

The University of York

Department of Computer Science

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Evolutionary agent-based simulation modelling of human life-history evolution

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Number of words = 2001, as counted by `wc -w`.
This includes the body of the report only.

Abstract

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Contents

1	Introduction	9
1.1	Motivation	9
1.2	Aims	9
1.2.1	Check validity of computational model	9
1.2.2	Rewrite model into an object oriented language	9
1.3	Thesis Outline	10
1.4	Statement of Ethics	10
2	Literature Review	11
2.1	Agent Based Modelling	11
2.1.1	Explantion	11
2.1.2	Applications	11
2.2	Genetic Algorithms	11
2.2.1	Explanation	11
2.2.2	Applications	11
2.2.3	Relationship to evolution	11
2.3	Menopause	12
2.3.1	Patriarch Hypothesis	13
2.3.2	Grandmother hypothesis	14
2.3.3	Reproductive conflict	14
2.3.4	Other hypotheses	14
2.4	Evolution	14
2.4.1	Key concepts/terms	14
2.5	Modelling in biology	15
2.5.1	Deterministic modelling	15
2.5.2	Stochastic modelling	15
2.6	Conclusions from Literature	15
3	Problem Description	16
4	Design and Implemenation	17
5	Results and Evaluation	18

Contents

6 Conclusion

19

List of Figures

List of Tables

1 Introduction

1.1 Motivation

The senescence of organisms is a long standing evolutionary puzzle: why would genes which cause an organism to degrade over time be selected for? In particular, why could genes which cause a reduction in fertility with age provide evolutionary benefit versus reproducing until death? Menopause is of particular interest since it both only occurs within females, but within limited number of species.

Although we know the the biological cause of menopause, there are many theories about why it is beneficial for a species to cease reproduction long before death.

1.2 Aims

1.2.1 Check validity of computational model

This project focuses on reproducing a computational model [1] that implements the patriarch hypothesis [2], a theory that males' preference for younger females caused long post-reproductive lifespans. Replicating models is useful to check their validity and discover any flaws they may possess. Replication also provides a jumping off point for improving the model or for adapting it to other hypotheses to do with the evolution of menopause or population modelling in general.

1.2.2 Rewrite model into an object oriented language

The model is also being adapted from C, a performant but verbose and old imperative language, into Python, a modern object oriented language designed to be as readable as possible. Python is also popular among scientific research, so this will make the model more accessible.

1.3 Thesis Outline

Chapter Two Literature Review The literature review provides an overview of modelling, the different theories for the origin of menopause, and the basic concepts of evolution.

Chapter Three Problem Description looking at what the problem consists of

Chapter Four Design and Implementation designing a solution to the problem

Chapter Five Results and Evaluation presenting and analysing the results produced by the solution

Chapter Six Conclusion making judgement of the solution and the results, suggesting new work.

1.4 Statement of Ethics

The project is implementing a computational model which is purely theoretical. Although it concerns human reproduction, it does not involve human subjects and implementing it with them would be impossible due to time constraints (as evolution take place over many many years), there are no real ethical concerns.

2 Literature Review

Project is covering computational models of populations to try and understand how menopause might be caused by evolution, therefore it is important to talk about them.

2.1 Agent Based Modelling

2.1.1 Explantion

2.1.2 Applications

2.2 Genetic Algorithms

2.2.1 Explanation

2.2.2 Applications

2.2.3 Relationship to evolution

2.3 Menopause

What is menopause. Somatic vs reproductive senescence. Short vs long PRLS.

Which animals has it been show to occur in (Humans, Short Finned Pilot Whales, Orcas (Killer Whales)) Wild vs captive. Human vs Primates.

Possible reasons for menopause Patriarch Hypothesis, Grandmother, reproductive conflict. Overview in [3]

2.3.1 Patriarch Hypothesis

The Patriarch Hypothesis [2] hypothesises that menopause came about due to older, high status males having access to younger female mates allowing them to reproduce for much longer. This increased the proliferation of genes linked to longevity, increasing both the lifespan of males and females. This is reliant on several factors:

- That females have a limited number of oocytes (immature ova) which are depleted over time, and that reproduction naturally comes to an end when they run out. [4] In early females, before female longevity increased, most females died before their supply of oocytes had been completely depleted, and so did not experience menopause.
- That longevity causing mutations are on the X rather than the Y chromosome. If the gene were on the Y chromosome then the increase longevity would only be present in the males. The paper suggests that female longevity (and therefore have long post reproductive lifespans) is a result of females being "dragged along" by male longevity being passed on through the X chromosome.
- That older men continue to reproduce and pass on their longevity causing genes. High status males (normally those with a better reputation for hunting and gathering) would start a new family with a second, younger wife once their first wife had undergone menopause. Thus males carrying longevity causing genes would have greater opportunity to pass them on.

A deterministic model of the hypothesis was created [5], which models

. was created but this is not without its problems, the main problem being that model but this has fixed age of end of reproduction –

Stochastic model done in [1] – main focus of report. Fixes many of the flaws of [5] (including removing the fixed age of the end of reproduction) but still has problems.

2.3.2 Grandmother hypothesis

The Grandmother Hypothesis states that the

2.3.3 Reproductive conflict

Grandmothers stop reproducing so that their offspring are not competing with their grandchildren for resources. [6]

2.3.4 Other hypotheses

Follicular depletion, healthcare/lifespan improvements - not evolutionary but epiphenomenon, Risk from late age reproduction.

2.4 Evolution

Overview [7]

2.4.1 Key concepts/terms

Selection

Selection is the process in which survival and reproduction of a species is affected by the phenotype (physical expression of genetics). A trait that increases lifespan and allows more time for reproduction will cause there to be a greater chance for more offspring with that trait to be produced. By comparison a trait that decreases lifespan or realised fertility will tend to become less prevalent in the population as they have fewer offspring and these offspring if they have the same phenotype will inherit the lower survival chances. In essence useful traits survive, whereas traits that are less useful will gradually disappear.

Mutation

Mutation is the random genetic change that occurs between parents and offspring

Crossover

Description of crossover

Coevolution

Description of co-evolution

2.5 Modelling in biology

2.5.1 Deterministic modelling

Populations often modelled with exponential growth/differential equations

2.5.2 Stochastic modelling

Multiagent systems, genetic algorithms, neural networks, machine learning to reduce dimensionality,

2.6 Conclusions from Literature

3 Problem Description

This should be about 1500 words long.

4 Design and Implementation

This should be about 2500 words long.

5 Results and Evaluation

This should be about 2500 words long.

6 Conclusion

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Bibliography

- [1] R. A. Morton, J. R. Stone, and R. S. Singh, "Mate choice and the origin of menopause," *PLOS Computational Biology*, 2013. [Online]. Available: <http://dx.doi.org/10.1371/journal.pcbi.1003092>
- [2] F. Marlowe, "The patriarch hypothesis," *Human Nature*, 2000. [Online]. Available: <http://dx.doi.org/10.1007/s12110-000-1001-7>
- [3] D. P. Croft, L. J. Brent, D. W. Franks, and M. A. Cant, "The evolution of prolonged life after reproduction," *Trends in Ecology & Evolution*, 2015. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S0169534715001044>
- [4] J. Wood, S. Weeks, G. Bentley, and K. Weiss, "Human population biology and the evolution of aging," *Biological Anthropology and Aging: Perspectives on Human Variation over the Life Span*, 1994.
- [5] S. D. Tuljapurkar, C. O. Puleston, and M. D. Gurven, "Why men matter: Mating patterns drive evolution of human lifespan," *PLOS ONE*, 2007. [Online]. Available: <http://dx.doi.org/10.1371/journal.pone.0000785>
- [6] D. P. Croft, R. A. Johnstone, S. Ellis, S. Nattrass, D. W. Franks, L. J. N. Brent, S. Mazzi, K. C. Balcomb, J. K. B. Ford, and M. A. Cant, 2017.
- [7] C. Darwin, *On the origin of species*. John Murray, 1859.