Winner Winner Chicken Dinner

Introduction

Have you ever thought those two chickens in front of you were about to fight? No? me neither, but what if there was a mathematical model to predict this? Well, knowing chickens, they are very aggressive and terrifying, as they establish social hierarchies, commonly known as pecking orders, where they determine who is dominant or not. This is a behaviour that has been studied by scientists for over a century.

Knowing this, the first and most important thought you'd probably have is: can a mathematical model predict when two chickens are about to fight?

The answer would be yes. Mathematical models used to describe behavioural science in animals is not a novelty in the field, as there already exists models to describe how animals compete, interact and form social structure. If mathematics is capable of this, then of course it will be capable of answering the pressing question of whether two chickens are about to engage in a full-scale poultry war.

Observing Chicken Behaviour

Before even mentioning any maths, the first step is to discuss what causes a chicken to fight. Chickens, despite their reputation for being violent critters, do not just randomly attack each other, rather they are influenced by a vast array of factors.

The most obvious factor that gets to me too, is hunger. A hangry chicken is more likely to compete for its food and be aggressive, this can be seen through chickens sprinting towards a pile of grain when it is mealtime.

Furthermore, an important factor to take into account is distance. The probability of two chickens coming in contact or thereby interacting decreases the farther they are from each other.

Following those factors, their past interactions also matter. This is because if one chicken has already been pecked by another, it holds a grudge, almost like my sister, and then retaliates later. Chickens are able to remember previous encounters, leading to conflicts to be escalated.

Last but not least, there is the issue of confidence or dominance. Some chickens are far more assertive than other chickens are they're far more likely to be aggressive and initiate a fight in order to dominate other members of the flock.

Now we have gathered all the factors, we can represent these mathematically using a state vector, this contains numerical values representing the chicken's current condition. An example of this would be:

$$x = \begin{bmatrix} H \\ D \\ P \\ C \end{bmatrix}$$

This is where: H represents the hunger levels of the chicken, D represents the distance between another chicken, P represents the past encounters the chicken has had, and C represents the confidence or the dominance levels of the chicken.

This vector will be our summary of how to model the mood of the chicken in a mathematical way.

Constructing the Matrix Model

Like every other animal, including my sister, the behaviour of chickens fluctuates as variables change, such as the variables we explored earlier on like hunger or distance from another chicken. To illustrate these systems continuously changing, we can model it using a rather simple matrix transformation.

A version for a model of how the state changes from one second to the next would be:

$$\mathbf{X_{t+1} = AX_t}$$

This is called a Linear Discrete Dynamical system, a formula used to predict the next state of a system based on the current state as well as a transition matrix. Here, the X_t represents the current state of the chicken, while the X_{t+1} represents the state of the chicken in the next moment. Furthermore, A is a matrix, one which describes how the different variables affect each other.

For example, we could define the matrix A as:

$$A = \begin{bmatrix} 1.1 & -0.2 & 0.3 & 0.1 \\ 0 & 1 & 0.1 & 0 \\ 0.2 & 0 & 1.2 & 0.4 \\ 0.1 & 0 & 0.2 & 1.2 \end{bmatrix}$$

Each of the entries within the matrix describes how one of the factors affects another. For example, hunger may increase aggression slightly which is why the hunger value is larger than 1. Previous peck interactions may increase the likelihood of revenge, meaning the aggression component increases over time. Meanwhile, distance may reduce aggression slightly because chickens that are further apart are less likely to confront one and other.

Then, multiplying the matrix by the state vector repeatedly allows us to witness how the system evolves over a time period. Or in other words, it's like a set of rules that dictates chicken behaviour before they start assaulting one another.

Predicting when a fight occurs

Despite chickens being angry critters, not every interaction between them results in a fight. Therefore, for the purpose of this model, we can define a threshold level of aggression. When all the aggression variables surpass this threshold, the model will predict that a fight is about to break loose.

Or rather, in mathematical terms we can articulate when a fight occurs when:

$$\text{Aggression} > T$$

Where, T represents the aggression threshold.

An interesting feature to keep in mind when it comes to matrix models is that they can produce varying outcomes depending on their structure. In some cases, aggression may slowly decrease, suggesting the chickens will eventually calm down, but in other cases, aggression may increase exponentially, leading to an inevitable poultry war.

To analyse this behaviour, we are able to use the concept of eigenvalues. Without going into the details of these, eigenvalues aid in the determination of whether a system grows, shrinks or remains stable over time. If the dominant eigen value of the matrix is larger than 1, the system amplifies the behaviour. In our chicken context, this means that the aggression grows over time. Eventually, the aggression level will cross the threshold spoken about, and the model predicts that the chickens will start throwing hands (or beaks? – fighting)

In other words, the mathematics suggests that if the right factors align, it makes chicken violence mathematically inevitable.

A possible example

Let's get into the fun of this poultry massacre, to see how this works in practice, imagine two chickens standing near each other. To spice things up, lets name one of the chickens, Mr Newton and the other Mr Wilhelm Leibniz – a feud that lasted for over 30 years.

Now, Mr Newton is quite 'peckish' and wants some food but has recently been pecked by another chicken.
And Mr Wilhelm Leibniz, is a confident chicken who doesn't give a cluck.

At first, the aggression levels will be relatively low, however, as time passes, and Newton's hunger increases as well as previous pecks from Wilhelm Leibniz, behaviour starts to change. When the matrix transformation is applied repeatedly, the aggression variables gradually grow larger and larger.

Eventually our variable in the system crosses the aggression threshold, and the model is predicting a poultry war, where Newton and Leibniz stop egg-noring each other.

At this point, you and I, as observers, may notice classic signs of chicken conflict, their puffed feathers, cruel eyes and rapid, aggressive pecking motions. The beginning of a worthy fight to spectate. The mathematical model would interpret this as the obvious and natural outcome of the system dynamics.

This is where Newton and Wilhelm Leibniz finally break loose and start pecking at each other with a fuel of hatred, hunger and confidence. Who will win? We've yet to answer that in real life so we will remain the outcome of this poultry war a mystery.

Limitations of this Model

Despite this, this model has some obvious limitations, though convincing on paper.

The most significant limitation is that chickens are not purely mathematical objects, rather sentient beings who behave unpredictably, especially when food appears unexpectedly or when something distracts them.

Second of all, there are other external factors which we did not take into account. For example, a farmer might enter the coop, or a sudden noise scares them, or one chicken simply decides to be the bigger chicken and walks away.

Finally, the model works underlying the assumption that behaviour can be described using a limited number of variables, whilst in reality this isn't the case as animal behaviour is far more complex.

However, despite these limitations, the mathematical model is still capable of illustrating how ideas in the real world can be explored in mathematical terms. Which is something that is beautiful on its own.

Conclusion

While predicting the likelihood of a chicken fight is a very serious application of maths, the whole concept is illustrating the potential of mathematical modelling. This can be done with any system, via identifying the variables within it and then describing the interactions between the animals using a matrix.

The use of matrix models is a significantly simplified approach to demonstrate how variables may affect behaviour. However, as all other living creatures on Earth, there are far more factors that evolve as time progresses.

It brings me great sadness to come to the realisation that the model I explored here is unlikely to be adopted by professional chicken farmers, but despite this, I have completed one thing. That is, demonstrating the capabilities of maths in a very serious but unusual way, which I find to be deeply beautiful in its own regard.

Now, next time you and your mate are walking down a path and see two chickens giving each other a sinister look, place a bet on whether Newton or Leibniz are going to begin a battle, and ensure to always win.

Sources:

Thomson CE, Winney IS, Salles OC, Pujol B (2018) ‘A guide to using a multiple-matrix animal model to disentangle genetic and nongenetic causes of phenotypic variance’ *PLoS ONE*. *[online]* Available at : https://doi.org/10.1371/journal.pone.0197720

Shuto H, Mandai M, Yamada T, Sho J, Hayakawa C, Koike C, Takahashi M, Matsuyama T. (2025) ‘Hidden Markov Model-Based Behavioral Classification Reveals Visual Function Recovery After Retinal Organoid Transplantation in Mice’ *Neurosci Res*. *[online]* Available at: *https://pmc.ncbi.nlm.nih.gov/articles/PMC12284846*