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Hive Simulation

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Introduction

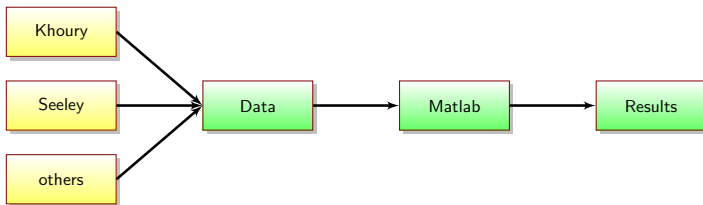


Figure 1: *Diagram of our work [khoury13] [seeley95].*

Description of the Standard Model

It consists of four differential equations:

- Change of brood number
- Change of hive bee number
- Change of forager bee number
- Change of food

Description of the Standard Model

Let's look into one equation: **Change of brood number**

$$\frac{dB}{dt} = LS(H, f) - \phi B \quad (1)$$

- L is the laying rate of the queen
- S is the survival rate
- H is the amount of hive bees
- f is the amount of food
- ϕ is the adult bee emerging factor

Environmental Influences

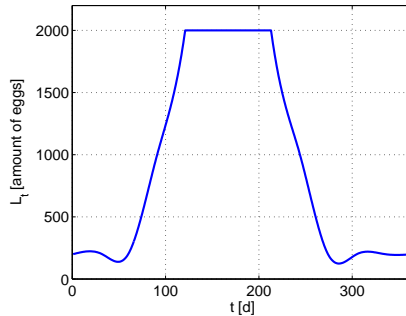


Figure 2: *The laying rate of the bee queen plotted over a year.*

Environmental Influences

Comparison between the environment dependent equation and the standard one:

- static equation: $\frac{dB}{dt} = LS(H, f) - \phi B$
- dynamic equation: $\frac{dB}{dt} = L_t S(H, f) - \phi B$

→ small changes in the formulae have significant effects (cf. Discussion).

Advanced model: Environment simulation

Model overview

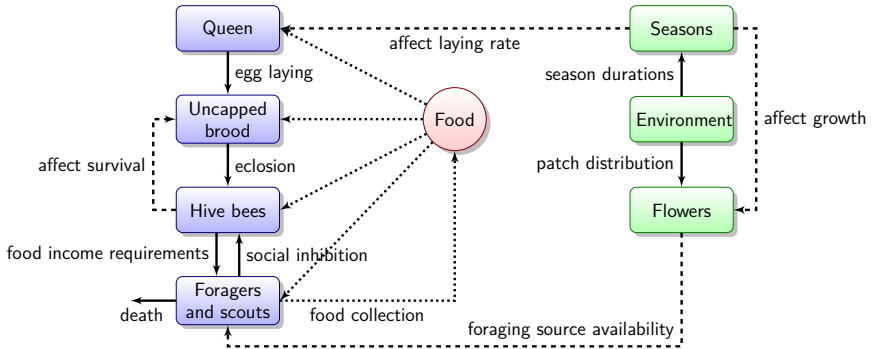


Figure 3: *Honey bee social dynamics and environmental influences covered by our advanced model.*

Agents: Assigning jobs

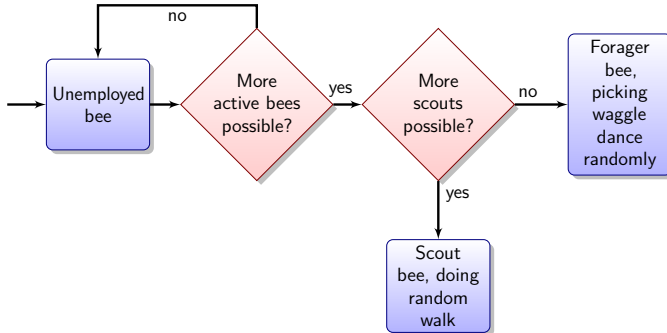


Figure 4: *Assigning jobs to unemployed bees. Scouts and foragers are possible.*

Foragers' distribution across flower patches

- Bees will focus on newly reported and then on the most profitable food sources
- Driving factors for evaluating a patch ($p < q$):
 1. Patch quality (b_w)
 2. Distance from the hive (d_w)
 3. Patch size (A_w)
- Relative evaluation based on what other foraging sources are available

Agents: Scout bees

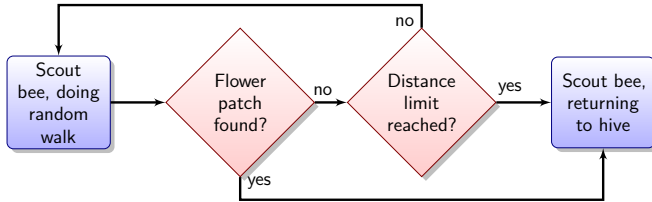


Figure 5: *Scouting behaviour until a flower patch is found or the maximum distance is reached.*

Scouts' random walk

The path a scout bee walks is recorded in a vector of x and y coordinates:

$$\begin{pmatrix} x_0 & x_1 & \dots & x_n \\ y_0 & y_1 & \dots & y_n \end{pmatrix}$$

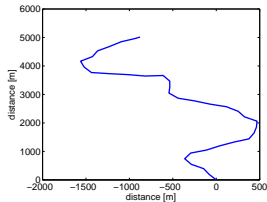


Figure 6: *Example of a random walk executed by a scout bee.*

Agents: Forager bees

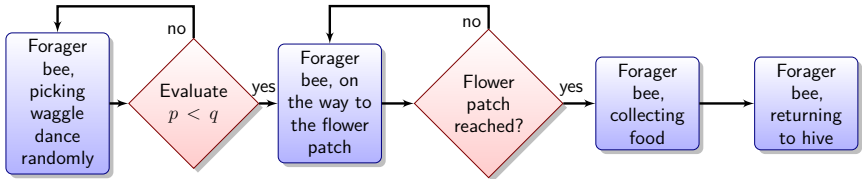


Figure 7: *Foraging behaviour.*

Path optimization

- Bees are able to orientate themselves in the environment with sun positioning [seeley95]
- Every second way point is skipped
- Starting- and endpoints are preserved
- Triangle inequality $\Rightarrow L^2$ norm of the distance can only become smaller

$$\begin{pmatrix} x_0 & x_1 & x_2 & x_3 & x_4 & \dots & x_{n-3} & x_{n-2} & x_{n-1} & x_n \\ y_0 & y_1 & y_2 & y_3 & y_4 & \dots & y_{n-3} & y_{n-2} & y_{n-1} & y_n \end{pmatrix}$$
$$\Rightarrow_{\text{optimization}} \begin{pmatrix} x_0 & x_2 & x_4 & \dots & x_{n-4} & x_{n-2} & x_n \\ y_0 & y_2 & y_4 & \dots & y_{n-4} & y_{n-2} & y_n \end{pmatrix}$$

Path optimization

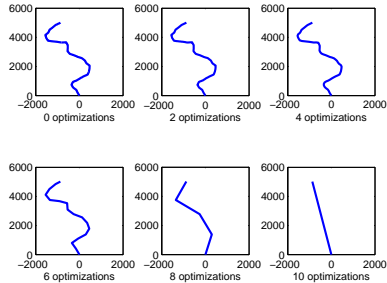


Figure 8: *Example of path optimization used to short cut the path to flower patches.*

Agents: Returning to the hive

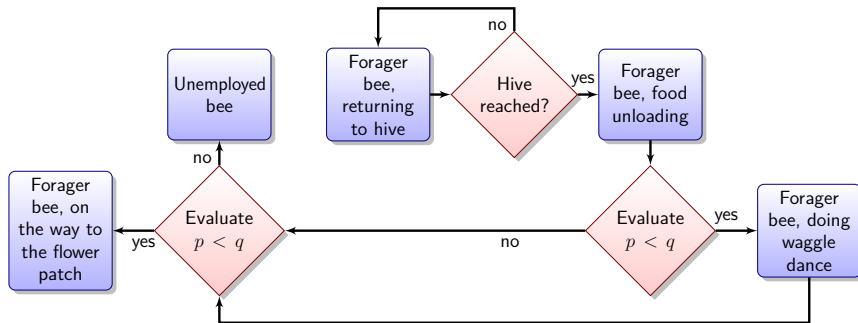


Figure 9: *Forager bee, returning from foraging.*

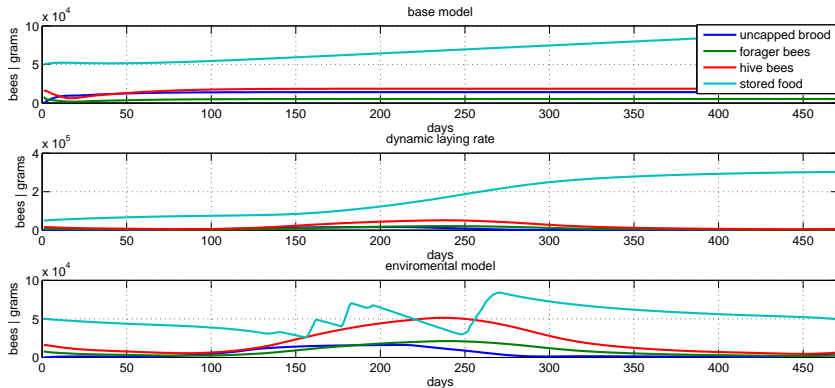
Agent based model: recorded sample clips

- Day 158, recorded sample with scouts displayed
- Day 158, recorded sample without scouts displayed
- Two different runs, not the same flower patches are being selected

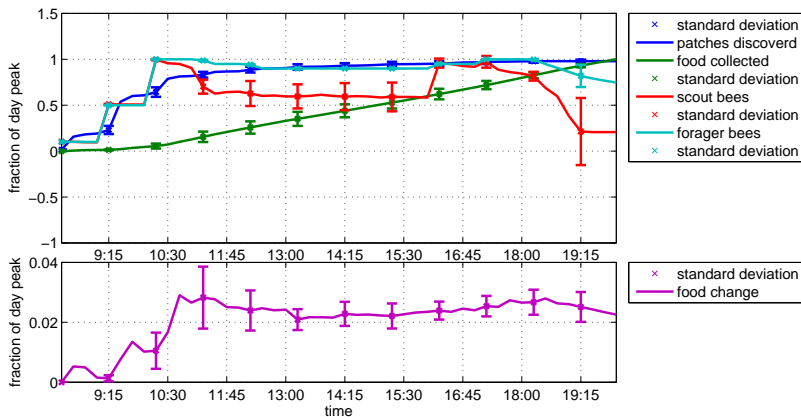
Simulation results and analysis

- Evolution of the model
- Missing flower season comparison
- Critical points in the fall season

Evolution of the model



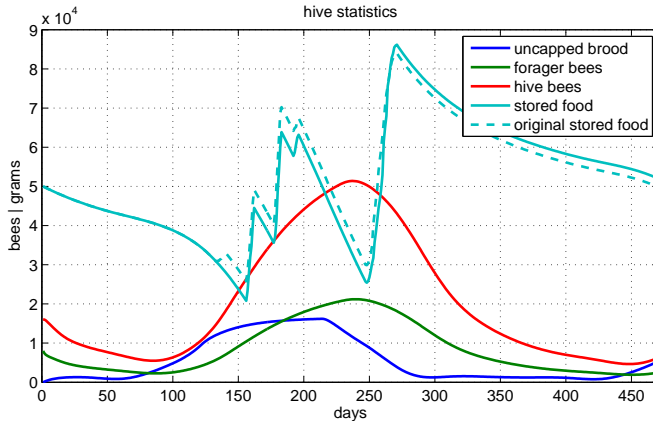
Daily simulation



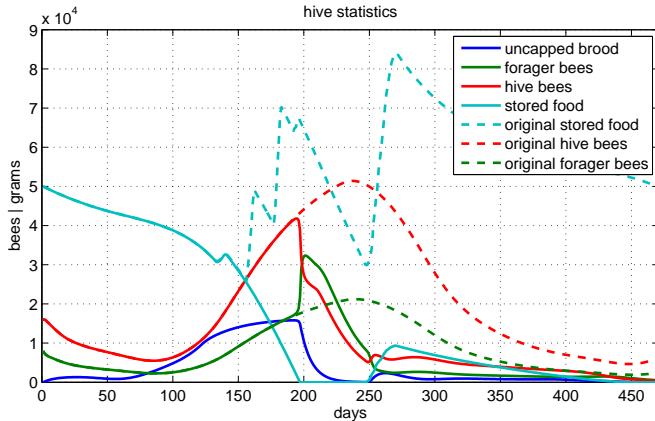
Missing flower season comparison

- Eliminate non critical seasons
- Study effects of missing season
- Observe the hives compensation measures

Spring



Summer



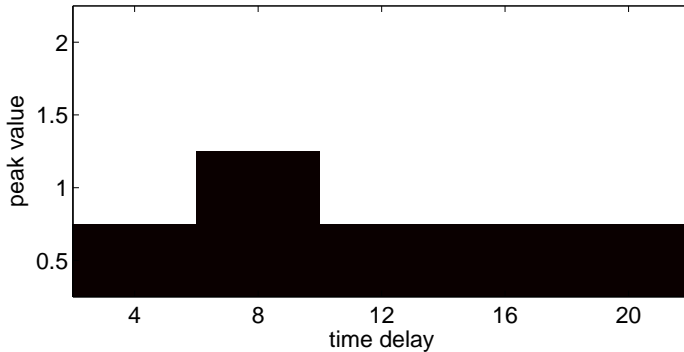
Critical points in the fall season

Death criteria:

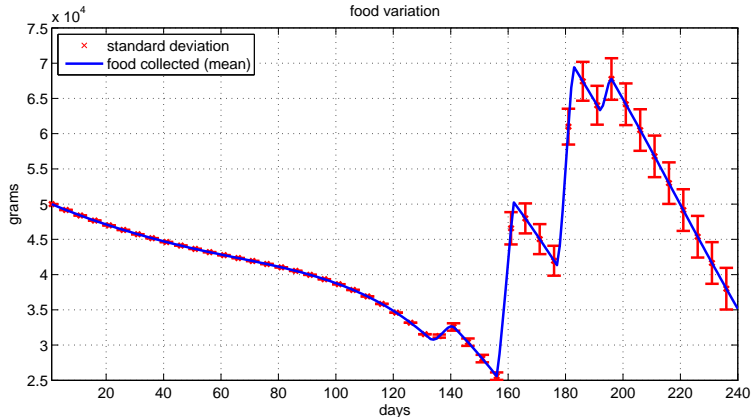
- Less than 1000 bees at day 400
- Less than 20 kg of stored food at day 400

Overview

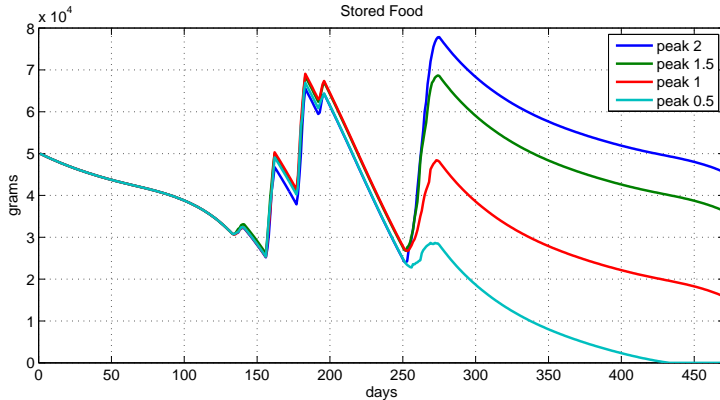
Survival graph



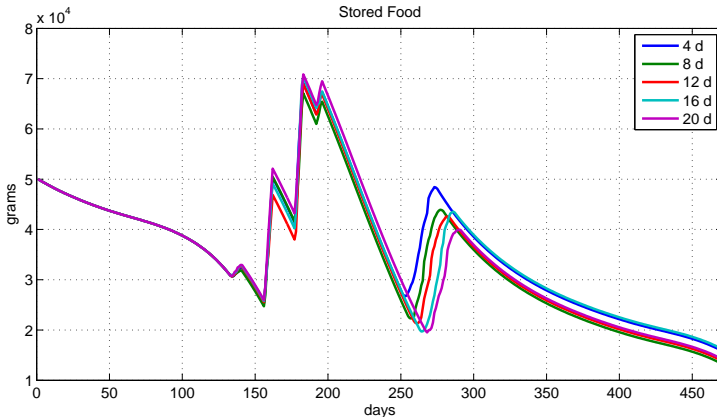
Stored food variation before fall



Peak value influence



Delay influence around breaking point



Summary

- Standard Model after *D.S. Khoury*.
- Advanced Model: Environment simulation
- Autumnal shift is indifferent
- Hive is rather stable
- Model restrictions

The background of the slide features a repeating pattern of yellow hexagons with black outlines. A horizontal band of dark green color with a faint hexagonal pattern runs across the middle of the slide.

Questions?