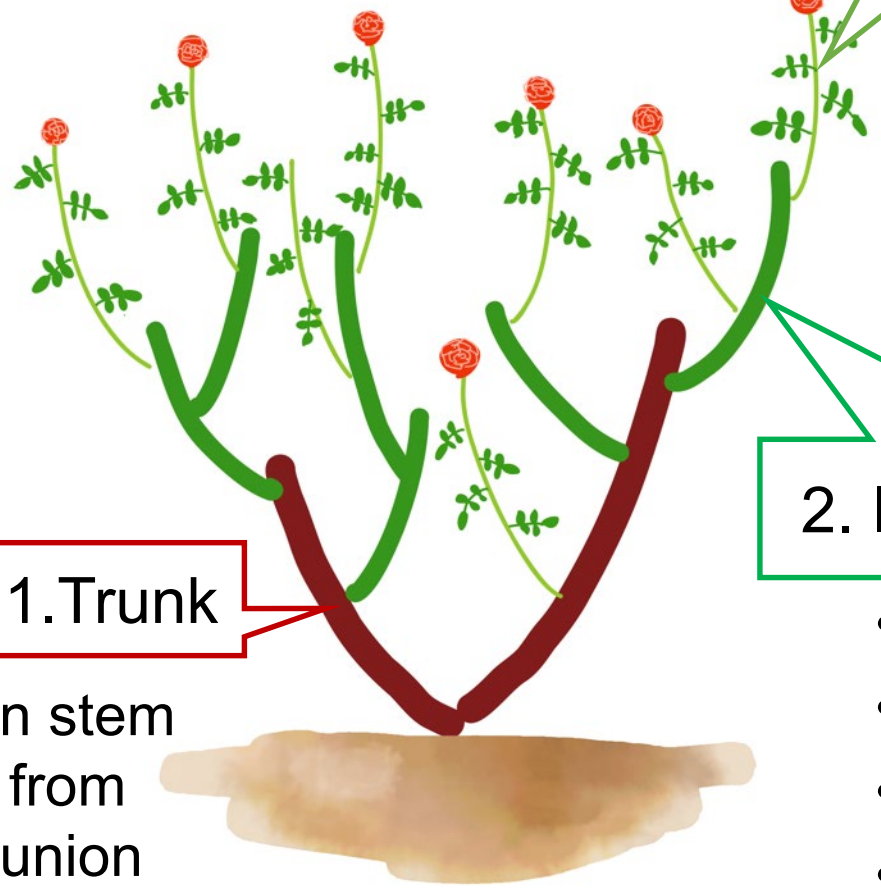
- Shrub rose
  - Multiple self-sustained trunks
  - Silhouette is similar to a bush and tree



- Climbing rose (out of our scope)
  - Secured to a trellis or other structure
  - Not hard enough to support their weight



Terminology: Branch Type



3. Terminal stem

- Grow from a middle point on a parent stem
- Have child leaves on them and some blooms at their tips
- No child stems
- A gardener does not prune terminal stems during the blooming season until the blooms wither

2. Intermediate stem

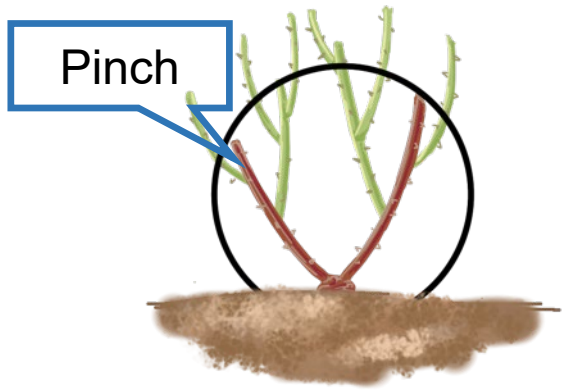
- Grow from a parent stem
- They have multiple child stems
- No blooms or leaves
- Tips are manually cut

1.Trunk

The main stem growing from the bud union

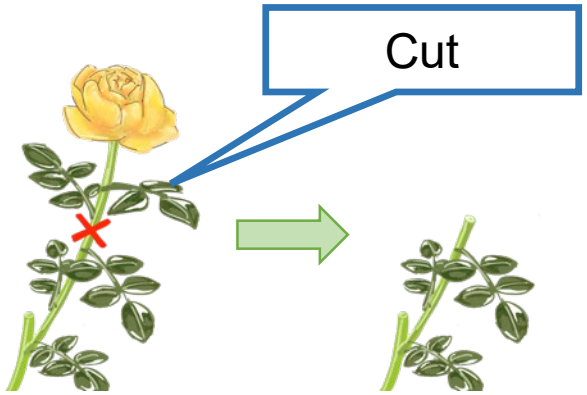
Typical Pruning Procedure

Pinching out trunks



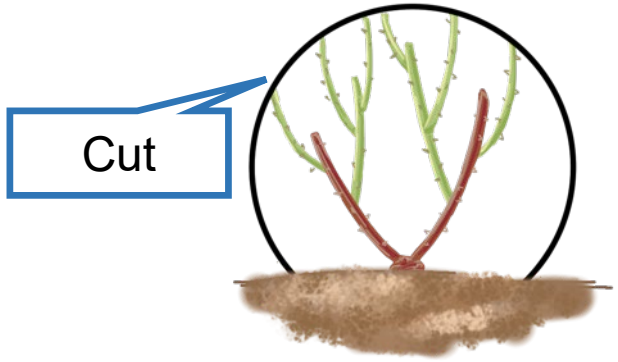
The pinched trunk to stop growing

Deadheading



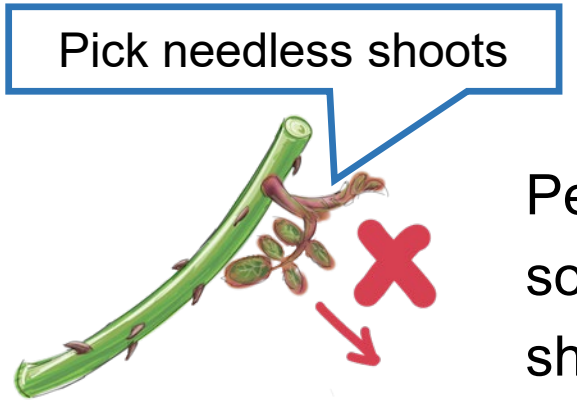
Remove faded and spent flowers before they set seed

Pruning of Stems



Prune to maintain the plant shape.

Shoot picking



Performed after pruning so that only selected shoots continue growing

Algorithm

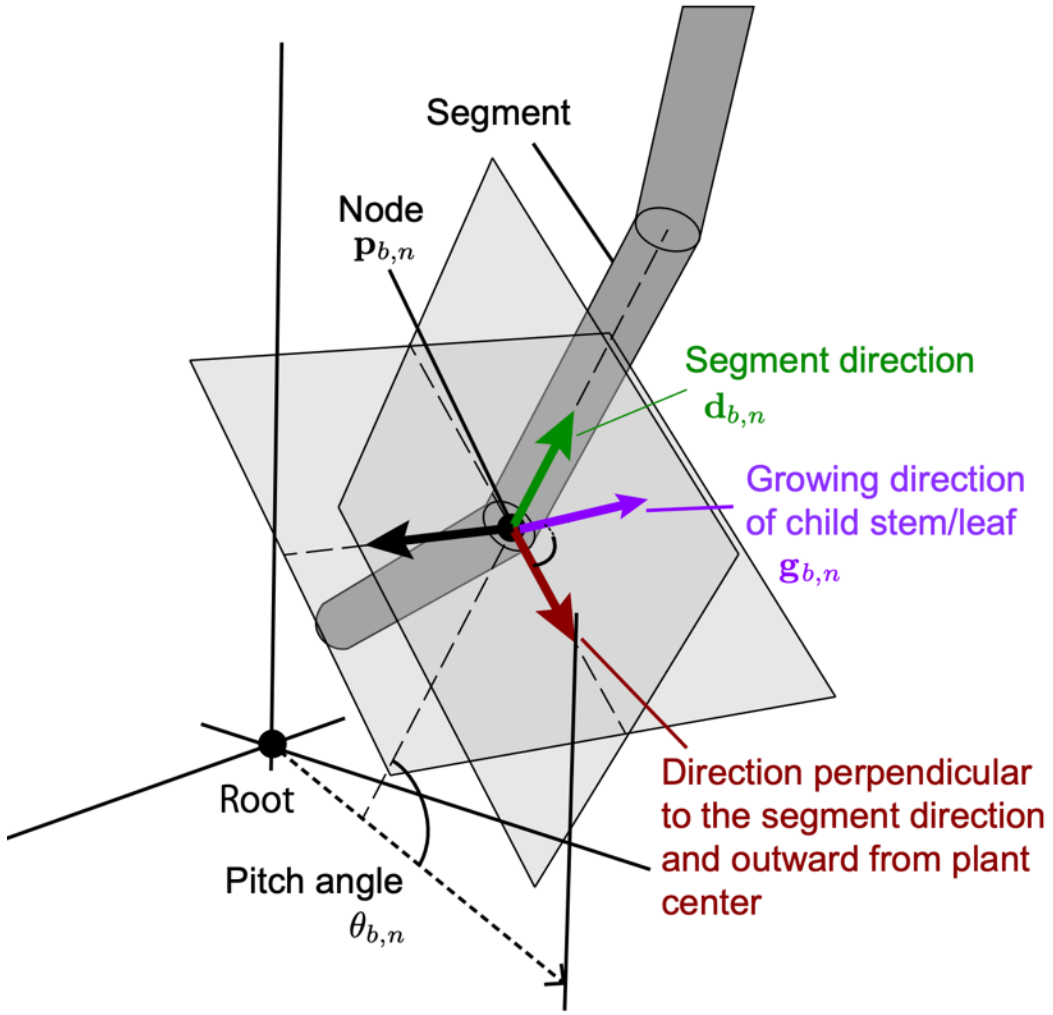
Algorithm

- Output: Branching skeletal structure of stems
  - The length and curvature of each stem
  - Branching location
  - Branching angle between parent and child stems
  - Attachment points of blooms and leaves
    - Assuming that the shape model of the blooms and leaves is given

- User input: numerical parameters
  - About twenty parameters (explain later)

Stem Model

- Connection of short segments
- Recursively generated from the stem base to the tip
  1. The first node : locate at the stem base
  2. The (n + 1)-th node position :
     - $p_{b,n+1} = l\, d_{b,n} + p_{b,n}$
  3. Repeat while # of segments remains less than the upper limit and until the node position is within the boundary region



User Input

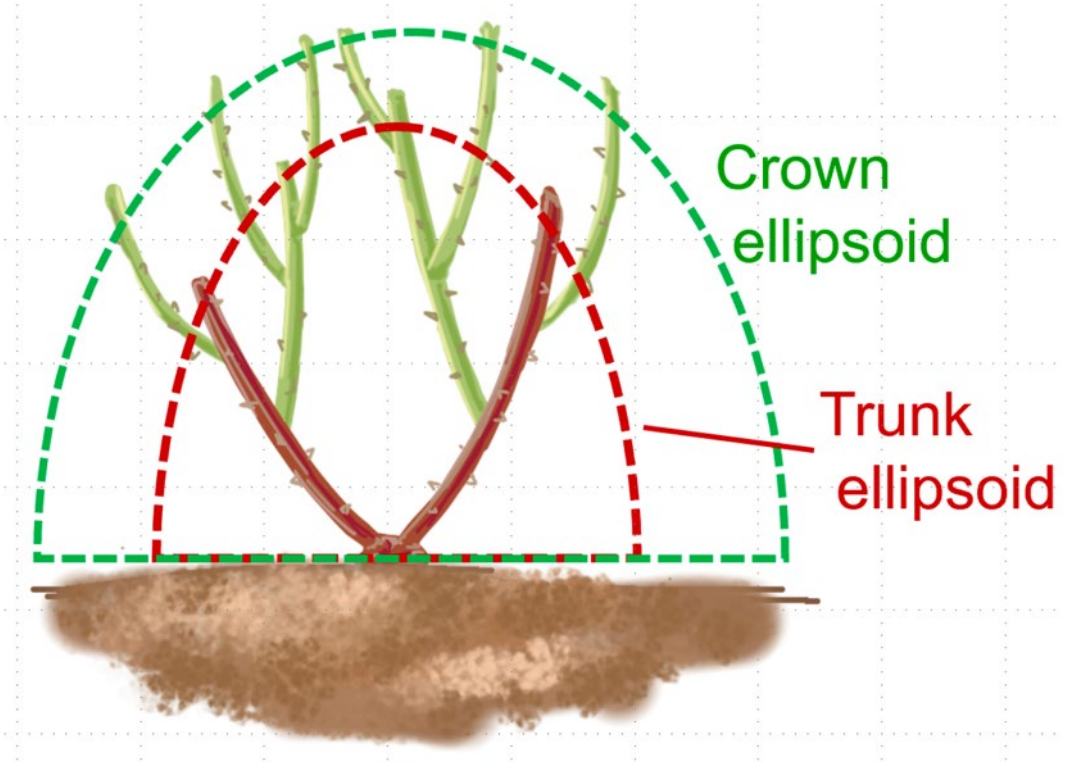
- Segment length
- Branch curvature
- The target of pitch angle
- The number of intermediate stem's segments

Boundary Ellipsoids

- The height and spread of the tree are controlled using two ellipsoids

- Trunk ellipsoid
  - The growth limit of the trunks that mimic pinching-out trunks

- Crown ellipsoid
  - Bound the growth of stems, which mimics the pruning of stems
  - To design the bounding shape (crown) of the tree

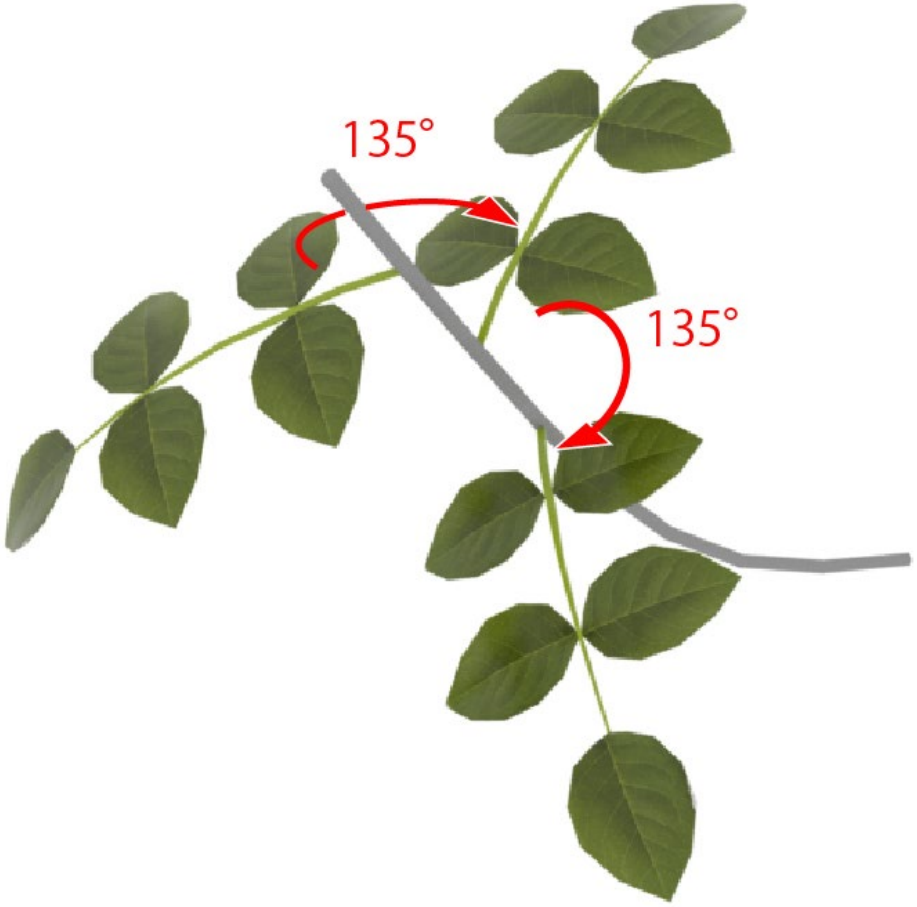


User Input

- Trunk ellipsoid height/width
- Crown ellipsoid height/width

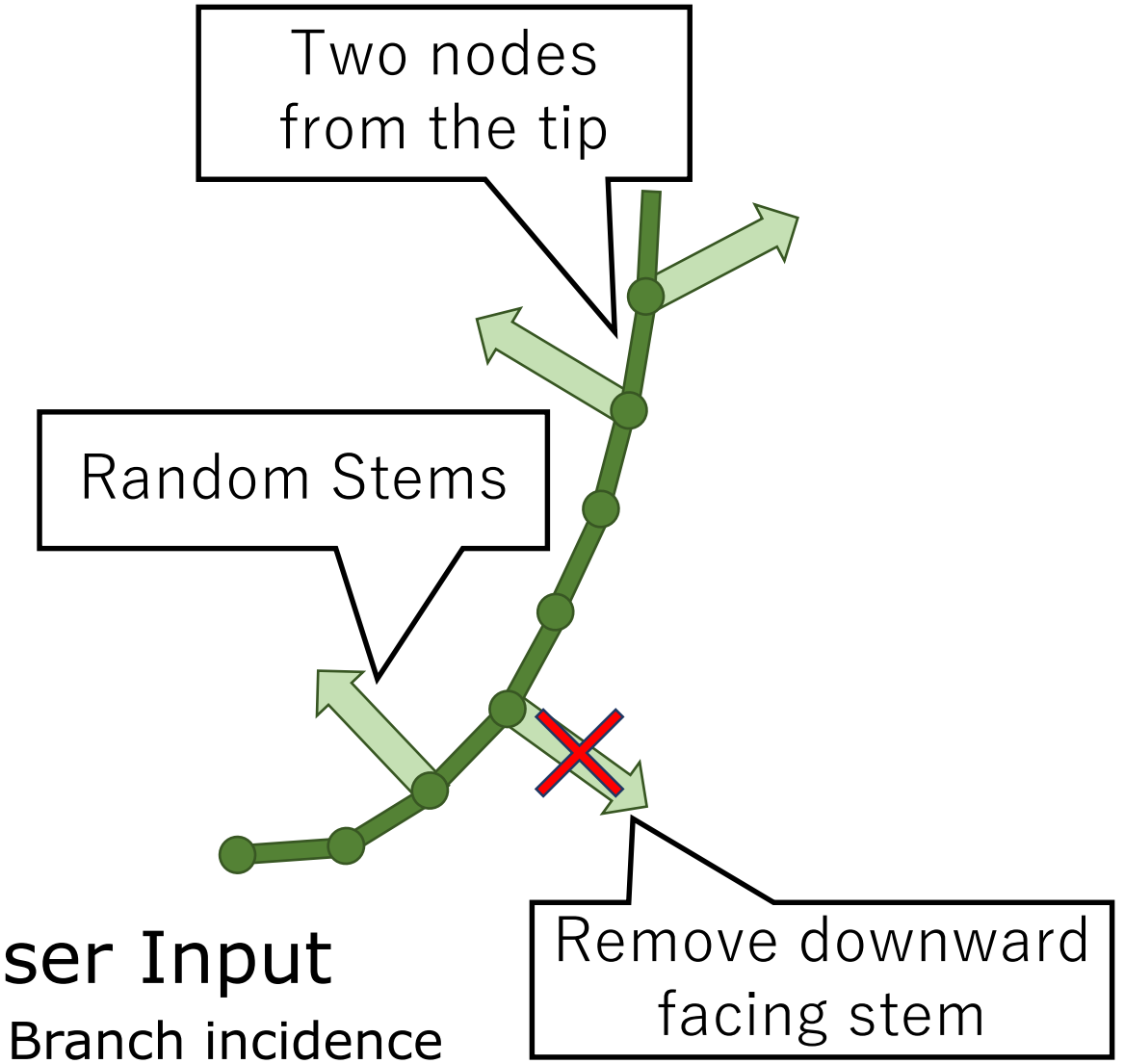
Phyllotaxis

- 3/8 phyllotaxis
  - Child stems execute a spiral with an angle of 3/8 of a full rotation along a parent stem
- Constrain the child's direction at the parent tip to improve the appearance of the plant shape



Branching Rules

- Artificial care
  - Limit of branches
  - Remove downward facing stems
- Intermediate or terminal stem are generated from trunks and intermediate stems
  - New Intermediate stem from two nodes from the tip
  - Random branches from other nodes

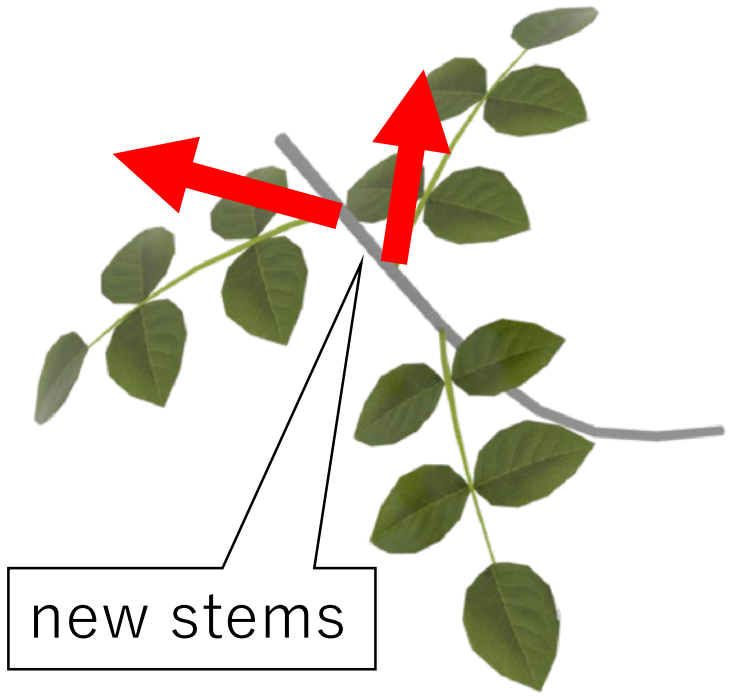


User Input

- Branch incidence

Branching Rules

- The horizontal angle of the new branch is determined by 3/8 phyllotaxies

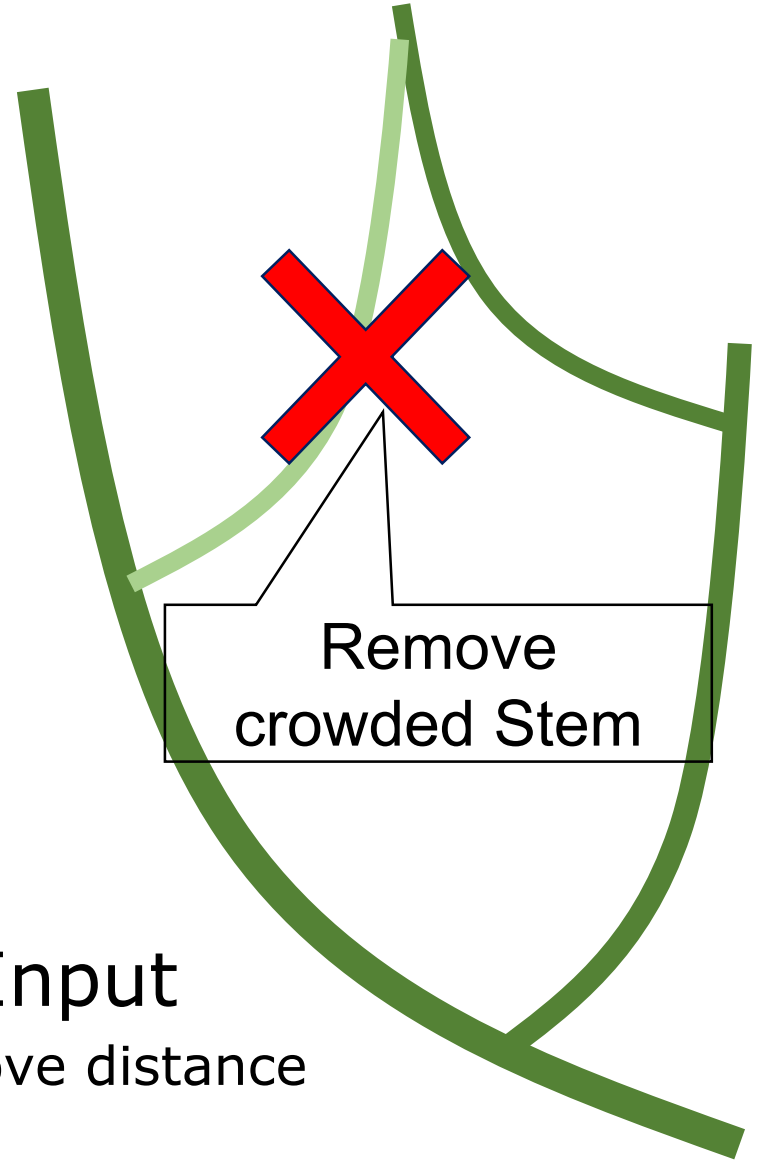


Deadheaded Branch

*Trunks and Intermediate stems don’t have leaves.

Density and Appearance Control

- Consider the maintenance of a certain separation distance between stems
- Removes new child stems after their generation if they are too close to an existing stem
- Assuming that a skilled gardener can predictably remove new shoots that will eventually penetrate other stems

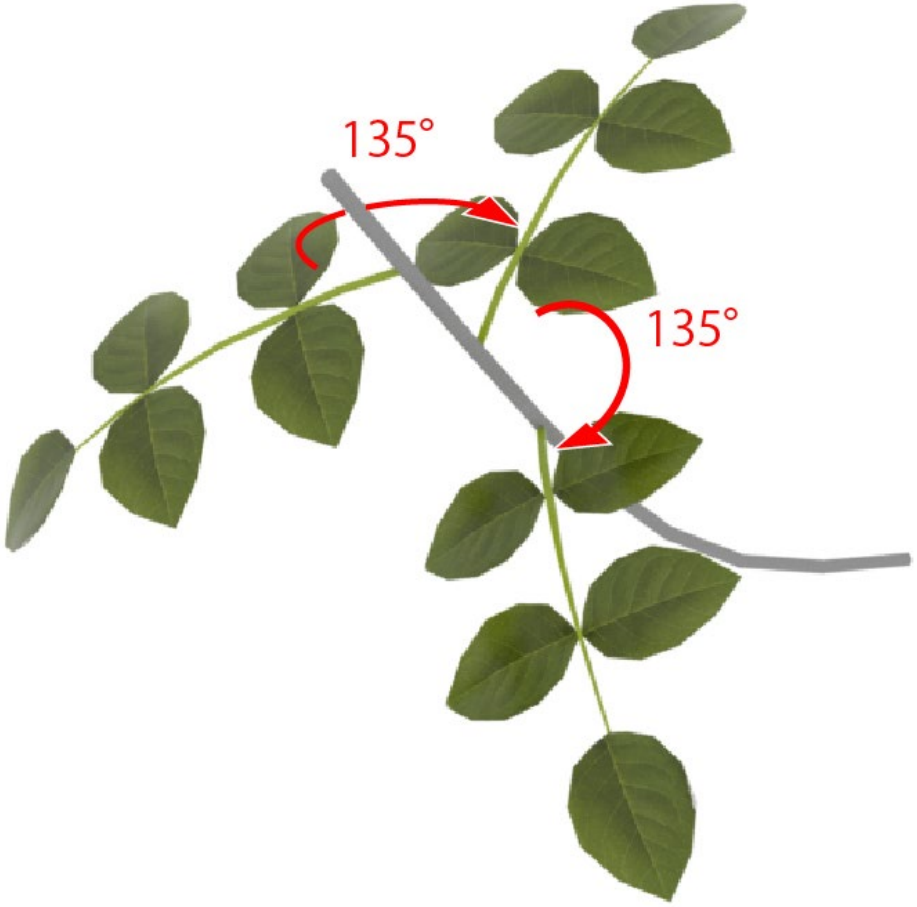


User Input

- Remove distance

Leaves

- Grow only from the terminal stems
- The number of leaves per stem is determined by the rose variety
- Locate one attachment point of the petiole at each segment of the terminal stem according to the 3/8 phyllotaxis
- Leaves are not removed even if they grow downward



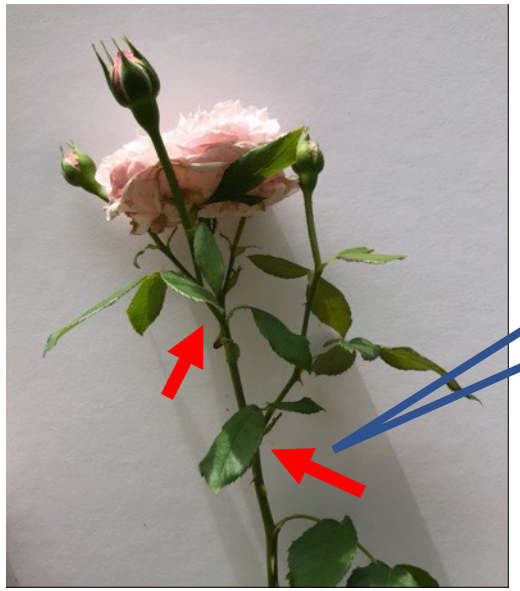
Peduncles and Blooms

- Multiple blooms are attached at the tip of each terminal stem
- Up to three blooms per stem
  - Generated at the tip of each terminal stem
- Others
  - Generate an additional stem at the two-node back from the tip
  - Additional stems have the same number of segments as the number of nodes to the tip of the terminal stem

(a) One bloom attached via one peduncle.

(b) Three blooms attached to one terminal stem via branched peduncles.

(c) Five blooms attached using one additional stem.

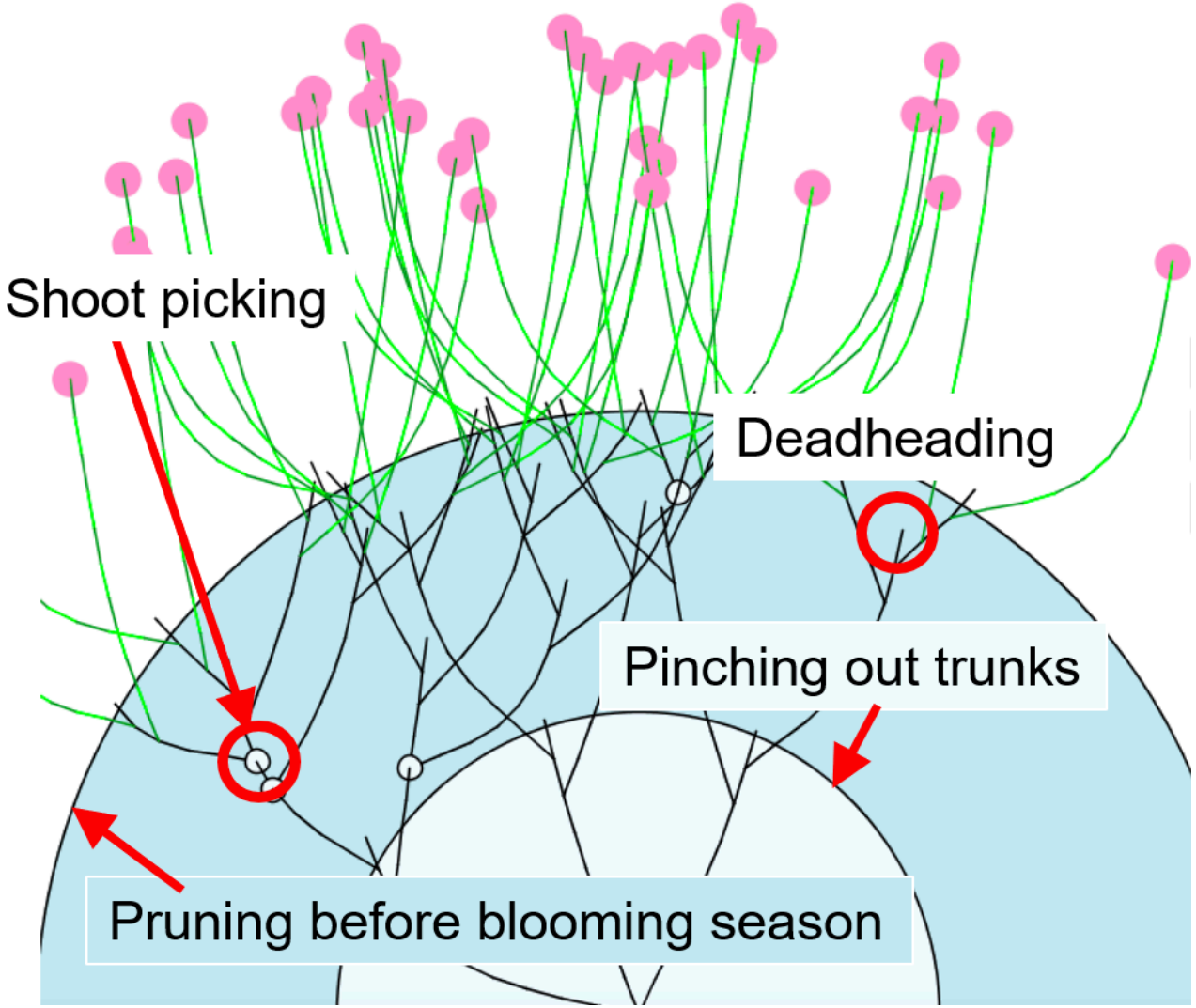


User Input

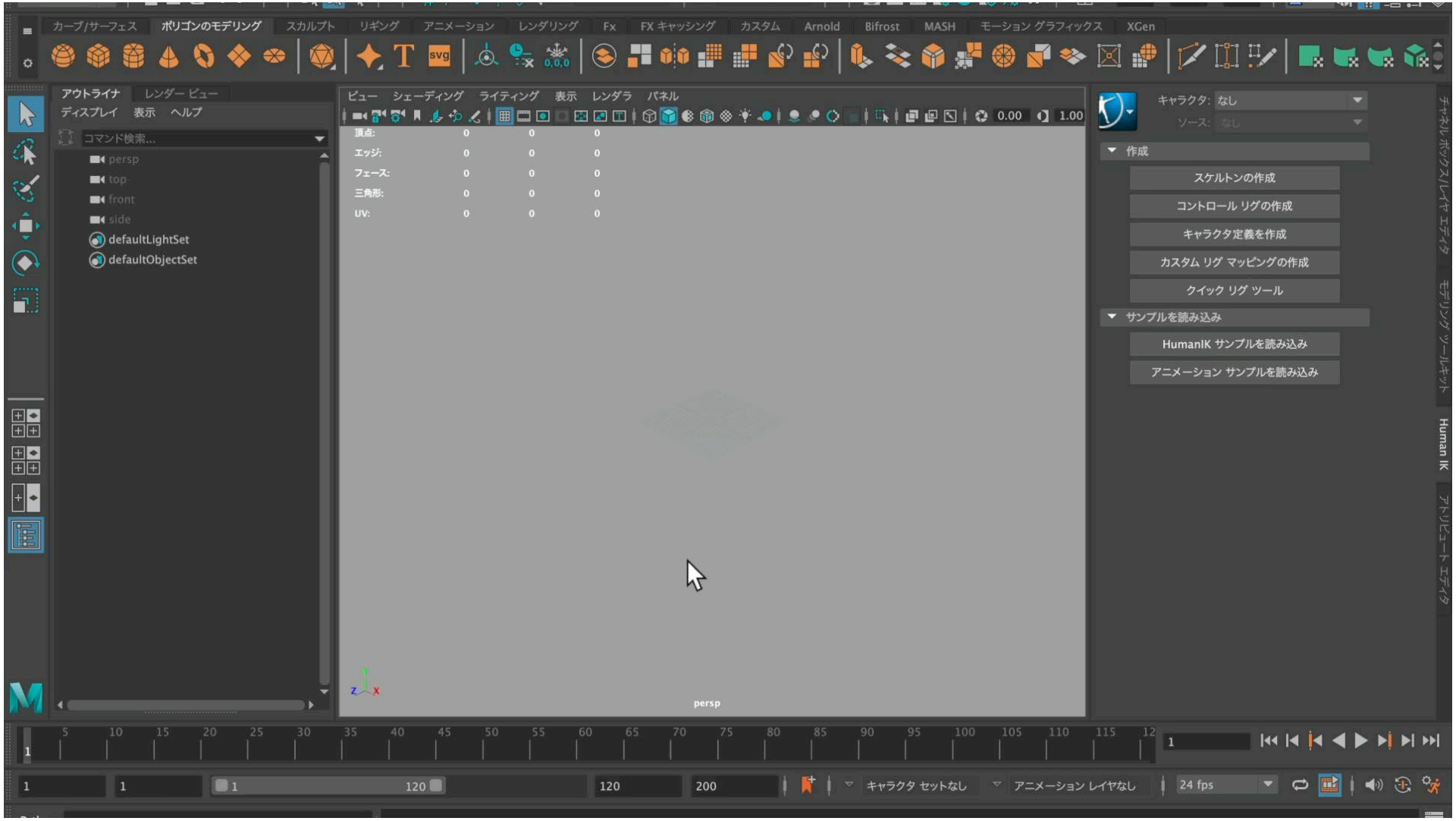
- The number of flowers

Results

Branching Structure in 2D



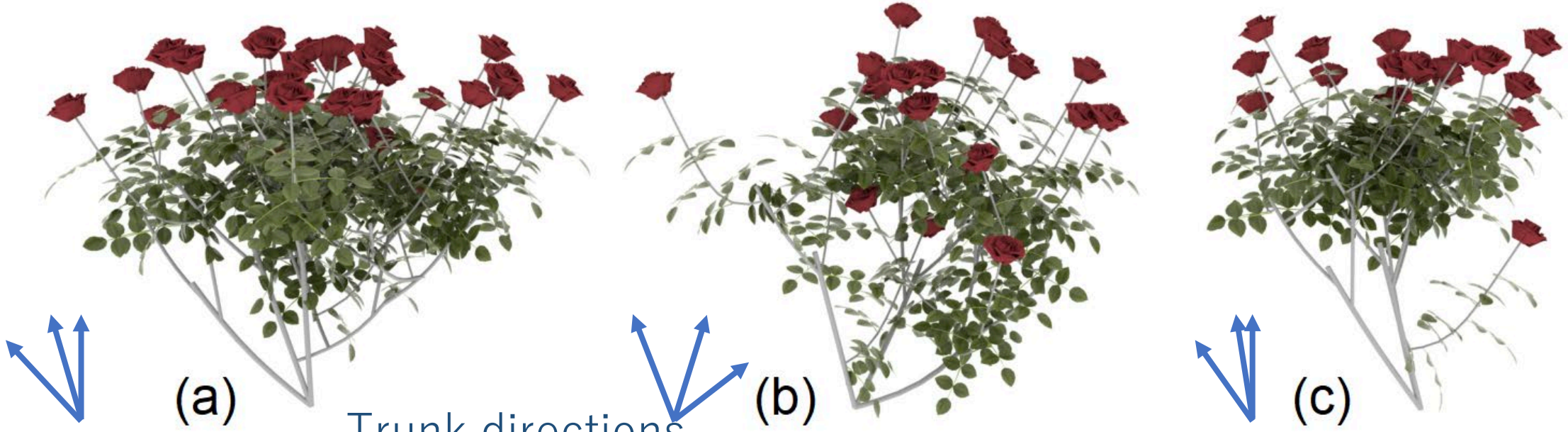
Demonstration



2x speed
Non parameter adjustment

Individuality of Trunk Direction

- The specified number of trunks grow from the bud union in random directions, which corresponds to individual differences of the same rose variety
- Differences in trunk direction affect the final tree shape and branching structure



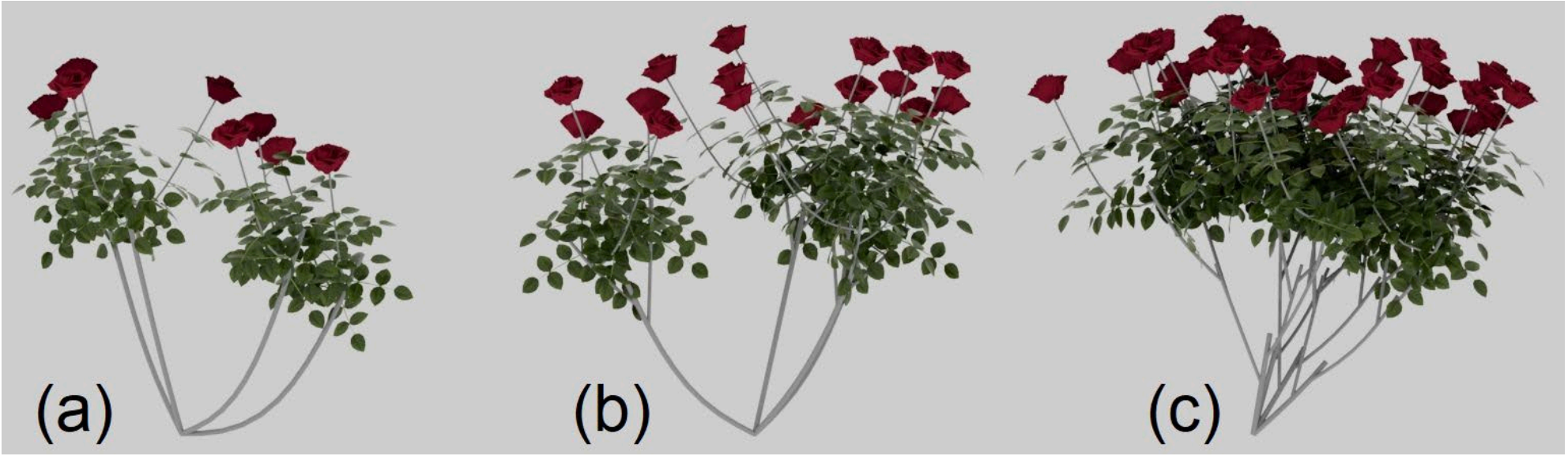
Growing Direction

- Pitch angle affects branching structure.

- Low
  - Repeat sideways and upward fallen branches
- Middle
  - Alternate sides
- High
  - Only Upturned branches

Control with Trunk Ellipsoids

- The difference between Trunk and Crown ellipsoids affects the number of stems and flowers



Trunk ellipsoid size: Large ← Small

# of stems and flowers: Few → Many

Purpose-built Controls

- Differences by pruning
- Assuming the same variety

- Left
  - A tall and slim silhouette
  - Fewer stems and leaves
  - For tight spaces and when surrounded by other plants
- Right
  - A broader and shorter shape
  - More stems and leaves
  - Enhance the garden's openness

Compare with Real Rose

Reference photo

Generated model

Discussion

- Procedural method for modeling the skeletal structure of shrub roses
  - Considers both the species-specific structural rule and typical process of artificial care
- Limitations
  - Only well-maintained shrub roses
    - a visually appearing rose in the high season with few mistakes in manual care
  - Does not guarantee a physically valid result
    - Kinematic method rarely reproduces the effect of gravity or wind

Discussion

- Procedural method for modeling the skeletal structure of shrub roses
  - Considers both the species-specific structural rule and typical process of artificial care
- Limitations
  - Only well-maintained shrub roses
  - The growth rules represent a visually appearing rose in the high season with few mistakes in manual care

https://github.com/Wataru-U/ProcedualModelingOfBushRose

Acknowledgment
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