Coherent Control of Atomic Population Using the Genetic Algorithm

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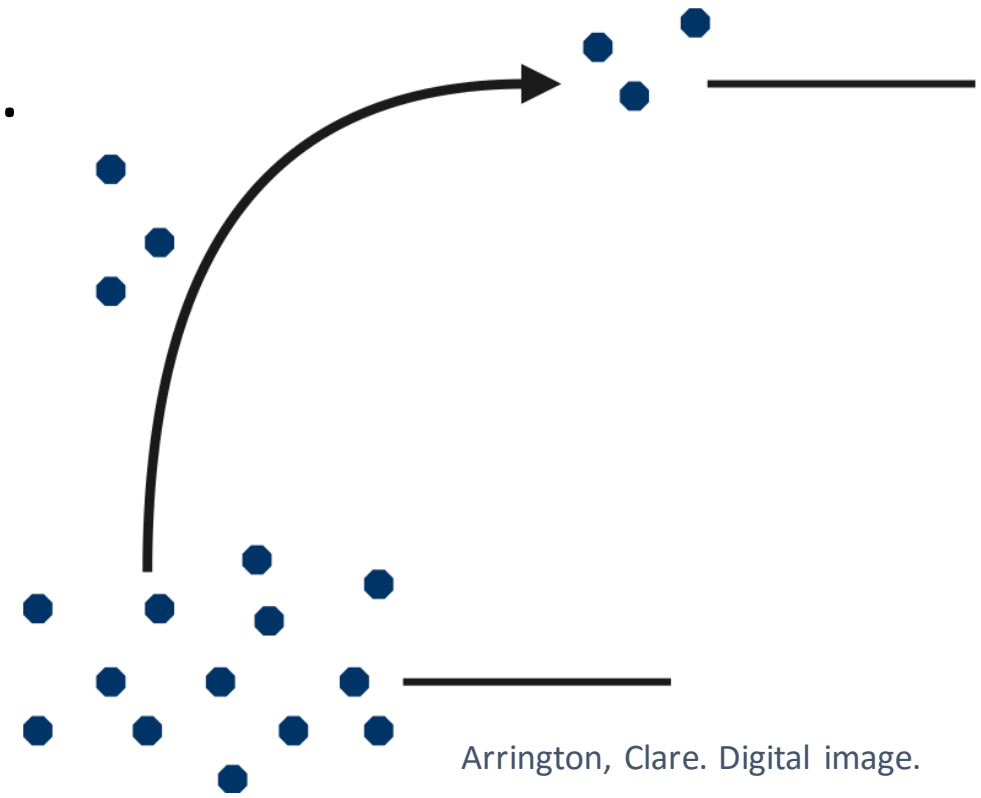
Research Goal

- Create a program that gives the parameters needed for two lasers to excite a desired amount of ^{87}Rb to an upper excited state.
- Otherwise known as Coherent Control



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Outline

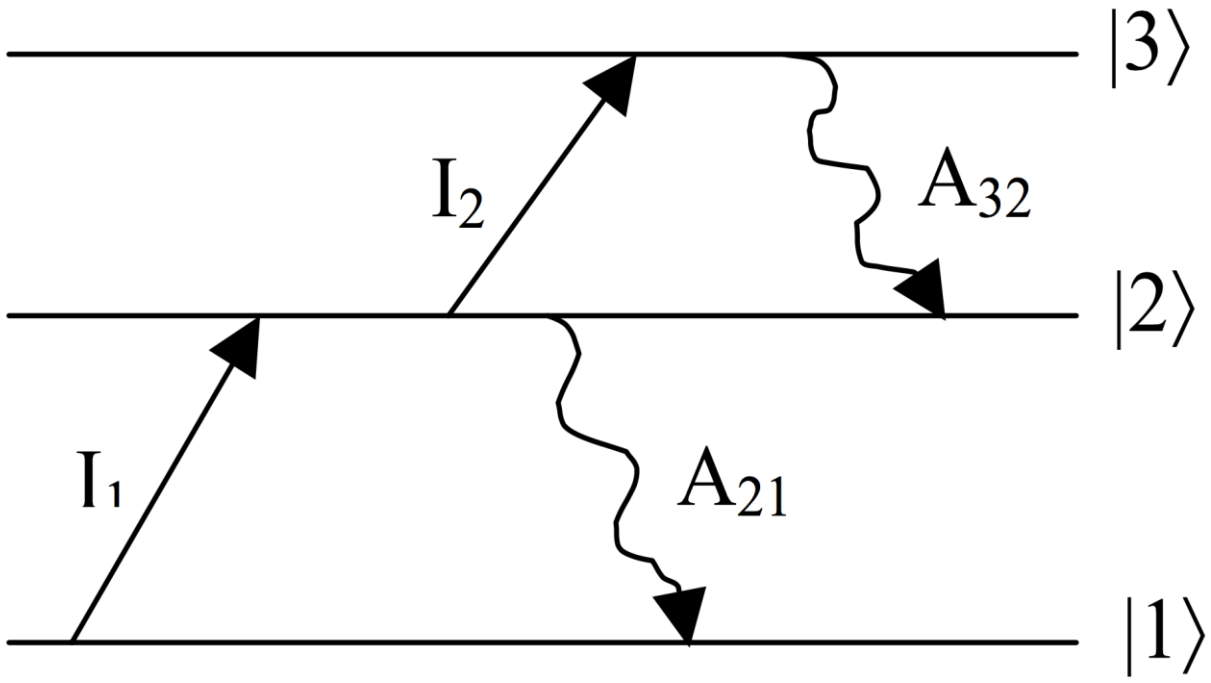
Background

- An atom's interaction with light
- Technique for excitation
- Goal of coherent control
- Applications of coherent control

Methods

- Modelling population dynamics
- Implementing the Genetic Algorithm

Atom's Interaction with Light

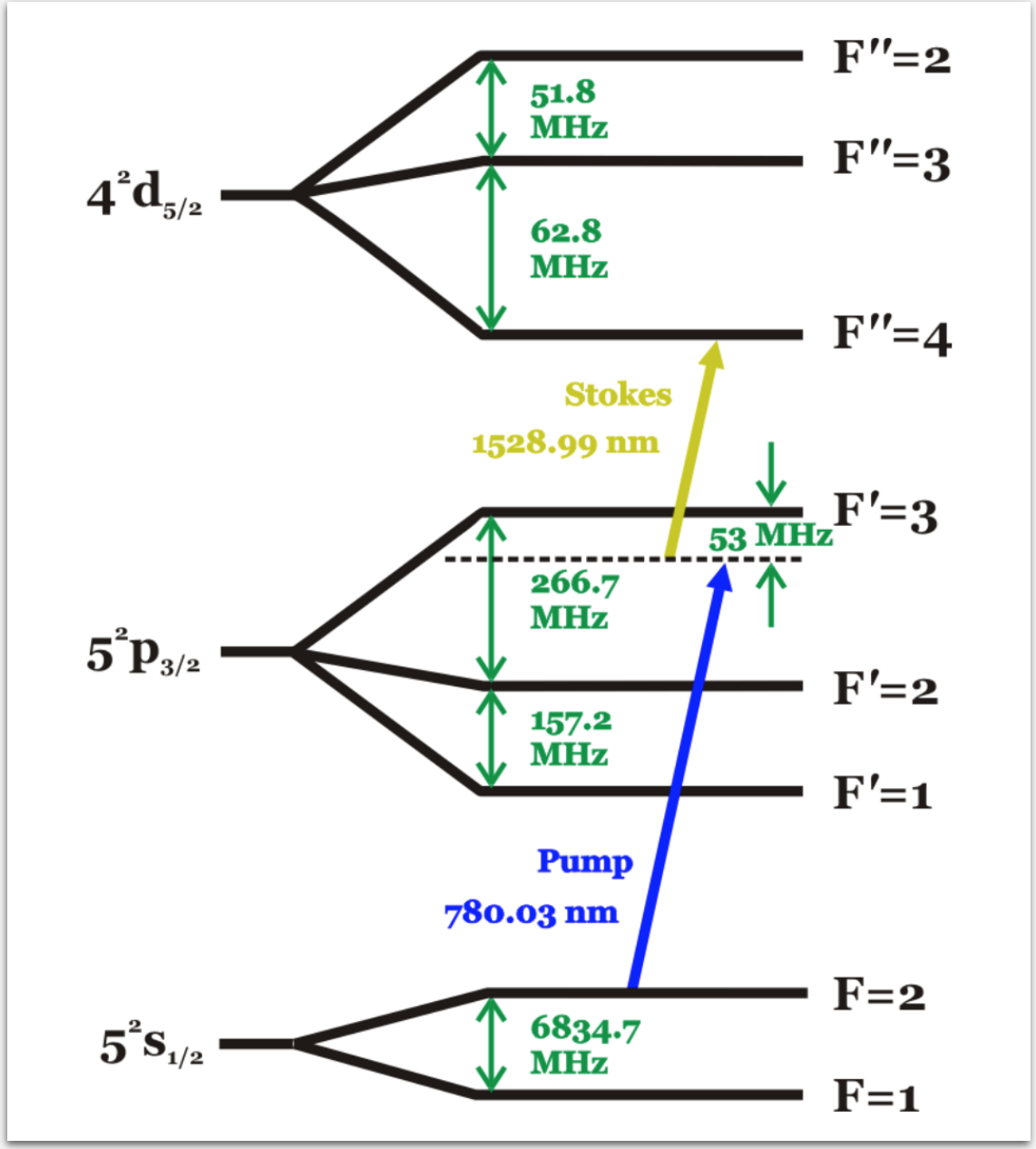


DePaola, B. Notes for Spring 2003 AMO Course: Lectures on Coherent Excitation

- Light increases the amount of energy in a system
- Energy levels in an atom are discrete

Coherent Excitation

- This is a technique to excite atoms efficiently
- The pump couples the ground and the transition state
- The stokes couples the transition state with the upper excited state



H.A. Camp, Ph.D. thesis, Kansas State University, 2005

Applications

Bounded Quantum Storage Model

- Eve can store a limited number of quantum bits
- So Bob and Alice need fine control of the information transfer

Arrington, Clare. Digital image.

Methods

Modelling Population Dynamics

- The Hamiltonian describes the interaction effects between the different energy levels
- The Liouville equation creates 9 coupled differential equations to work with

$$H = \begin{pmatrix} 0 & \Omega_1[t] & 0 \\ \Omega_1[t] & 2\Delta_1 & \Omega_2[t] \\ 0 & \Omega_2[t] & 2\Delta_2 \end{pmatrix}$$

Hamiltonian

$$\frac{\partial \rho}{\partial t} = \frac{1}{i\hbar}[H, \rho]$$

Quantum Liouville Equation

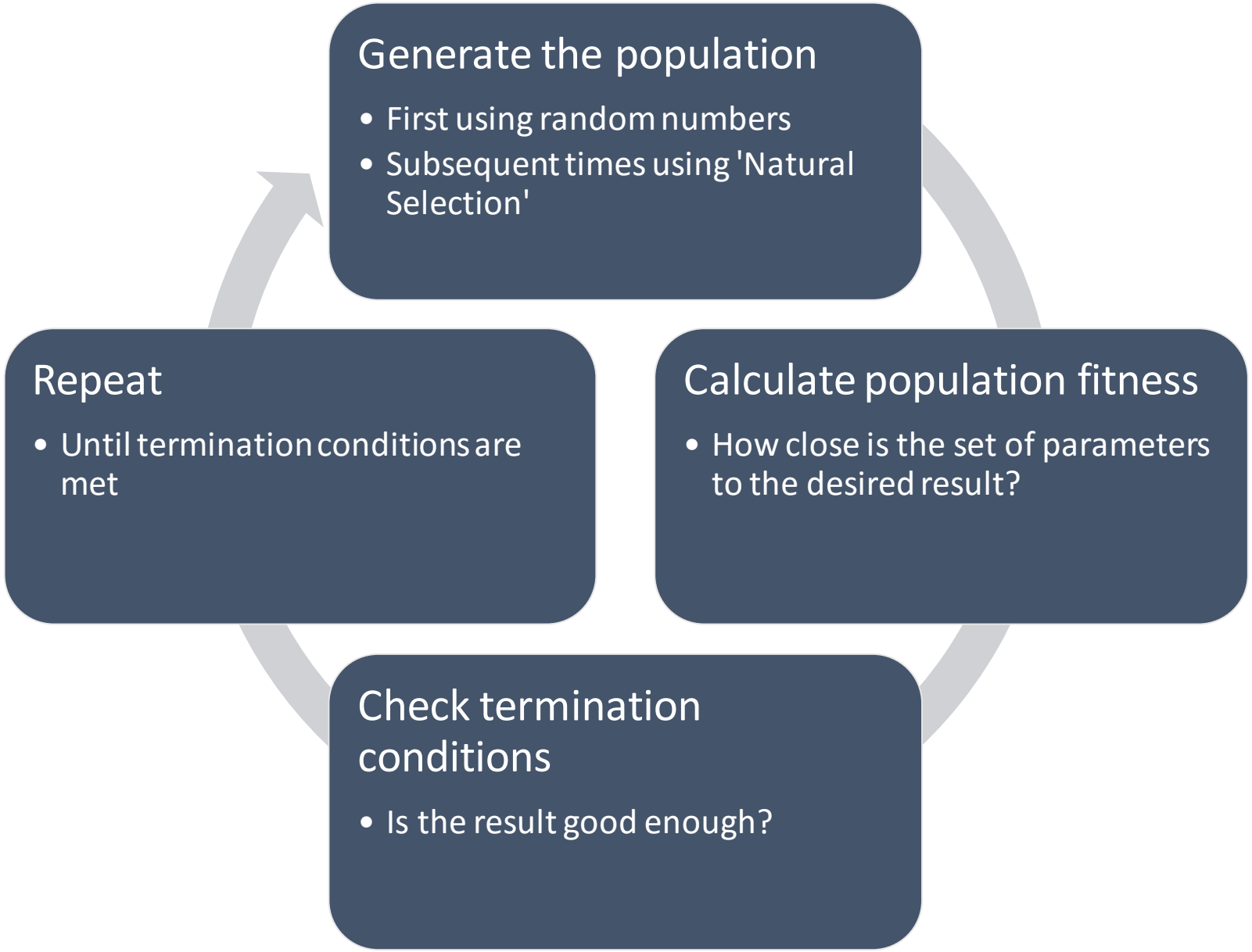
Density Matrix

Why Genetic Algorithm

Intuitive and easy to implement

Efficient way of searching the possible parameter space

How the Genetic Algorithm Works



Generate the Initial Population

Generate a set of parameters randomly within a valid parameter range

- For example, intensities can be from 0 to 100 mW/cm^2

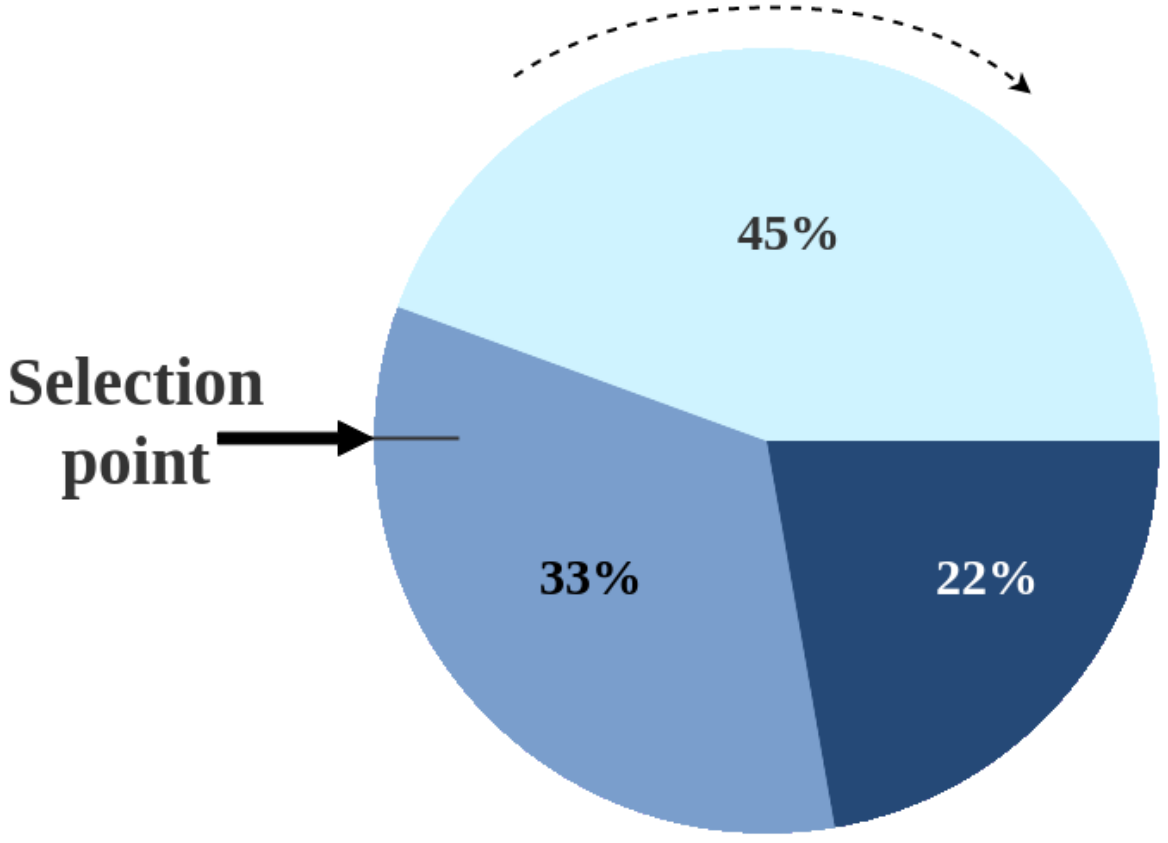
Calculate the Population Fitness

How close is the amount transferred to the desired amount?

$$fitness = \frac{1}{|target - transfered|}$$

Obtaining the Parents

- Use the fitness values to assign weightings to the different parameters. The higher the fitness value, the more likely it is to be chosen
- Use the weightings to sample from the existing population to select the parents



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New Generation

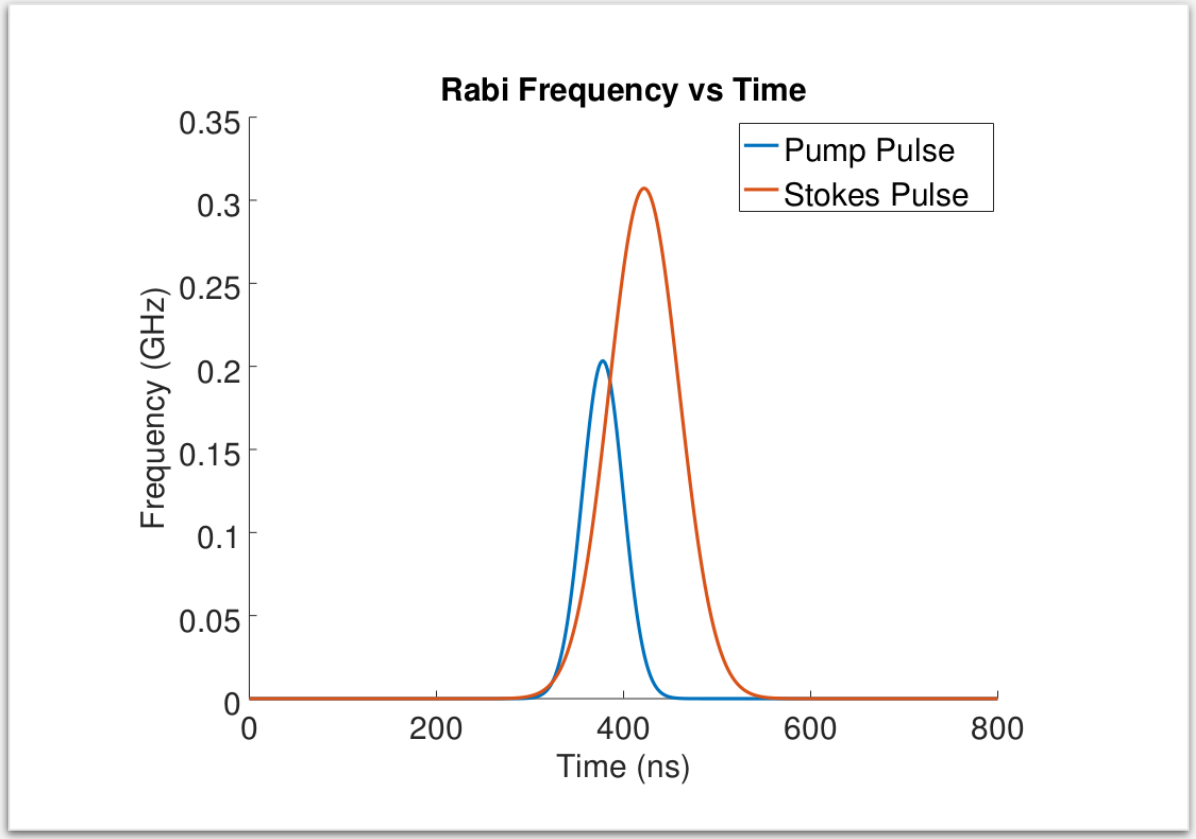
Crossover	Mutation	Repeat
Use the parent's 'genetic code' to create the new parameter set (child)	Slight probability that a parameter in the child regenerates.	Many times to replace the existing population with the new one

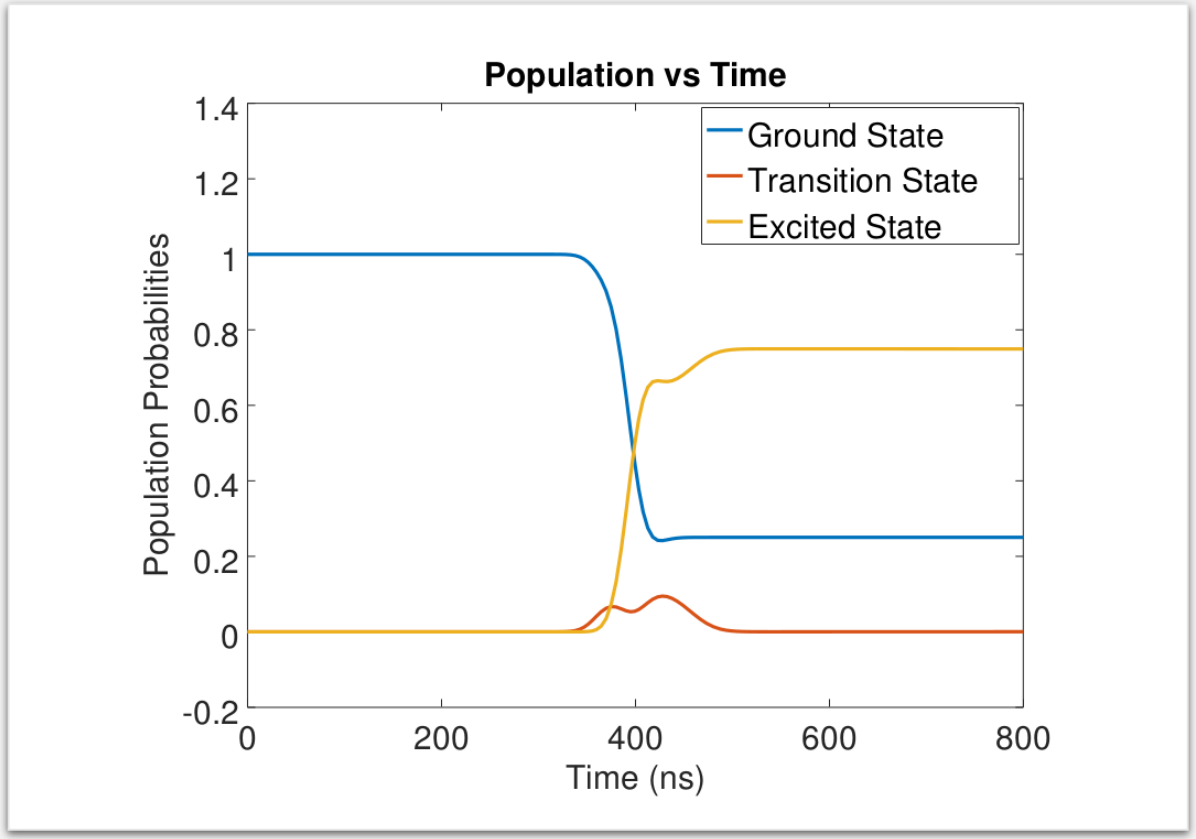
Termination Condition

This is what stops the algorithm

Stops when algorithm barely improves its findings

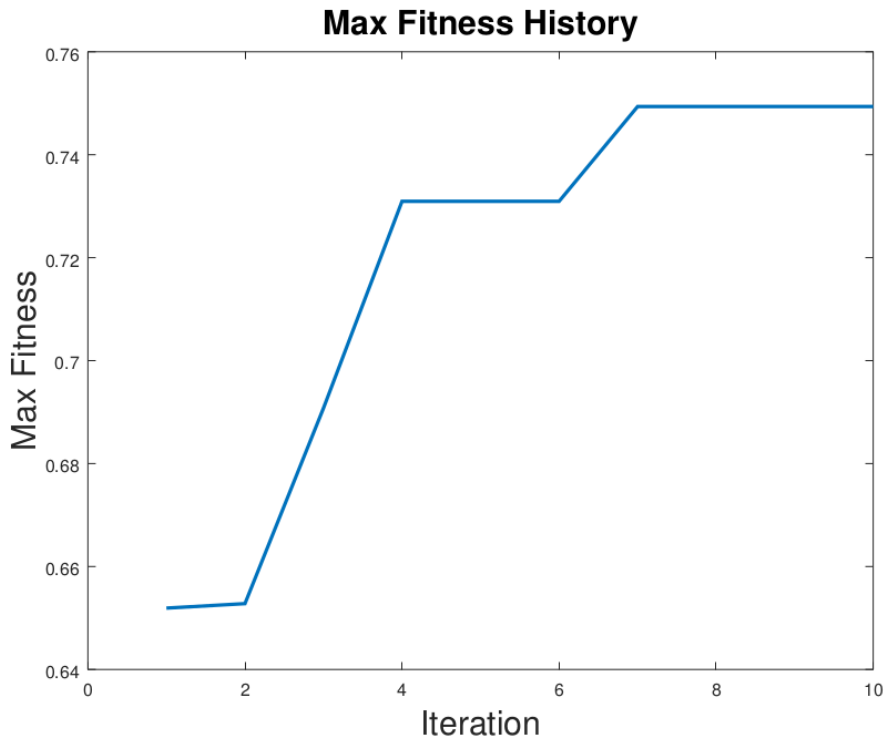
Report back the best result found when met

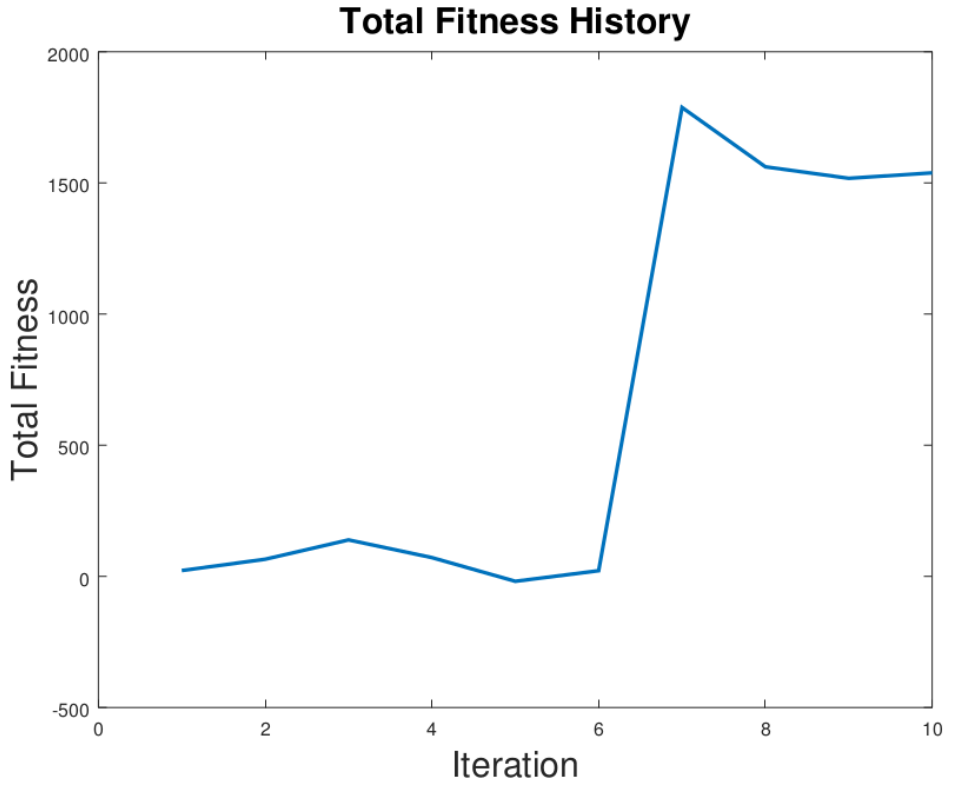




Sample Result

Finding the parameters needed for 75% population transfer





Algorithmic Efficiency

References

- H.A. Camp, Ph.D. thesis, Kansas State University, 2005.
- Daniel A. Steck. Rubidium 87 D Line Data, Los Alamos, 2001.
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Acknowledgements

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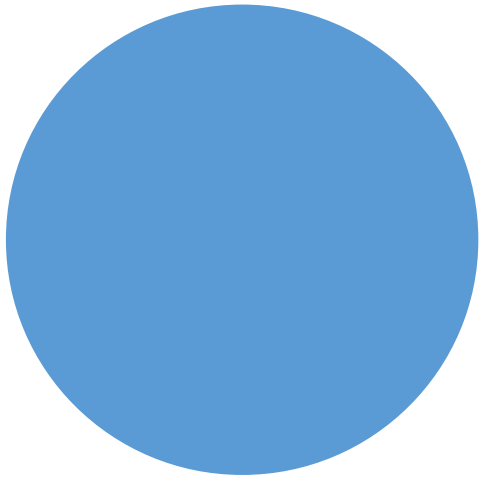
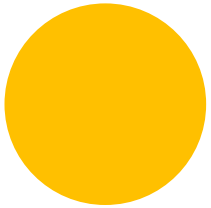

Questions?