Chaos in a Dripping Tap

Stephen Fisher
Supervised by Dr Cathal Flynn

Personal Details
Upon successfully completing the first year of the Applied Sciences and Computing degree, I chose Physics as a subject for second and third year ahead of Maths and Chemistry. At the beginning of fourth year, I again chose Physics, ahead of Software Engineering, as a degree subject. Along with Physics, I chose both Computer Science and French as final year subjects. French was useful because I spent the second half of third year on the Erasmus program in the south east of France, studying in the IUT Chateau Neuf, Bayonne.

Project Summary
Chaos is an emerging scientific discipline with its origins dating back to the 1960s. It is the irregular, unpredictable behaviour of deterministic non-linear dynamical systems. Three of the most common ways in which a system becomes chaotic is quasiperiodicity, intermittency and period doubling.

The aim of this project was to construct a PC-interfaced apparatus to show the period doubling route to chaos in a dripping tap. The apparatus was to be constructed so that it could be used as a future third year laboratory experiment. The project was designed to study the time-interval of drips falling from a tap when the dripping rate was increased. The drip rate was the control parameter of the system.

An apparatus to replicate a dripping tap was built to provide the dripping conditions and circuit was constructed to provide the data acquisition and storage. The main components of the circuit were a GaAs infrared LED, TSL250 detector and a 555-timer. The circuit was set up in such a way that when the beam travelling from the LED to the detector was broken, the 555-timer produced an output pulse determined by an RC network. The idea behind the circuit was that when a drip passed through the LED/detector path an output pulse was produced. The time between these pulses would constitute the time between the drops. A pipe was used to hold the LED and detector and allowed for greater mobility of the apparatus.

Upon completion of the circuit a Marriott’s Flask was used to replicate the set-up of a dripping tap. The output of the flask contained a nozzle that provided the well-controlled dripping conditions. The water would exit the Marriott’s Flask and fall through the pipe that contained the LED and detector producing a pulse for each drop. A photo of the set-up can be seen in figure 1.

The pulses were sent to the computer via a data acquisition card. A program was written in Labview that accepted the data and stored the results. Results were recorded for drip-rates ranging from 1.8 drips/s to 10 drips/s. For each set of results a graph of ‘Time Interval’ versus ‘Drop Number’ and a graph of ‘Time Interval’ versus ‘Preceding Time Interval’ was produced.

Figure 1. A picture showing the vertical pipe containing the LED and detector along with the dripping apparatus above it.
For low drip rates the system was seen to be periodic with most of the time intervals occurring close to the mean value. This can be seen for a drip rate of 1.8 drips/s in figure 2. As the drip rate was increased, the system showed elements of period doubling for a drip rate of 3.57 drips/s. In this state, a long time interval was followed by a short time interval. A long time interval then followed once more. As the drip rate was increased further, the system progressed further still on its route to chaos. Figure 3 shows the results for a drip-rate of 5.5 drips/s. The drip intervals could now be seen to occur over a range of 50 milliseconds. The drip interval is now unpredictable. The system had now progressed from a periodic state to a chaotic state.

It was hoped to show a clear indication of period doubling in the dripping tap. However only elements of period doubling could be seen. The reason for this was the sensitivity of the nozzle that controlled the drip rate. For period doubling to be shown, a change of approximately 10 milliseconds was required in the drip rate. This sensitivity was not possible with the apparatus.

Upon obtaining the results, the system was also modelled using a set of first order differential equations. Time limitations resulted in this work being incomplete. Future work in this area could model the dripping tap further and to compare the results with those obtained experimentally.