Why are physicists interested in crowds?

Crowds are dynamic entities. Above a critical density, a crowd moves like a fluid rather than like a collection of individuals. At crowd densities of about seven people per square metre, the crowd becomes almost a fluid mass[w1]. Shock waves pass through crowds that can cause people to move involuntarily over large distances, and people may literally be lifted out of their shoes.

This makes crowds interesting examples of fluid mechanics, sometimes unfortunately with tragic consequences. Stampeding crowds have resulted in fatal accidents for example during the Hajj, the Muslim pilgrimage to the city of Mecca, Saudi Arabia, where about three million pilgrims gather each year[w1, w2] and during the 2010 Love Parade in Bochum, Germany, an electronic dance music festival. For a list of major crowd disasters, see the Panic – A Quantitative Analysis website[w3].

Crowds involve multiple interactions. Individuals within crowds interact with their neighbours. These interactions can take a number of forms. Some people push or pull their neighbours to move through the crowd. Many stop acting independently (this is also known as the herd effect, commonly seen in wildebeest migration[w3, w4]). Others instinctively avoid contact with unknown humans, which in terms of physics can be analysed similarly to electron–electron repulsion.

Boundary conditions are important. Crowds react to their environments. Spatial constraints can change their behaviour, forming or blocking crowds[w1, w3]. During fire evacuations, for example, even in a full corridor, people can typically move quickly as they are all heading in the same direction. However, stoppages occur at exit points (where the crowd is funnelled by the door) and this can lead to serious consequences.

Fluctuations can cause spontaneous formation of crowds. For example, a driver suddenly breaking can cause a *phantom* traffic jam in the absence of roadworks or accidents[w5]. This makes it important to take fluctuations into account, because without them, models would fail to predict such behaviour. Crowds can also transition from free-flowing to stationary very quickly. An interactive tool demonstrating the effect of speed on traffic jam formation can be found online[w6]. Predicting and dealing with spontaneous crowd formation is a serious issue for urban planners.

Web references

w1 – Following several stampedes with serious outcomes, scientists from Germany and Saudi Arabia investigated crowding during the Hajj, which led to changes in the way the crowd is organised. Their website contains background information and short videos of their analyses, as well as a list of links to other crowd analysis and simulation studies. See: www.trafficforum.ethz.ch/crowdturbulence

One of the scientists, Dirk Helbing, has since moved to the ETH Zürich, Switzerland. His homepage provides a good collection of videos, links and simulations of crowding and other mass social behaviour such as synchronised clapping. See: www.soms.ethz.ch/research/Videos

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Supporting material for:

Saunders T (2011) The physics of crowds. *Science in School* **21**: 23-27. www.scienceinschool.org/2011/issue21/crowding

w2 – To observe the fluid-like behaviour of the crowd at the Hajj, see: www.trafficforum.org/crowdturbulence and www.cbsnews.com/video/watch/?id=1203505n

w3 – A team of German and Hungarian scientists has simulated escape panic in a computer model. Their free website features an article that they published in *Nature* in English and Hungarian, videos simulating various escape scenarios with and without panic or herd effect, a list of major crowd disasters and background information. See: www.panics.org

w4 – For a particularly tragic instance of wildebeest displaying the *herd effect* ('Wildebeest die in mass drowning'), see the *National Geographic* website (www.nationalgeographic.com) or use the direct link: http://tinyurl.com/6zehbc9

w5 – A team of US scientists has set up a website to present their simulation data on the formation of traffic jams. It includes a good explanation of their research and results, as well as a number of videos showing how *phantom* traffic jams form. See: http://math.mit.edu/projects/traffic

w6 – With this great online tool from the Technical University Dresden, Germany, you can simulate a range of traffic jams, modulating different parameters. The website is available in Catalan, English, French, German, Portuguese, Spanish and Turkish. See: www.traffic-simulation.de

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