Modelling Complex Systems

Simulations, data visualisation/ reporting, project work.

This lecture includes adapted slides of David Sumpter, Olivia Woolley, Stefano Balietti, Lloyd Sanders, Dirk Helbing

- Tue 3rd Office hour 1-2pm, office 74116 (hus 7 floor 4) + zoom link will be emailed out.
- Wed 4th 9am-12pm Lab 3 - processes on networks.
- Wed 4th 1-3pm timeslots to discuss final project. No afternoon lecture.
- Mon 9th 10am-12pm lecture
- Thurs 12th 1-4pm Lab 4 - self propelled particles. (3-4pm timeslots to discuss projects).
- Fri 13th 1-4pm Lab 5 (3-4pm timeslots to discuss projects).
- Mon 16th 9am-12noon Lab 6.
- Tue 17th, Thur 19th, Tue 24th : Lab time for final project. Discussion with groups
- 3rd June: deadline for final project.
- Resit period - opportunity to resit each Lab separately.

Summary Of Approach To Complex Models

- Try running simulation for different values see what happens.
- Define a measure to capture the simulation - evaluate measure by thinking about special cases.
- Run for different parameter values. Make a phase transition diagram.
- Investigate special cases by looking at simulation - think about if you can explain the behaviour in simple cases - approximations and heuristics ok.

Phase Transition Diagram

- How the simulation behaves after many steps/ at equilibrium as we change a parameter.
- Often number of individuals or a transition rate is changed. For GA - mutation rate or cross-over rate.
- Can often summarise total model behaviour in one figure.
- Can be used to show agreement between experiment and model

Recall: Locusts

Buhl et al. (2006), *Science*
Yates et al. (2009), *PNAS*

Alignment model in one dimension

- Run 'Align1D'

current position

current velocity

future position

$$x_i(t+1) = x_i(t) + v_0\, u_i(t)$$

$$u_i(t+1) = a u_i(t) + (1-a)\, s_i(t) + e_i(t)$$

future velocity

current velocity

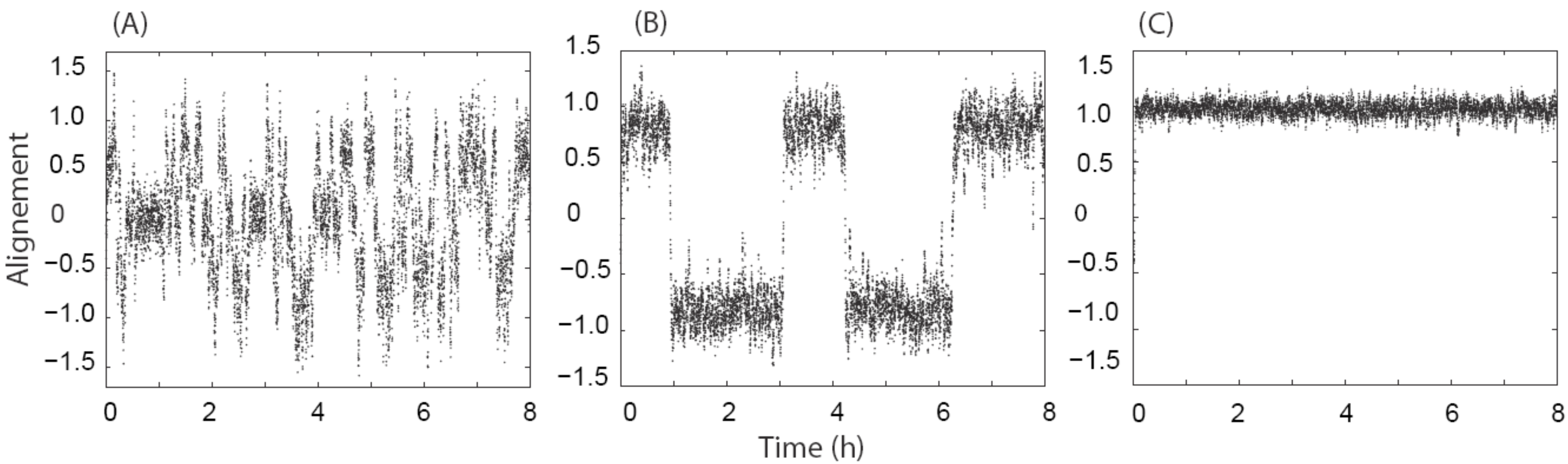
stochastic effect

velocity of neighbours

$$s_i = G\left(\frac{1}{|R_i|}\sum_{j\in R_i} u_j(t)\right) \qquad G(u) = \begin{cases}(u+1)/2 & for \quad u > 0\\ (u-1)/2 & for \quad u < 0\end{cases}$$

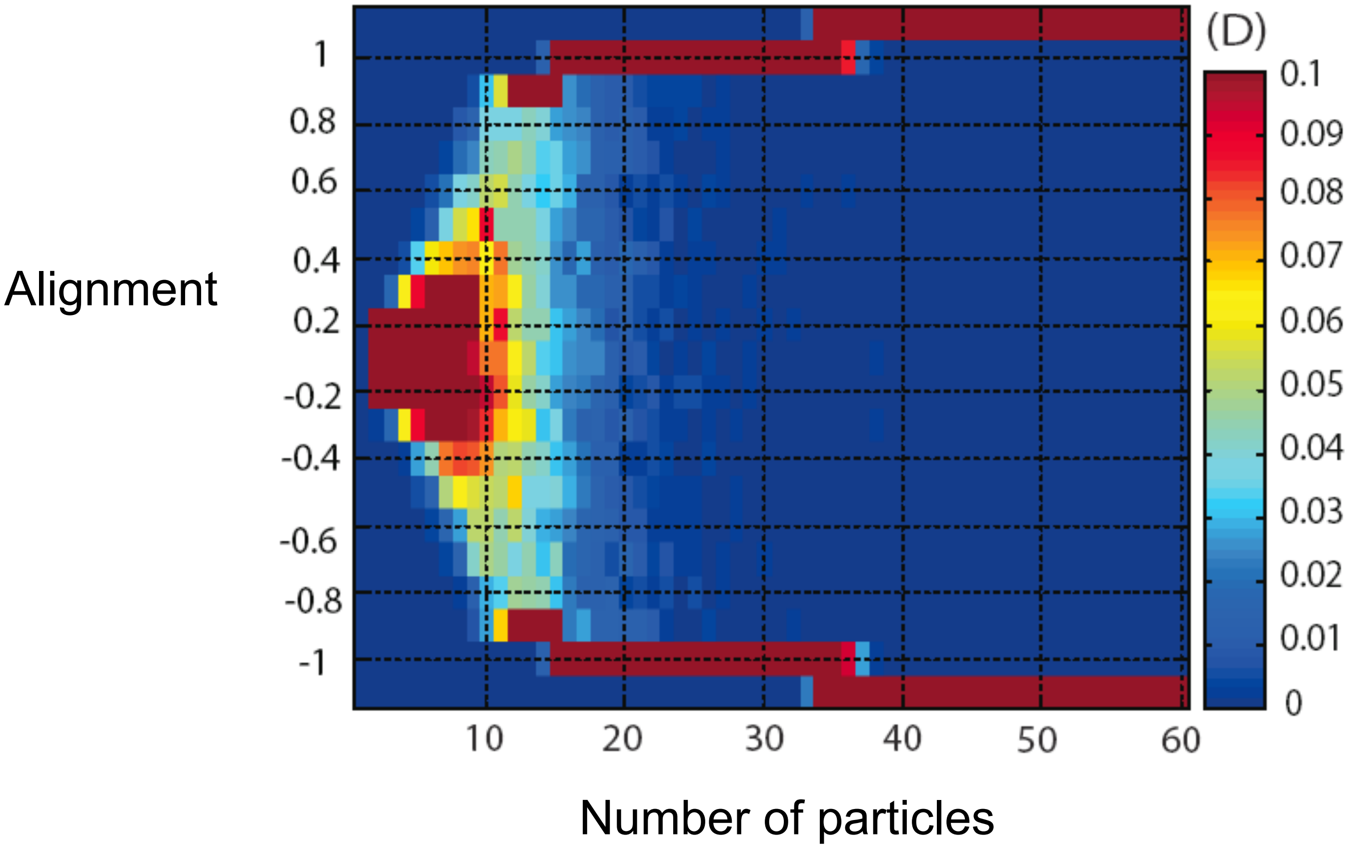
e is a random number selected uniformly at random from a range $[-\eta/2, \eta/2]$

Alignment



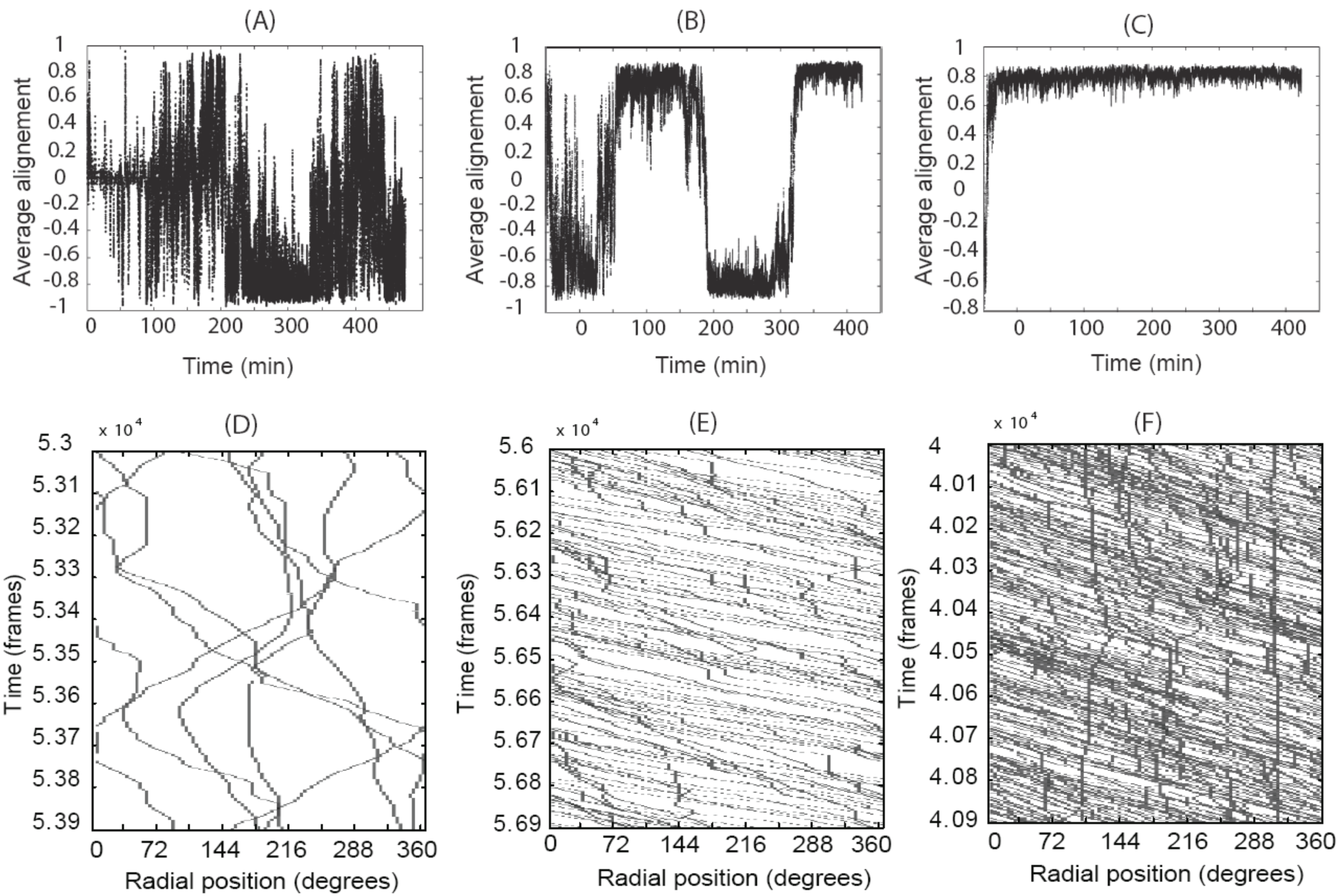
$$\phi = \frac{1}{n}\sum_{i=1}^{n} \underline{u}_i(t)$$ measures order in the system.

1D self-propelled particles

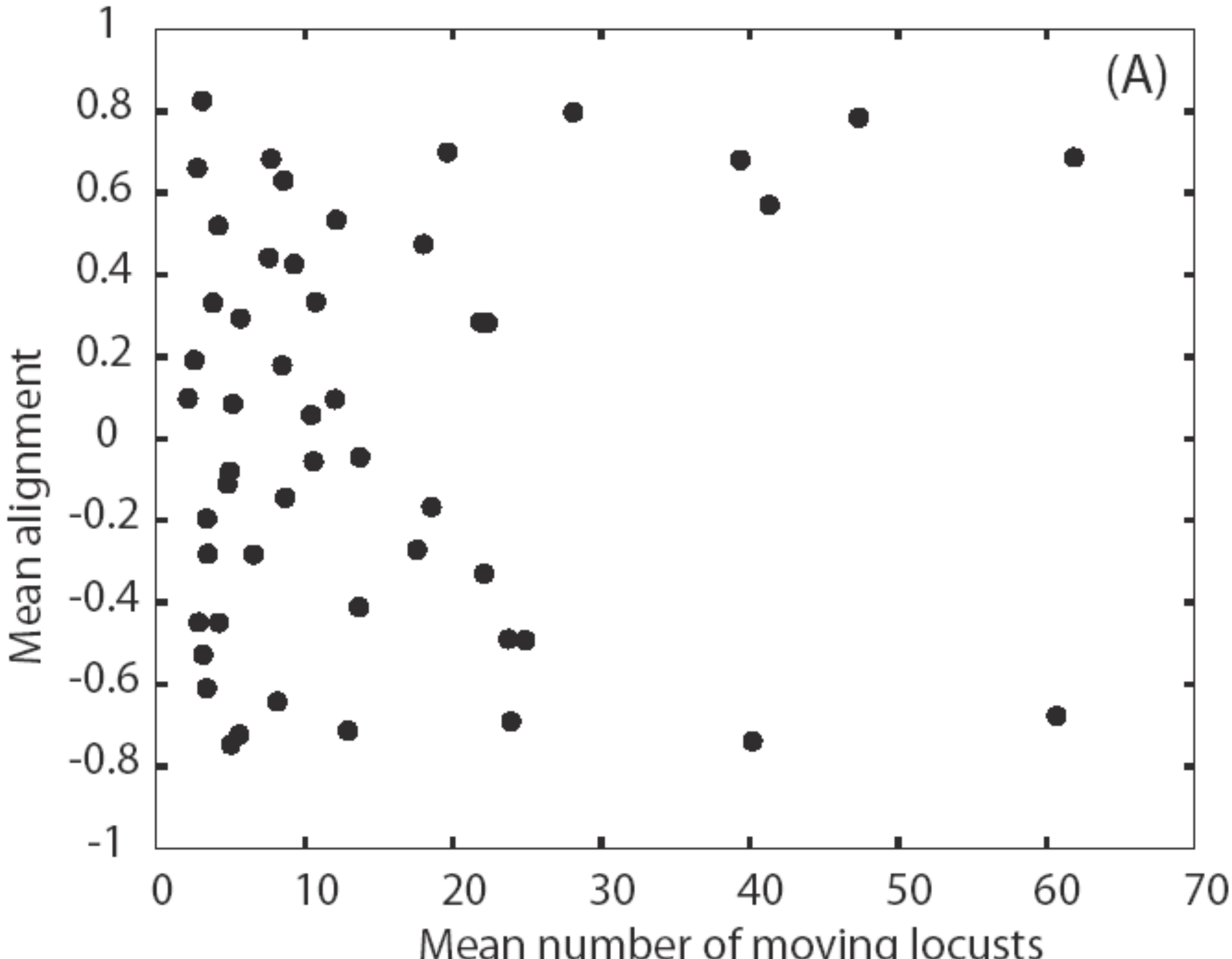


$$\phi = \frac{1}{n}\sum_{i=1}^{n} \underline{u}_i(t)$$ measures order in the system (alignment).

7 locusts | 25 locusts | 50 locusts

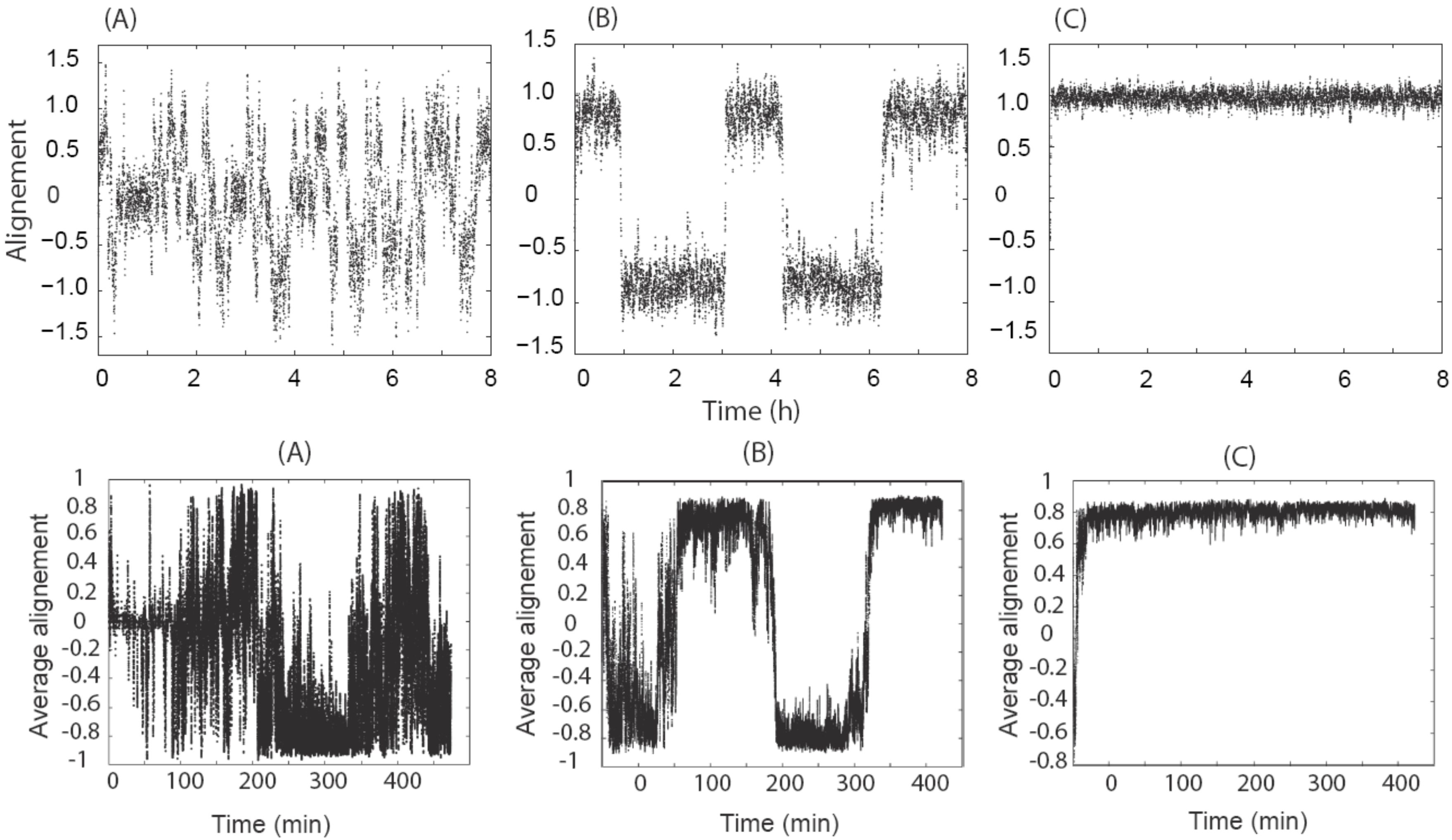


Buhl et al. (2006), *Science*

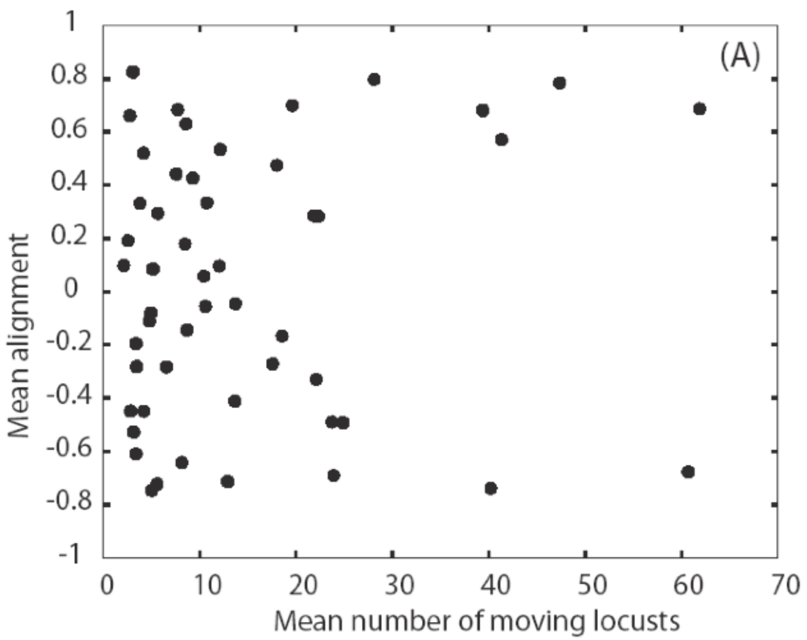


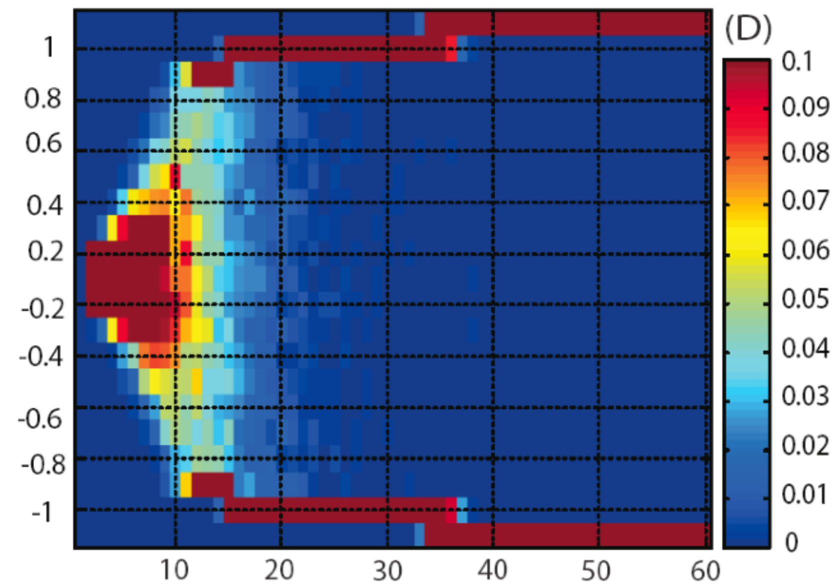
Buhl et al. (2006), *Science*

Model vs Experiment



Model vs Experiment



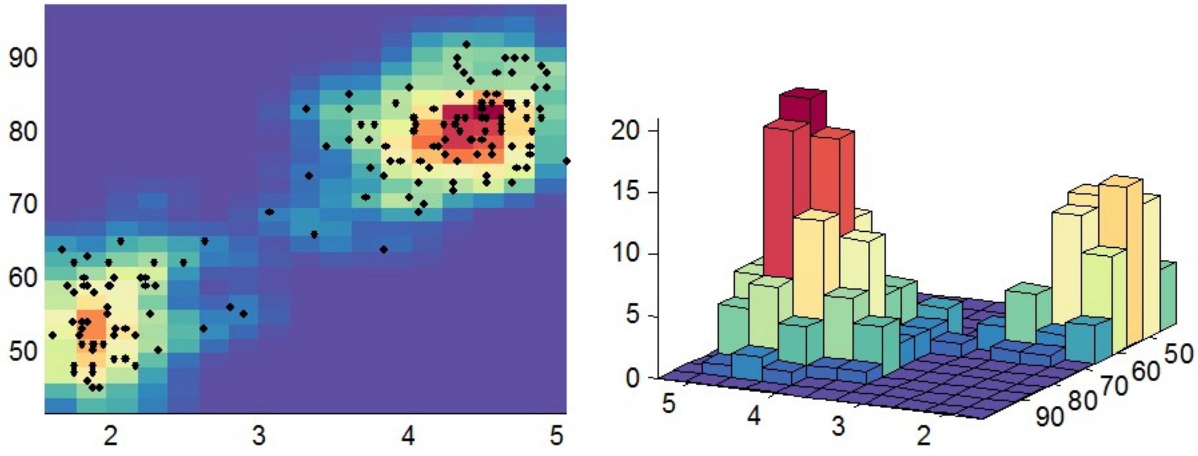


Points About Simulation Phase Transitions

- Use term phase transition when looking at simulation.
- Nearly always when working with a simulation your aim is to build a phase transition at some point.
- Make sure your simulation works first.
- Then try running a few replicates and plot them.
- When you think everything is working then run a longer simulation (max 30 minutes to one hour runtime is reasonable for this course).

Plotting Phase Transition Diagram

- 2D histogram - except instead of heights for each cell, magnitude represented by a colour

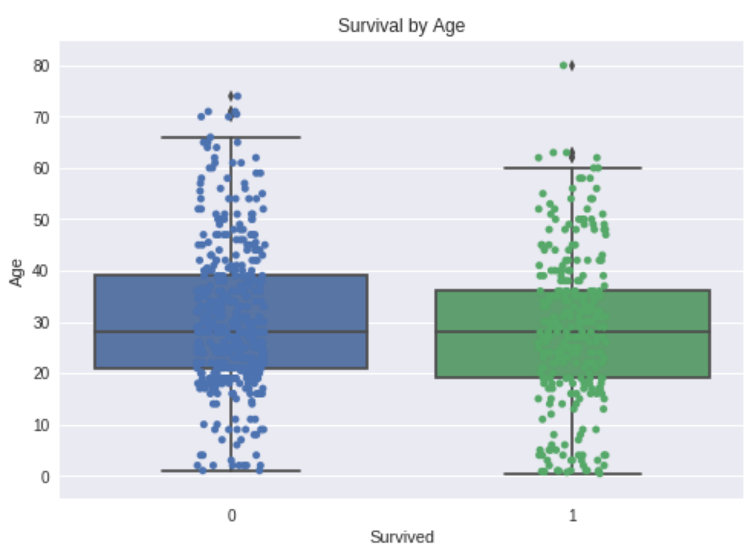


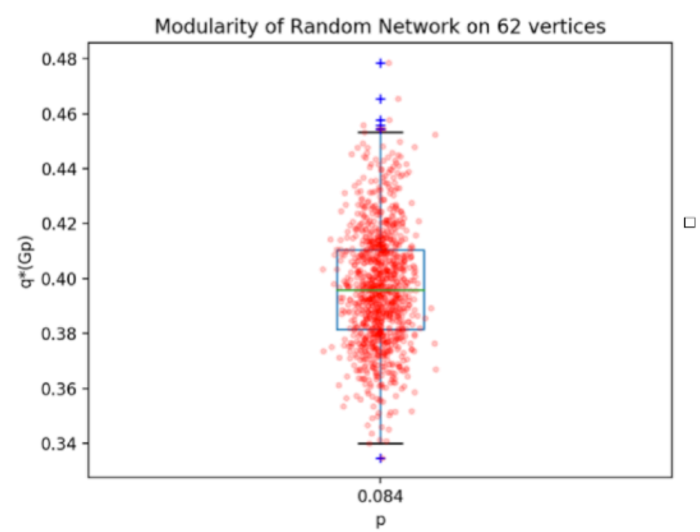
Plotting Phase Transition Diagram

- Python - can use plt.hist2d from matplotlib. Nice tutorial https://python-graph-gallery.com/83-basic-2d-histograms-with-matplotlib.
- Matlab - can use surf. Code uses *surf()*; input matrix *M* has as entry *(i,j)* the model fit for every combination of two parameters.

More Plotting Examples
Including Data Pts On Box Plots

- Python - tutorial here https://www.kaggle.com/code/saisivasriram/titanic-feature-understanding-from-plots/notebook. Add random noise to x co-ordinate of point to allow all points to be seen.





More Plotting Examples
Include Details

```
plot(x, (y(1,:))
```

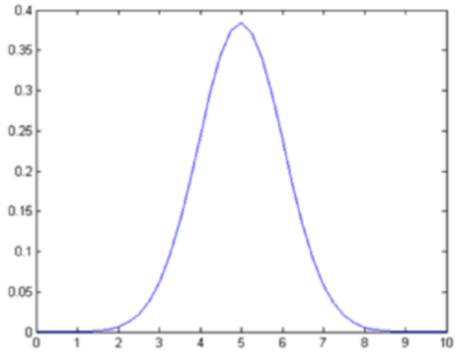


Figure 4: Simulation results.

```
errorbar(x,mean(y),std(y),'k','LineWidth',2)
set(gca,'FontSize',16)
xlabel('Time (days)')
ylabel('Fraction of happy agents')
xlim([0 10])
ylim([0 .5])
```

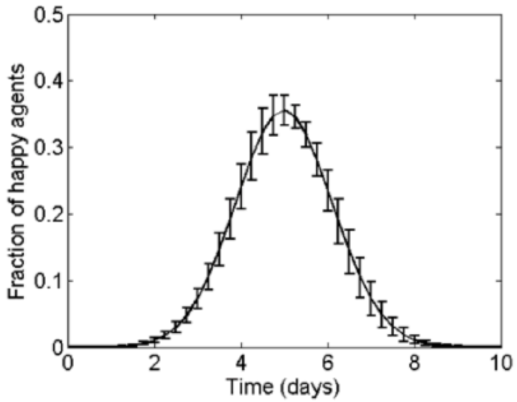


Figure 4: Fraction of happy agents as a function time, for 10 different simulation runs. The average value (solid line) and one standard deviation (error bars) are shown. The parameter values are a=1.0 and b=0.7.

More Plotting Examples
Data Visualisation

- Great Blog by Charlotte Muth - https://lisacharlottemuth.com/

Final Project

- Pragmatic choice of paper - available code e.g. GitHub repository, well written - attention paid to wording of paper is a good indication.
- Groups. Group size 3-4 ppl idea, from 1-5 ppl is ok.

  Group forming

- by 10am tomorrow (Tue 3rd May) if you would like help to form a group send me (by email fiona.skerman@math.uu.se): Your name, topic 1, topic 2, preferred group size, anyone else you have already planned to work with.
- By 10:30am for those who messaged me, I'll send emails to groups of people who have indicated similar project interest etc. Who you work with is completely your choice.
- Sign up for timeslot to discuss choice of paper/ possible extensions (optional). Link to google doc on website.