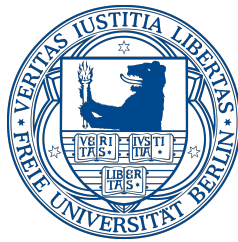


# **Behavioral clues for forager transitions in a fully tracked honeybee colony**



**Janek Szynal**

Supervisor: Dr. Tim Landgraf

Biorobotics Lab  
Free University of Berlin

This dissertation is submitted for the degree of  
*Bachelor of Computer Science*

March 2019



I would like to dedicate this thesis to my loving parents ...



## **Declaration**

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Acknowledgements. This dissertation contains fewer than 65,000 words including appendices, bibliography, footnotes, tables and equations and has fewer than 150 figures.

Janek Szynal  
March 2019



## **Acknowledgements**

And I would like to acknowledge ...





## **Abstract**

This is where you write your abstract ...



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# Chapter 1

## Introduction

### 1.1 The honeybee and the division of labor

A honeybee (*Apis mellifera*) colony contains multiple fascinating examples of complex adaptive behaviour. Localized cues exchanged between individuals amount to emergent directional signals for the entire colony in ways heavily investigated, but often still not completely understood.

One of the most notable and well-researched adaptive mechanisms of a colony is its division of labor (DOL). During the winter (a season of low activity for the bees), the colony focuses on survival and its workers are generalists, performing sets of tasks not easily distinguishable from those of other workers. For the spring-summer season, however, the hive's goals change and along with them, the patterns of labor division. Hive growth and resource accumulation take priority, and specialization eventuates amongst workers. They begin to fill different roles, the allocation of which highly correlates with age (an effect known as temporal polyethism), but is also grounded in the colony's current needs and in environmental factors affecting it (adaptive behaviour) [2] (Seeley 1982, Johnson 2008). Groups of workers that can be categorized as performing the same set of tasks are commonly referred to as castes. It is common to recognize four of them in the temporal caste system that the worker bees exhibit in the summer: cell cleaners, nurses, middle-aged bees (MABs), and foragers. This work concentrates on the transition between MABs and foragers, possibly the most distinguishable and important in the lifecycle of a bee.

## 1.2 The foraging phase

The foraging phase is the last one in a bee's life and it comes with an increased risk of death. It is often proposed that this has to do with the extreme strain foraging puts on their bodies - essentially causing them to work themselves to death. This is supported for example by (Williams et al, 2008), who have shown honeybee flight to cause extremely high metabolic rates and induce oxidative stress, likely significantly accelerating the ageing process and causing early deaths. On the other hand, the results of [2] (Visschard and Dukes, 1997) suggest that foragers' deaths are usually caused not by senescence, but by the heightened risks of outside life (like predation) that come with their function. According to their data, mortality rates were constant with respect to age, and not accelerating - as would have been suggested by the body strain hypothesis.

Regardless of the reasons behind it, foraging nearly always ends in the death of a bee. That fact, combined with an estimate of the length of the foraging phase (mean of 7.7 days  $\pm$  0.75 days, median of 7 days, and range of 2 to 17 day according to [2] Visschard and Dukes, 1997), should allow us to get a very simple estimate of the foraging period, which we can then use to validate the results we produce with more involved methods.

# Chapter 2

## My second chapter

### 2.1 Reasonably long section title

I'm going to randomly include a picture Figure 2.1.

If you have trouble viewing this document contact Krishna at: [kks32@cam.ac.uk](mailto:kks32@cam.ac.uk) or raise an issue at <https://github.com/kks32/phd-thesis-template/>

### Enumeration

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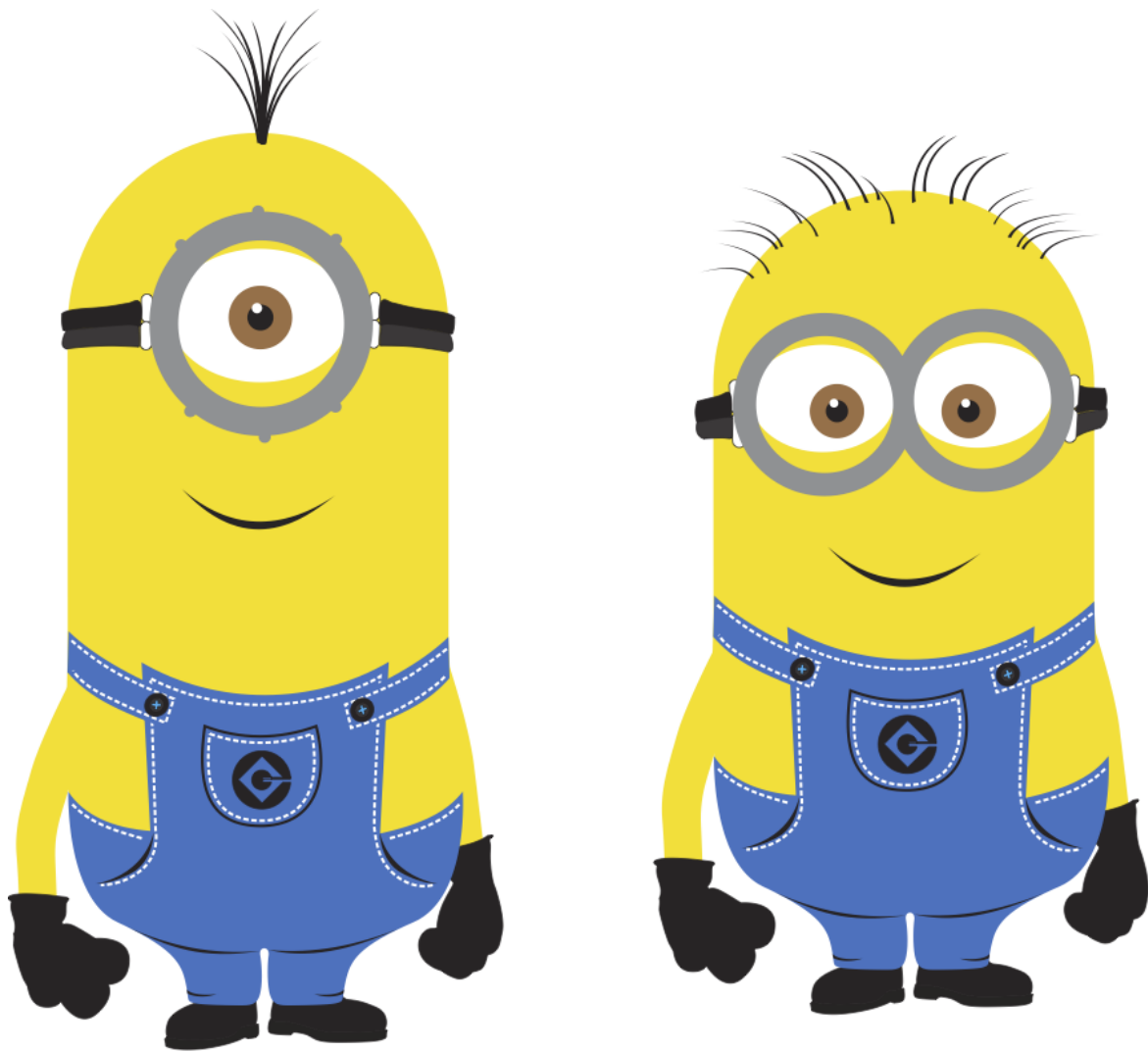


Fig. 2.1 This is just a long figure caption for the minion in Despicable Me from Pixar

porttitor, quam sem luctus massa, eu fermentum arcu diam ac massa. Praesent ut quam id leo molestie rhoncus. Praesent nec odio eget turpis bibendum eleifend non sit amet mi. Curabitur placerat finibus velit, eu ultricies risus imperdiet ut. Suspendisse lorem orci, luctus porta eros a, commodo maximus nisi.

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1. The first topic is dull
2. The second topic is duller
  - (a) The first subtopic is silly
  - (b) The second subtopic is stupid
3. The third topic is the dullest

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## Itemize

- The first topic is dull
- The second topic is duller
  - The first subtopic is silly
  - The second subtopic is stupid
- The third topic is the dullest

## Description

**The first topic** is dull

**The second topic** is duller

**The first subtopic** is silly

**The second subtopic** is stupid

**The third topic** is the dullest

## 2.2 Hidden section

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---

<sup>1</sup>My footnote goes blah blah blah! ...



Fig. 2.2 Best Animations

## Subplots

I can cite Wall-E (see Fig. 2.2b) and Minions in despicable me (Fig. 2.2c) or I can cite the whole figure as Fig. 2.2



# Chapter 3

## My third chapter

### 3.1 First section of the third chapter

And now I begin my third chapter here ...

And now to cite some more people Read [3], Ancey et al. [1]

#### 3.1.1 First subsection in the first section

...and some more

#### 3.1.2 Second subsection in the first section

...and some more ...

##### First subsub section in the second subsection

...and some more in the first subsub section otherwise it all looks the same doesn't it? well we can add some text to it ...

#### 3.1.3 Third subsection in the first section

...and some more ...

##### First subsub section in the third subsection

...and some more in the first subsub section otherwise it all looks the same doesn't it? well we can add some text to it and some more and some more and some more and some more and some more and some more and some more ...

### Second subsub section in the third subsection

... and some more in the first subsub section otherwise it all looks the same doesn't it? well we can add some text to it ...

## 3.2 Second section of the third chapter

and here I write more ...

## 3.3 The layout of formal tables

This section has been modified from “Publication quality tables in L<sup>A</sup>T<sub>E</sub>X<sup>\*</sup>” by Simon Fear.

The layout of a table has been established over centuries of experience and should only be altered in extraordinary circumstances.

When formatting a table, remember two simple guidelines at all times:

1. Never, ever use vertical rules (lines).
2. Never use double rules.

These guidelines may seem extreme but I have never found a good argument in favour of breaking them. For example, if you feel that the information in the left half of a table is so different from that on the right that it needs to be separated by a vertical line, then you should use two tables instead. Not everyone follows the second guideline:

There are three further guidelines worth mentioning here as they are generally not known outside the circle of professional typesetters and subeditors:

3. Put the units in the column heading (not in the body of the table).
4. Always precede a decimal point by a digit; thus 0.1 *not* just .1.
5. Do not use ‘ditto’ signs or any other such convention to repeat a previous value. In many circumstances a blank will serve just as well. If it won't, then repeat the value.

A frequently seen mistake is to use ‘`\begin{center}`’ ... ‘`\end{center}`’ inside a figure or table environment. This center environment can cause additional vertical space. If you want to avoid that just use ‘`\centering`’

Table 3.1 A badly formatted table

	Species I		Species II	
Dental measurement	mean	SD	mean	SD
I1MD	6.23	0.91	5.2	0.7
I1LL	7.48	0.56	8.7	0.71
I2MD	3.99	0.63	4.22	0.54
I2LL	6.81	0.02	6.66	0.01
CMD	13.47	0.09	10.55	0.05
CBL	11.88	0.05	13.11	0.04

Table 3.2 A nice looking table

Dental measurement	Species I		Species II	
	mean	SD	mean	SD
I1MD	6.23	0.91	5.2	0.7
I1LL	7.48	0.56	8.7	0.71
I2MD	3.99	0.63	4.22	0.54
I2LL	6.81	0.02	6.66	0.01
CMD	13.47	0.09	10.55	0.05
CBL	11.88	0.05	13.11	0.04

Table 3.3 Even better looking table using booktabs

Dental measurement	Species I		Species II	
	mean	SD	mean	SD
I1MD	6.23	0.91	5.2	0.7
I1LL	7.48	0.56	8.7	0.71
I2MD	3.99	0.63	4.22	0.54
I2LL	6.81	0.02	6.66	0.01
CMD	13.47	0.09	10.55	0.05
CBL	11.88	0.05	13.11	0.04



# References

- [1] Ancey, C., Coussot, P., and Evesque, P. (1996). Examination of the possibility of a fluid-mechanics treatment of dense granular flows. *Mechanics of Cohesive-frictional Materials*, 1(4):385–403.
- [2] Aupetit, B. (1991). *A Primer on Spectral Theory*. Springer-Verlag, New York.
- [3] Read, C. J. (1985). A solution to the invariant subspace problem on the space  $l_1$ . *Bull. London Math. Soc.*, 17:305–317.



# Appendix A

## How to install L<sup>A</sup>T<sub>E</sub>X

### Windows OS

#### TeXLive package - full version

1. Download the TeXLive ISO (2.2GB) from  
<https://www.tug.org/texlive/>
2. Download WinCDEmu (if you don't have a virtual drive) from  
<http://wincdemu.sysprogs.org/download/>
3. To install Windows CD Emulator follow the instructions at  
<http://wincdemu.sysprogs.org/tutorials/install/>
4. Right click the iso and mount it using the WinCDEmu as shown in  
<http://wincdemu.sysprogs.org/tutorials/mount/>
5. Open your virtual drive and run setup.pl

or

#### Basic MikTeX - T<sub>E</sub>X distribution

1. Download Basic-MiK<sub>T</sub>E<sub>X</sub>(32bit or 64bit) from  
<http://miktex.org/download>
2. Run the installer
3. To add a new package go to Start » All Programs » MikTeX » Maintenance (Admin)  
and choose Package Manager

4. Select or search for packages to install

## **TexStudio - T<sub>E</sub>X editor**

1. Download TexStudio from  
<http://texstudio.sourceforge.net/#downloads>
2. Run the installer

## **Mac OS X**

### **MacTeX - T<sub>E</sub>X distribution**

1. Download the file from  
<https://www.tug.org/mactex/>
2. Extract and double click to run the installer. It does the entire configuration, sit back and relax.

### **TexStudio - T<sub>E</sub>X editor**

1. Download TexStudio from  
<http://texstudio.sourceforge.net/#downloads>
2. Extract and Start

## **Unix/Linux**

### **TeXLive - T<sub>E</sub>X distribution**

#### **Getting the distribution:**

1. TexLive can be downloaded from  
<http://www.tug.org/texlive/acquire-netinstall.html>.
2. TexLive is provided by most operating system you can use (rpm,apt-get or yum) to get TexLive distributions



## Installation

1. Mount the ISO file in the mnt directory

```
mount -t iso9660 -o ro,loop,noauto /your/texlive####.iso /mnt
```

2. Install wget on your OS (use rpm, apt-get or yum install)
3. Run the installer script install-tl.

```
cd /your/download/directory
./install-tl
```

4. Enter command 'i' for installation
5. Post-Installation configuration:  
<http://www.tug.org/texlive/doc/texlive-en/texlive-en.html#x1-320003.4.1>
6. Set the path for the directory of TexLive binaries in your .bashrc file

### For 32bit OS

For Bourne-compatible shells such as bash, and using Intel x86 GNU/Linux and a default directory setup as an example, the file to edit might be

```
edit ~/.bashrc file and add following lines
PATH=/usr/local/texlive/2011/bin/i386-linux:$PATH;
export PATH
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;
export MANPATH
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;
export INFOPATH
```

### For 64bit OS

```
edit ~/.bashrc file and add following lines
PATH=/usr/local/texlive/2011/bin/x86_64-linux:$PATH;
export PATH
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;
export MANPATH
```

```
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;  
export INFOPATH
```

**Fedora/RedHat/CentOS:**

```
sudo yum install texlive  
sudo yum install psutils
```

**SUSE:**

```
sudo zypper install texlive
```

**Debian/Ubuntu:**

```
sudo apt-get install texlive texlive-latex-extra  
sudo apt-get install psutils
```

# Appendix B

## Installing the CUED class file

$\text{\LaTeX}$ .cls files can be accessed system-wide when they are placed in the  $\langle\text{texmf}\rangle/\text{tex}/\text{latex}$  directory, where  $\langle\text{texmf}\rangle$  is the root directory of the user's  $\text{\TeX}$  installation. On systems that have a local  $\text{texmf}$  tree ( $\langle\text{texmflocal}\rangle$ ), which may be named “ $\text{texmf-local}$ ” or “ $\text{localtexmf}$ ”, it may be advisable to install packages in  $\langle\text{texmflocal}\rangle$ , rather than  $\langle\text{texmf}\rangle$  as the contents of the former, unlike that of the latter, are preserved after the  $\text{\LaTeX}$  system is reinstalled and/or upgraded.

It is recommended that the user create a subdirectory  $\langle\text{texmf}\rangle/\text{tex}/\text{latex}/\text{CUED}$  for all CUED related  $\text{\LaTeX}$  class and package files. On some  $\text{\LaTeX}$  systems, the directory look-up tables will need to be refreshed after making additions or deletions to the system files. For  $\text{\TeX}$ Live systems this is accomplished via executing “ $\text{texhash}$ ” as root.  $\text{MikTeX}$  users can run “ $\text{initexmf -u}$ ” to accomplish the same thing.

Users not willing or able to install the files system-wide can install them in their personal directories, but will then have to provide the path (full or relative) in addition to the filename when referring to them in  $\text{\LaTeX}$ .

