An Alternative Method for Characterization and Comparison of Plant Root Shapes

A thesis submitted to the
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in partial pulfillment of the requirements
for the degree of Master of Science
in the Department of School of Environment and Sustainability
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Existing Morphological Descriptors for Root Systems

An Alternative Mathematical Method for Shape Description

LRWs in Artificial Images

3.1 Circle and Rectangle

3.1.1 Image Description

- Image size: 1200×1000 pixels
- Surface area of shapes: 90000 pixels
- The centroid of the shape is located at the center of the image

3.1.2 Output Analysis

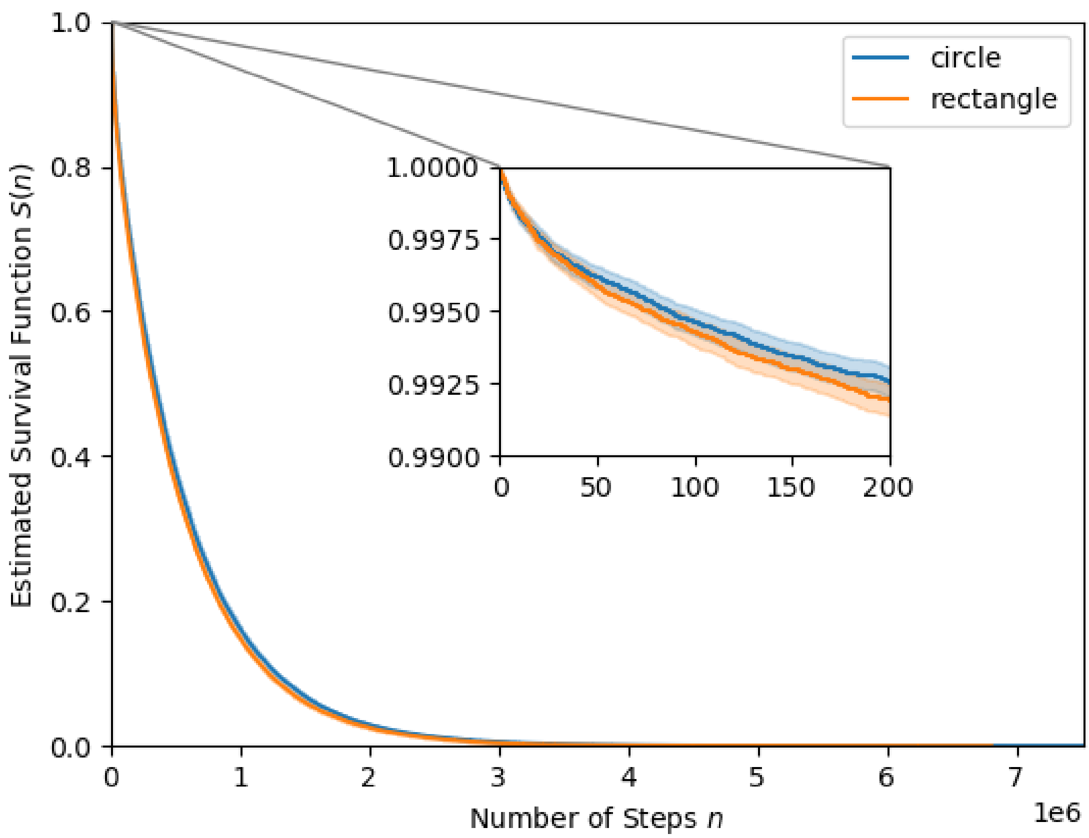


Figure 3.1

3.1.3 Conclusion

Given two distinct convex geometries

	test_statistic	p
Peto	137.23	0.0
Logrank	137.23	0.0
Tarone-Ware	134.31	0.0
Gehan-Breslow	123.83	0.0
Fleming-Harrington	123.83	0.0

Table 3.1

- the behaviours of the survival function of LRWs are consistent with the theoretical results.
- survival curves can be used to describe and distinguish them.

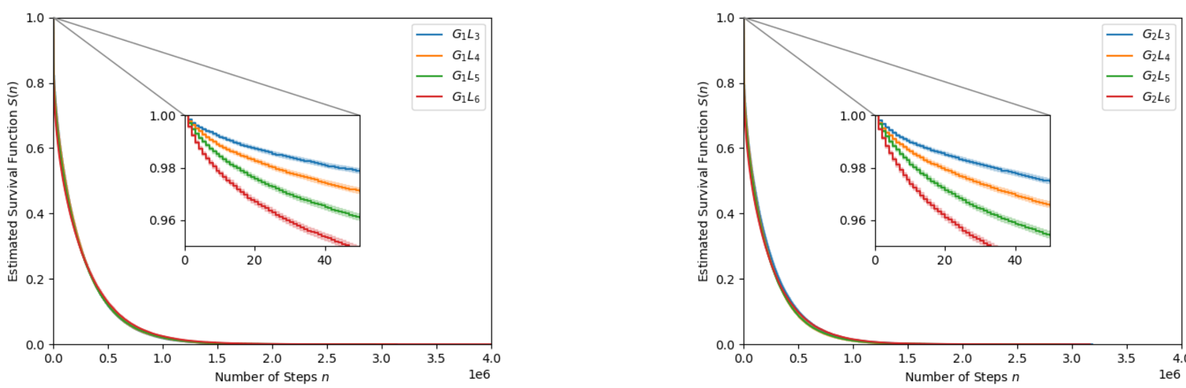
3.2 Complicated Branching Structures

3.2.1 Image Description

- Image size: 1200×1000 pixels
- Surface area of shapes: 90000 pixels
- Iterate the template 3, 4, 5, 6 times to produce the targeted branching geometries labelled as L_3, L_4, L_5, L_6.
- Two groups of images labelled as G_1, G_2
  - G_1: the target object G_1L_i $(i = 3, 4, 5, 6)$ is equidistant to the edges of an image.
  - G_2: the template of G_2L_i $(i = 3, 4, 5, 6)$ is distinct from G_1 (thickness and aspect ratio).

3.2.2 Output Analysis

3.2.2.1 $S(n)$



(a) **(b)**

Figure 3.2

3.2.2.2 $S(d)$

3.2.2.3 $S(R)$

3.2.3 Conclusion

- In a short time, the survival function of rectangle decays faster than the circle, which conforms to the analytical results.
- The differences of estimated survival functions between circle and rectangle are statistically significant, which coincides with the real shape dissimilarities.

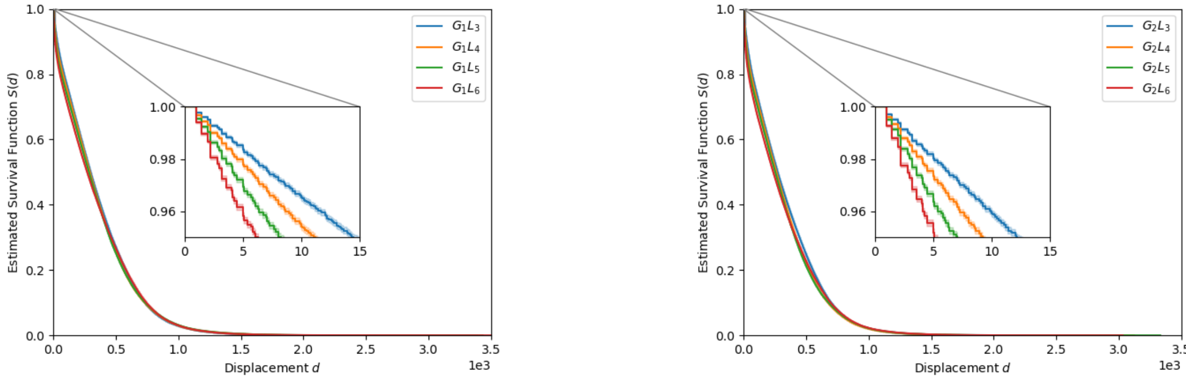
		p			
		Logrank	TW	GB	FH
G_1 L_3	G_1 L_4	0.4393	0.0285	0.0005	0.0005
	G_1 L_5	0.0	0.0	0.0	0.0
	G_1 L_6	0.0	0.0	0.0	0.0
G_1 L_4	G_1 L_5	0.0007	0.0	0.0	0.0
	G_1 L_6	0.0002	0.0	0.0	0.0
G_1 L_5	G_1 L_6	0.7223	0.0	0.0	0.0

Table 3.2

		p			
		Logrank	TW	GB	FH
G_2 L_3	G_2 L_4	0.0	0.0	0.0	0.0
	G_2 L_5	0.0	0.0	0.0	0.0
	G_2 L_6	0.0	0.0	0.0	0.0
G_2 L_4	G_2 L_5	0.0016	0.0	0.0	0.0
	G_2 L_6	0.0004	0.0	0.0	0.0
G_2 L_5	G_2 L_6	0.7199	0.0	0.0	0.0

Table 3.3

- Within a same group, when t is small, the more branching the object is, the faster the survival function decays.
- Within a same group, the pairwise survival functions are statistically different.
- The corresponding target structures in G_1 and G_3 are invariant shapes under translation since their survival function are not statistically different. In other words, periodic boundary conditions of the image can eliminate the effect of the locations.
- LRWs can describe and classify the geometries, their spatial configurations, and the unoccupied area in the image.



(a) **(b)**

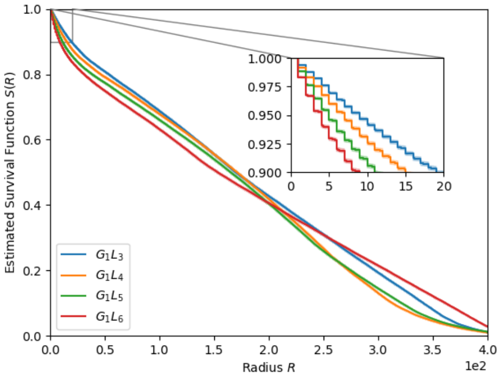
Figure 3.3

		p			
		Logrank	TW	GB	FH
G_1 L_3	G_1 L_4	0.0	0.0	0.0	0.0
	G_1 L_5	0.0	0.0	0.0	0.0
	G_1 L_6	0.0	0.0	0.0	0.0
G_1 L_4	G_1 L_5	0.0072	0.0	0.0	0.0
	G_1 L_6	0.0003	0.0	0.0	0.0
G_1 L_5	G_1 L_6	0.2883	0.0	0.0	0.0

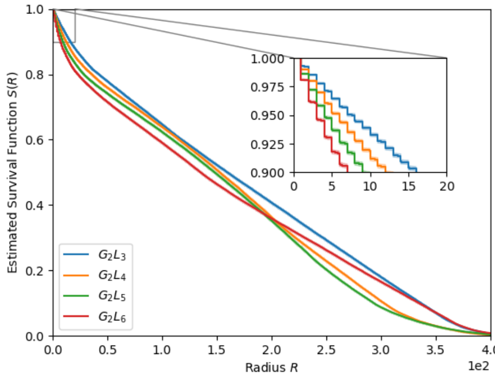
Table 3.4

		p			
		Logrank	TW	GB	FH
G_2 L_3	G_2 L_4	0.0	0.0	0.0	0.0
	G_2 L_5	0.0	0.0	0.0	0.0
	G_2 L_6	0.0	0.0	0.0	0.0
G_2 L_4	G_2 L_5	0.0001	0.0	0.0	0.0
	G_2 L_6	0.0015	0.0	0.0	0.0
G_2 L_5	G_2 L_6	0.7019	0.0	0.0	0.0

Table 3.5



(a)



(b)

Figure 3.4

		p			
		Logrank	TW	GB	FH
G_1 L_3	G_1 L_4	0.0	0.0	0.0	0.0
	G_1 L_5	0.0	0.0	0.0	0.0
	G_1 L_6	0.0	0.0	0.0	0.0
G_1 L_4	G_1 L_5	0.1773	0.0	0.0	0.0
	G_1 L_6	0.0	0.0	0.0	0.0
G_1 L_5	G_1 L_6	0.0	0.0	0.0	0.0

Table 3.6

		p			
		Logrank	TW	GB	FH
G_2 L_3	G_2 L_4	0.0	0.0	0.0	0.0
	G_2 L_5	0.0	0.0	0.0	0.0
	G_2 L_6	0.0	0.0	0.0	0.0
G_2 L_4	G_2 L_5	0.0	0.0	0.0	0.0
	G_2 L_6	0.0	0.0	0.0	0.0
G_2 L_5	G_2 L_6	0.0	0.0	0.0253	0.0253

Table 3.7

LRWs in Real Root Images

Conclusion

Future Work

Appendix A

Numerical Methods for Solving Parabolic Partial Differential Equations

A.1 Introduction

A.2 Summary of Commonly Used Numerical Techniques

A.3 Limitation in Practice

Appendix B

Method Validation in Annulus

B.1 Analytical Results

B.2 Numerical Approximation

B.3 Comparison of Numerical and Analytical Results

B.4 Conclusion

References