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# A computer model for particle-like simulation in broiler houses

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ABSTRACT

The behavior of chickens in broiler houses is affected by many conditions that involve, from the dimensions and design of the house, to the real-time control of temperature and humidity. A lot of experience is available which provides useful recommendations leading to reasonable efficiency of broiler houses. Trying different alternatives in practice is, or course, very expensive. For this reason, computer simulation becomes an extremely useful tool. Presently, standard computers make it possible to build and run simulation models in which each broiler is considered as a single "particle" whose behavior is subject to the interaction with other broilers and the environment. The objective of this paper is to introduce, discuss, and analyze a new computational model, that, to the best of our knowledge, is the first of this type. The model considers the displacements of the chickens as being analogous to the motion of physico-chemical particles (atoms or molecules), relying on Langevin dynamics and taking temperature, air speed, humidity, house dimensions, chicken population, availability of eaters, and water drinking systems into consideration. The parameters of our model were tunned both using extreme and standard assumptions on the behavior of chickens in a broiler house.



## 1. Introduction

Brazil is one of the biggest producers of chicken meat in the world and occupies the first place in regard to exportations. As a consequence, optimization of the conditions under which broilers are grown is of maximal economic relevance for this country.

In order to achieve the optimal growth of the birds, many researchers performed experiments trying to obtain relations between environmental parameters and chickens comfort and/or behavior (Carvalho et al., 2008; Costa et al., 2012; Menegali et al., 2013; Rosa et al., 2007).

In this paper it is adopted the point of view that the life of each individual chicken can be simulated taken into account natural physical and biological rules, as well as our empirical knowledge of relationships, obtained from the available literature and our own observations. The final product is a computer code that simulates the whole evolution of a broiler house population, for given environmental conditions.

This tool should help the researcher to investigate the consequences of climate changes, alternative feed regime, variations of breeding house dimensions and so on, avoiding as much as possible to perform costly physical experiments.

The model simulates the behavior of chickens in broiler houses. It considers that the displacement of chickens can be described using similar rules as the ones commonly used in Molecular Dynamics. Thus, we may rely on Newtonian mechanics. However, as the multidisciplinar laws for chicken displacements are quite complex, some of the involved forces are either unknown, or too complicated to be modeled. For this reason, the lack of knowledge about movement laws are compensated adding random forces to the system. As a consequence, Langevin equation is used to describe the movement (Lemons and Gythiel, 1997), which involves both interaction forces and random forces.

This paper is organized as follows: in Section 2 the Langevin dynamics are described and some of the modifications that were made to be applied to this problem are presented; in Section 3 an strategy to decrease the computational time performed to evaluate short range interaction forces is reviewed; Section 4 was reserved for the description of the parameters considered in the process; in Section 5 the forces that are involved in the system are described; some validation experiments are presented in Section 6 and conclusions regarding the experiments and the expectations of the possible uses for the simulation are available in Section 7.

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## 2. Langevin dynamics

Newtonian mechanics establishes that the motion of a particle can be described as

$$m\ddot{x} = \sum_{i=1}^{n} f_i(x, \dot{x}, t),$$

where $x$ is the position of the particle (as a function of time $t$), $\dot{x}$ and $\ddot{x}$ are the first and second derivatives of $x$, that is, the velocity and the acceleration of the particle, $m$is the mass, and the functions $f_i$ are the forces acting on the particle.

Langevin dynamics was introduced to represent the motion of particles in a fluid (Lemons and Gythiel, 1997). In our case, because of the complexity of the forces involved and since it is impracticable to model them, it is assumed that some of the forces are random. Therefore, mimiking the particle in a fluid under a resistance force (which is proportional to velocity) and under other (random) forces, we obtain the following motion equation:

$$m\ddot{x} = -\lambda\dot{x} + \eta(t), \tag{1}$$

where $\lambda$ is a positive constant, and $\eta$ is a normal distribution with mean 0. The correlation of $\eta$ is given by

$$corr(\eta(t), \eta(t')) = 2\lambda k_B T \delta(t - t'),$$

where $k_B$ is the Boltzmann constant, $T$ is the temperature and $\delta$ is the Dirac delta. More details on this model can be found in Lemons and Gythiel (1997) and Frenkel and Smit (2002). (However, in our case, these constants are irrelevant, as they are only associated with the particle dynamics).

If the presence of an external force $f$ in the system is considered, for example the collision between the particles, the Eq. (1) can be modified obtaining

$$m\ddot{x} = -\lambda\dot{x} + \eta(t) + f(x, \dot{x}, t). \tag{2}$$

Also, if chickens are considered as particles, the Eq. (2) can applied to describe their motion. One must take into account that the chicken system is not exactly a Newtonian dynamic, in the sense that mass does not linearly affect the differential equation of motion. Therefore, the equation that governs the system is rewritten as

$$\ddot{x} = -\lambda\dot{x} + \eta(t) + f(x, \dot{x}, t). \tag{3}$$

In order to obtain a computational implementation of the simulation, the Eq. (3) must be discretized with respect to time. It is done by defining:

$$x_i^{(t+1)} = x_i^{(t)} + v_i^{(t)}\Delta t + \frac{1}{2}\mathcal{F}_i^{(t)}\Delta t^2, \tag{4}$$

where $x_i^{(t)}$ represents the position of the chicken $i$at the instant $t$, $v_i^{(t)}$ is the velocity, and $\mathcal{F}_i^{(t)}$ is the resulting force. Since mass is being neglected in motion, the force can also be considered as the acceleration. The constant $\Delta t$ is the size of time discretization. By this relation, the motion is uniformly varied at each time interval. The velocity is updated by

$$v_i^{(t+1)} = v_i^{(t)} + \mathcal{F}_i^{(t)}\Delta t, \tag{5}$$

so only the forces that are involved in the system are left to be defined.

## 3. Linked cells

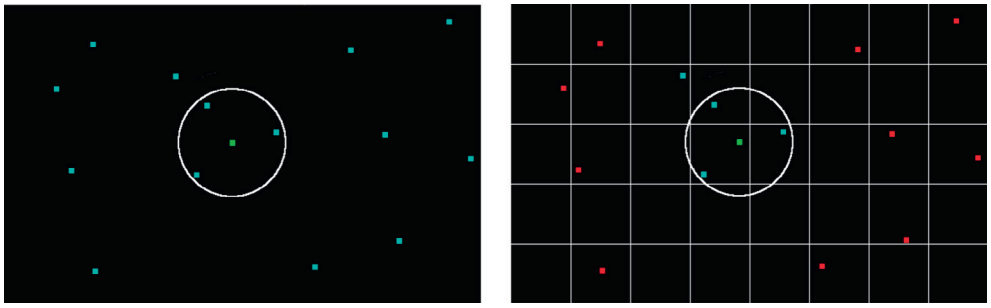
Short range forces are those whose intensity drops very quickly with the distance between the objects that are interacting, as the collision of particles. In this case, clearly one particle only interacts (collides) with another that is very close.

A strategy to reduce the computational cost of computing these forces is Linked Cells (Frenkel and Smit, 2002), where the space is partitioned, and instead of calculating the forces between all particles, it is computed for only those that are in neighboring partitions. In Fig. 1 it is presented an illustration of how this strategy can reduce computational cost.

The name Linked Cells, comes from the fact that partitions can also be called cells. In this strategy it is verified if there are interactions only in objects that are in cells linked to each other, that is, with objects that are in a $3 \times 3$ neighborhood.

## 4. Simulation parameters

In order to define the forces of the system, one must first know which parameters are considered. In Fig. 2 it is presented a



(a) Without linked cells: the green particle has potential to interact with all particles in the system, 14 forces have to be evaluated.

(b) With linked cells: the green particle has potential to interact only with the particles in neighboring partitions. In this case we have to evaluate only 4 forces. The dots in red represent the particles which it is already known that do not interact with the green ones.

**Fig. 1.** Example of the use of linked cells to evaluate a short-range force between particles in a system. The particle of interest is represented in green, the particles in blue are those that have a potential interaction, the blank circle indicates the region in which the interaction is non-zero, i.e., only the three blue particles inside the circle interact with the green one. Note that without the use of linked cells the forces for all the particles of the system are evaluated, while using it, only the interaction with the particles in the neighboring cells are evaluated. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)