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In This Edition

2 Pages

The shortest path between two points in a critical random blob model.

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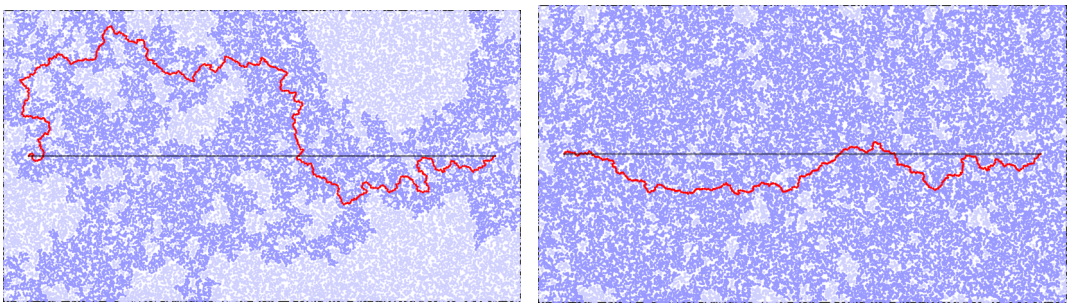

Figure 1: Two models with the same set of points. The darker blue discs form a single connected "island" in each. The left model has r = r_c. The radii for the right image are only 5 percent larger, but the path is much shorter and more direct.

Frankie Higgs is a postdoctoral researcher in the Probability Lab at the Department of Mathematical Sciences. His research, working with Mathew Penrose, looks into how boundary effects change the properties of models in random geometry, bringing together tools from probability, geometry and algebraic topology.

The *random blob model* (or Boolean model, or continuum percolation) is very easy to describe but very difficult to analyse, with many surprising properties.

Inside a large box, place a set of random points with intensity 1 (the intensity is the average number of points divided by the area). Then place a disc of radius $r > 0$ centred at each point. We can think of the discs as lilypads on a pond, and are interested in questions such as whether it is possible to travel between the left and right sides of the box using a path of overlapping lilypads. A more practical application could be peer-to-peer communication networks, where r represents the communication radius of mobile phones.

A surprising fact is the existence of a critical radius r_c which does not depend on the size of the box. If $r > r_c$ then with probability very close to 1 there is a path using discs from the left to the right of the box, while if $r < r_c$ the probability that such a crossing exists is very close to 0.

One of the most difficult and interesting problems in random geometry is to understand the behaviour of the model at the critical point $r = r_c$. This critical model is expected to have properties very different to both the subcritical ($r < r_c$) and supercritical ($r > r_c$) cases.

The celebrated work of Smirnov [1] proved, for a related percolation model, a long-standing conjecture made by physicists that critical models are *conformally invariant*: they have similar properties after many types of transformation. In particular Smirnov proved critical percolation was linked to the *Schramm-Loewner evolution*, a family of conformally invariant fractal random curves which appear in a wide range of physical models.

In ongoing work with Alex Giles at UCL, we are examining the shortest paths between two fixed points in the critical random blob model. Monte Carlo simulations of the supercritical random blob model [2] found that the shortest path of discs between two points x and y had average length proportional to $|x - y|$, only a constant factor longer than the straight line segment from x to y, and the standard deviation of the length was a multiple of $|x - y|^{0.20 \pm 0.01}$.

We ran our Monte Carlo simulations of the critical model on the Nimbus cluster. One major problem we faced is that the model is much less well-connected when $r = r_c$ than when $r > r_c$: we have to take between 6 and 7 samples of the model on average to find one with a path connecting x and y. Using an HBv3-series VM with 120 cores, we were able to sample many realisations of the model in parallel to find enough paths to estimate the mean length and other statistics.

We found that the length of the path from x to y was proportional to $|x - y|^{\gamma}$ where $\gamma \approx 1.14$, much longer than the supercritical case, and with standard deviation $\propto |x - y|^{\chi}$ where $\chi \approx 1.10$, also much higher.

We are also looking at other properties of the path examined in [2], such as the *deviation*: how far the path travels in the direction perpendicular to the straight line from x to y. In the critical model we found the deviation was proportional to $|x - y|$, while [2] found it was a multiple of $|x - y|^{0.60 \pm 0.01}$ for the supercritical model.

Videos of the transition between the two cases are available at:
https://www.youtube.com/playlist?list=PLiaV5rk6Gk7pr67fSF8ppy6cGKpi0z8LL

References

[1] Alexander P. Kartun-Giles, Marc Barthelemy, and Carl P. Dettmann. Shape of shortest paths in random spatial networks. Physical Review E, 100(3), September 2019. doi:10.1103/physreve.100.032315.

[2] Stanislav Smirnov. Critical percolation in the plane: conformal invariance, Cardy's formula, scaling limits. Comptes Rendus de l'Acad´emie des Sciences - Series I - Mathematics, 333 (3):239–244, August 2001. doi:10.1016/s0764-4442(01)01991-7.

HPC News and Updates

Isambard 3, NVIDIA Grace superchip, ARM based supercomputer is online and currently going through its final testing phase with early access projects. The system consisting of 55298 cores will be available for researcher use early next year.
Bath has a 10% share of the system and to register interest please submit a ticket to research computing via **TOPdesk**.

Additional resources can be applied for from UKRI's 60% share, the call for these resources is currently open for January access (closing date: 28/11/2024):
https://www.ukri.org/opportunity/access-to-high-performance-computing-facilities-autumn-2024/

After the successful deployment of Nimbus 2.0 earlier this year, development on Nimbus 3.0 is in full swing. The main upgrade will be the required operating system change from CentOS 7.8 to Alma Linux 8 improving security and Azure support. The current plan for deployment of Nimbus 3.0 is February 2025, with volunteers required for testing, please look out for the call for volunteers early next year if you would be happy to contribute.

We are in the process of updating the **research computing website** with an aim to improve documentation and accessibility surrounding our systems, so please be aware that some links may be unavailable during this time.

We are also planning some departmental HPC Q&A sessions over the coming months so please keep an eye out via the website and departmental communications for relevant sessions if they would be valuable for you.

Linux and Nimbus Command Cheat Sheet

Linux Command	Usage
vi	Open a file
cd	Change directory
cp *old new*	Copies a file
mkdir *name*	Creates a new directory
rm *name*	Deletes a file
ls	Lists the files in the current directory
pwd	Prints the path to the current directory
ssh username@remote-computer	Log into remote computer
scp path/to/file/to/move path/to/new/location	Copy file from one computer to another

Edit File Command	Usage
i	Enter insert (edit) mode
esc	Switch to command mode
:w	Save and continue editing
:wq	Save and exit file
:q!	Quit file without saving
yy	Copy a line of text
p	Paste a line of text
dd	Cut a line of text
G	Go to last line in file
gg	Go to first line in file
x	Delete a single character

Navigating Nimbus Command	Usage
ssh *username*@nimbus.hpc.bath.ac.uk	Log into Nimbus
cd /campaign/*RA-code/…*	Move into campaign directory (code and job scripts go here)
scp */path/to/local/file.txt* *username*@nimbus.hpc.bath.ac.uk:/campaign/*RA-code/file.txt*	Copy file from local machine to campaign directory on Nimbus
scp *username*@nimbus.hpc.bath.ac.uk:/campaign/*RA-code/…* */path/to/local_file.txt*	Copy file from Nimbus to local machine
module avail	See what modules are available to run in the current instance
module check [instance_type] [module_name]	Check which modules are available on an instance
Submitting Jobs (slurm) Command	**Usage**
sinfo	View information about SLURM nodes and partitions
squeue	View jobs in the queue
sbatch *jobscript.slm*	Submit job to Nimbus
scancel *[job_id]*	Cancel a job submitted to Nimbus
sacctmgr show associations user=*userid* --parsable2	Find what RA-codes you have access to

Acknowledgements

The Research Computing team would like to thank all contributors for the current issue of ***HPCBytes***.

- **We are looking for case studies!** If you would like to contribute an article to be featured in ***HPCBytes***, please get in touch with the Research Computing team.
- If you would like to hear more, please subscribe to the Research Computing mailing list here: https://forms.office.com/e/rF8rLWbakA

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