Network in micro-roller motion

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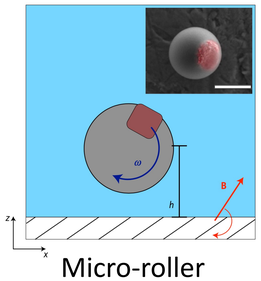
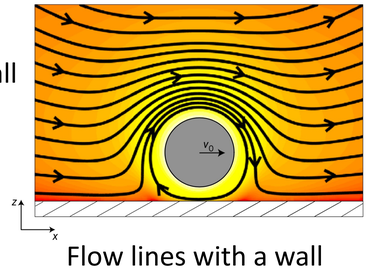
Overview: When micro-rollers in a suspension move together in large numbers, some may come closer, while some goes farther way from each other creating clusters and gaps. Networks can be constructed based on the rollers' location and their analysis can give new insights to such motion.

Introduction



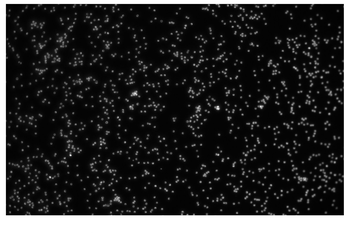
Micro-roller

A colloidal particle having a magnetic core, when subjected to a rotating magnetic field will roll at one position within the liquid bulk, but near a wall because of symmetry breaking will also show translation. These particles will be referred as micro-rollers. Flow of them in large numbers is complicated because of the long-range hydrodynamic interactions of these particles.



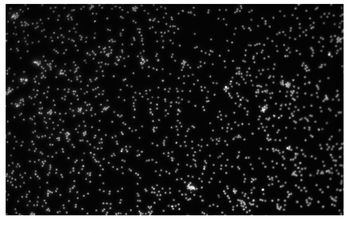
Flow lines with a wall

Method



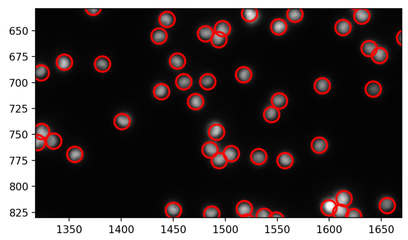
Before motion

60 s under $\vec{B}$

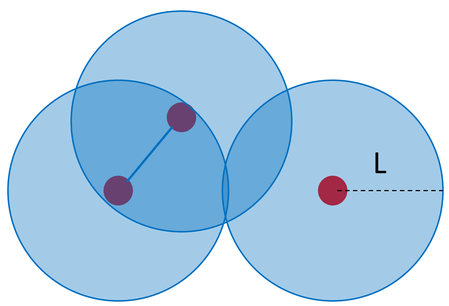


After motion

Micro-rollers suspended in water is taken in a capillary chamber , which is observed under a microscope. They are subjected to magnetic field for a fixed time. The location of the rollers were detected by approximating them as Gaussian blobs using Trackpy. The network is constructed by joining two roller locations that are within a linking length L.



Micro-roller location detection with Trackpy



2µm particles made of a fluorescent TPM shell and a hematite core, suspended in water is used for this study.

Discussion

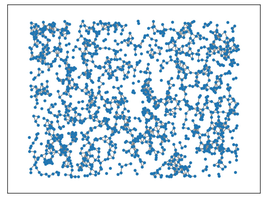
For L=50, the network for the before motion, is well connected (only around 25 out of 1394 nodes are disconnected). In this L, after motion network shows a significantly different degree distribution with the presence of an exponential tail towards higher degrees. Also, after motion network shows existence of higher degrees.

For L=20, where networks are almost disconnected and only connected when there are close clusters, there is a significant increase in the average clustering coefficient after motion. In fact, the relative change in average clustering coefficient increases with decreasing L.

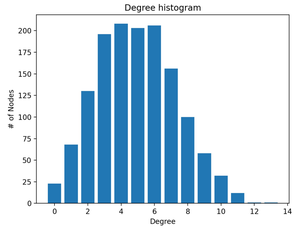
Results

Networks for 3 values of L are shown here: L = 50, 20, 60

Before magnetic field

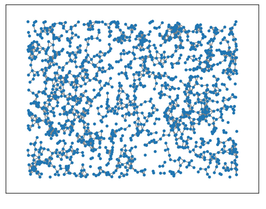


L=50 # of edges = 3445

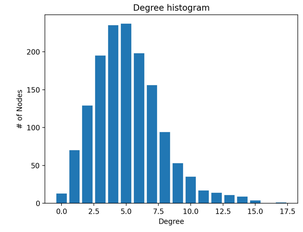


Average clustering = 0.5463

After magnetic field

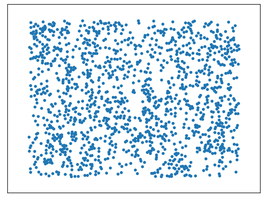


L=50 # of edges = 3799

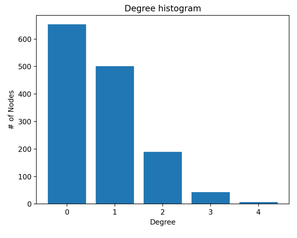


Average clustering = 0.5552

Before magnetic field

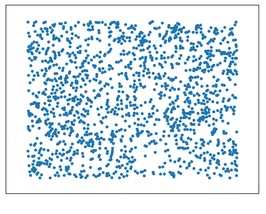


L=20 # of edges = 519

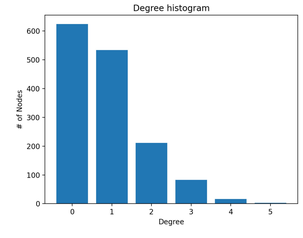


Average clustering = 0.0671

After magnetic field

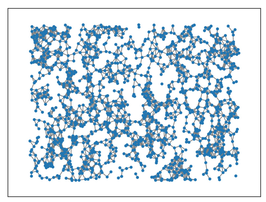


L=20 # of edges = 642

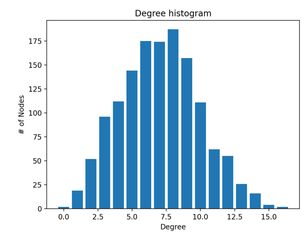


Average clustering = 0.0925

Before magnetic field

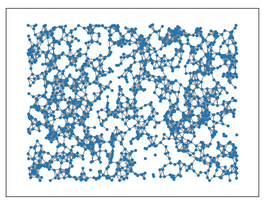


L=60 # of edges = 4931

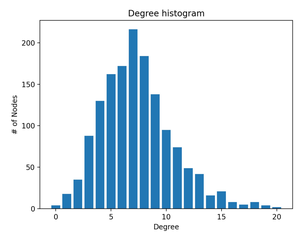


Average clustering = 0.5847

After magnetic field



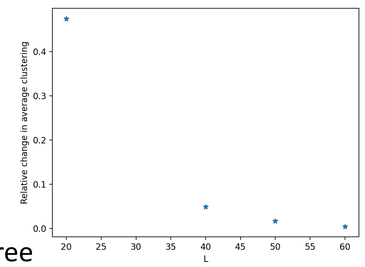
L=60 # of edges = 5425



Average clustering = 0.5867

Discussion

For L=60, there is no significant change in the degree distribution and average clustering coefficient in before and after motion. At larger L, the networks are getting over connected and effects due to the small clusters and gaps are getting obscured.



Network construction on proximity resulted in low number of low degree (k=1,2,..) nodes as when they are distant, they became disconnected and when they are close, more edges get constructed. Other models like "closest n neighbors" can give more low degree nodes. Also, the number of high degree nodes will not change much from now, as our present model captures the clusters well. With such model, based on our observation for L=50, we can expect a power law fit for after motion degree distribution which will suggest scale-freeness and existence of hubs.

References & Acknowledgements

- R. de Regt et al., Network analysis of the COSMOS galaxy field
- B. C. Coutinho et al., The Network Behind the Cosmic Web
- A. L. Barabasi, Book: Network Science

The diagrams in 'Introduction' are from
M. Driscoll et al., Unstable fronts and motile structures formed by microrollers

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