Earth's Human Carrying Capacity

Terran Woolley

Differential Equations

Final Project

Introduction

In this presentation I will be exploring:

- the Human population growth rate
- What affects the growth rate?
- Is there a limit to the number of humans the earth can support? (carrying capacity)
- Logistic model for human population growth

Introduction

In this presentation I will be exploring:

- the Human population growth rate
- What affects the growth rate?
- Is there a limit to the number of humans the earth can support? (carrying capacity)
- Logistic model for human population growth

Introduction

In this presentation I will be exploring:

- the Human population growth rate
- What affects the growth rate?
- Is there a limit to the number of humans the earth can support? (carrying capacity)
- Logistic model for human population growth

Introduction

In this presentation I will be exploring:

- the Human population growth rate
- What affects the growth rate?
- Is there a limit to the number of humans the earth can support? (carrying capacity)
- Logistic model for human population growth

Uncertainty

- There have been many attempts to model the Earth's human population.
- Human population models are prone to errors.
- Will the population die off and leave a more reasonable number to support?
- At what point will the Earth's resources be unable to support the human population?

Past Behavior

The annual rate of increase of the global population grew from a an average of 0.04% per year between A.D. 1 and 1650 to a peak of 2.1% around 1965 to 1970, then down to 1.6% per year in 1995. The population rate has continued to decline and is now at about 1.2%. It should be noted that world population calculations are prone to problems with accuracy.

What affects the growth rate?

Not taking into account for natural disasters that can affect the human population, the main factors that affect the growth rate of the human population are:

- food supply
- water supply

What affects the growth rate?

Not taking into account for natural disasters that can affect the human population, the main factors that affect the growth rate of the human population are:

- food supply
- water supply

$$\text{Population that can be fed} = \frac{\text{food supply}}{\text{individual food requirement}}$$

$$\text{Population that can be Watered} = \frac{\text{water supply}}{\text{individual water requirement}}$$

Population that can be fed and watered

$$= \text{minimum of}$$

$$\left\{ \frac{\text{food supply}}{\text{individual food requirement}}, \frac{\text{water supply}}{\text{individual water requirement}} \right\}$$

The Logistic Equation

The logistic equation is commonly used to model population growth.

$$P' = rP(1 - P/K)$$

where $P = P(t)$ is the population at time t, and $K = K(t)$ is the carrying capacity of the environment.

The model will be in one of three states:

- If $P(t) > K$ then $P'(t) < 0$ and the population will decrease.
- If $P(t) = K$ then $P'(t) = 0$ and the population will stay the same.
- If $P(t) < K$ then $P'(t) > 0$ and the population will increase.

The Logistic Equation

The model will be in one of three states:

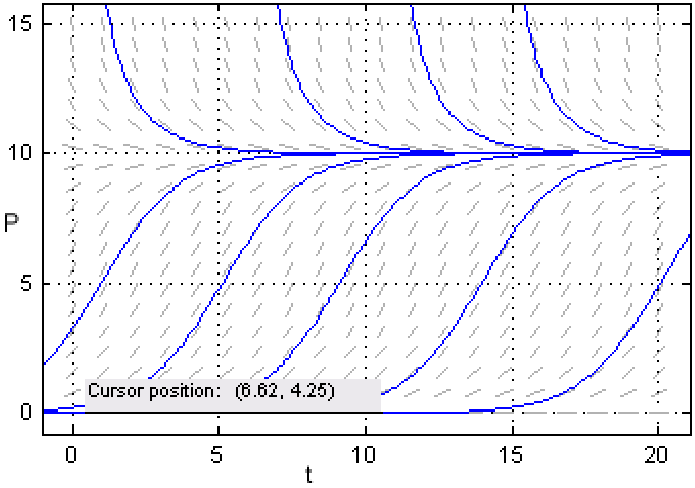
- If $P(t) > K$ then $P'(t) < 0$ and the population will decrease.
- If $P(t) = K$ then $P'(t) = 0$ and the population will stay the same.
- If $P(t) < K$ then $P'(t) > 0$ and the population will increase.

The Logistic Equation

The model will be in one of three states:

- If $P(t) > K$ then $P'(t) < 0$ and the population will decrease.
- If $P(t) = K$ then $P'(t) = 0$ and the population will stay the same.
- If $P(t) < K$ then $P'(t) > 0$ and the population will increase.

The Logistic Equation



Modifying the Equation

This model can be modified to fit the parameters of the particular system. If we fit this model to the limiting resources, we can attempt to model the Human population.

Modifying the Equation

For example, Humans have the ability to create new ways of growing and supplying food and water, therefore increasing the amount of people that can be fed and watered.

Modifying the Equation

An individual will, through his/her actions, cause the carrying capacity to either:

1. Increase
2. Decrease

This implies that Humans can affect their own carrying capacity.

Variable carrying capacity

To incorporate this into our model we can let the constant carrying capacity K in the logistic equation become a variable $K(t)$.

Variable carrying capacity

So the equation becomes:

$$\frac{dP(t)}{dt} = rP(t)[K(t) - P(t)].$$

Variable carrying capacity

The rate of change of the carrying capacity over time is proportional to the rate of change of the population over time. In other words:

$$\frac{dK(t)}{dt} = c\frac{dP(t)}{dt}$$

Defining c

- The amount that an additional person can increase $K(t)$ depends on the amount of resources available to make their hands productive.
- These resources are shared among more people as $P(t)$ increases.

Defining c

- The amount that an additional person can increase $K(t)$ depends on the amount of resources available to make their hands productive.
- These resources are shared among more people as $P(t)$ increases.

Variable c

If we replace the constant c for a variable $c(t)$ that decreases as $P(t)$ increases. Let

$$c(t) = \frac{L}{P(t)}$$

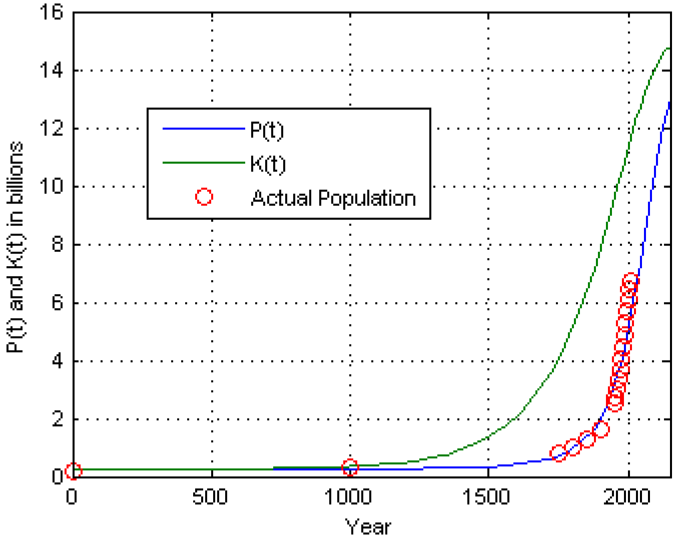
with $L > 0$

Carrying Capacity

Substituting $c(t)$ in for c we get:

$$\frac{dK(t)}{dt} = \frac{L}{P(t)}\frac{dP(t)}{dt}.$$

graph of a solution to P and K



$P(0) = 0.2523$, $K(0) = 0.252789$, $r = 0.0014829$, $L = 3.7$

Problems with the model

- Cannot accurately determine the value of L.
- Does not take into account for natural disasters.
- To apply the model we have to fit the curve to collected data, data we know to be inaccurate.
- We cannot accurately predict the future behavior of the population.

Problems with the model

- Cannot accurately determine the value of L.
- Does not take into account for natural disasters.
- To apply the model we have to fit the curve to collected data, data we know to be inaccurate.
- We cannot accurately predict the future behavior of the population.

Problems with the model

- Cannot accurately determine the value of L.
- Does not take into account for natural disasters.
- To apply the model we have to fit the curve to collected data, data we know to be inaccurate.
- We cannot accurately predict the future behavior of the population.

Problems with the model

- Cannot accurately determine the value of L.
- Does not take into account for natural disasters.
- To apply the model we have to fit the curve to collected data, data we know to be inaccurate.
- We cannot accurately predict the future behavior of the population.