Introduction to Simulation

Assignment 4: Glucose and Insulin

Glucose and Insulin are two of the important substances in keeping our bodies running. Glucose is a simple sugar and the substance that our digestive system breaks most food down into. It is then absorbed into the blood stream.

Insulin is an enzyme that the bodies of all healthy humans produce. It is essential for our body cells to absorb glucose from the blood stream into the cell itself, and thus to use the energy stored in glucose to "power" our body.

Having a too high or too low blood sugar level should be avoided since it may permanently damage the human body. For healthy humans, the body itself regulates insulin production to stabilize the blood glucose level. A person with diabetes type 1, however, cannot produce insulin and needs regular injections of insulin to stay alive.

Model 1: A healthy person

We consider the following continuous and positive variables:

- G : blood glucose level (initial value 6000 mg/l)
- I : blood insulin level (initial value 9000 units/l)

We assume the following interactions between these values:

- Insulin decomposes at a rate of I/18.
- Glucose is used by the cells at a rate proportional to the current glucose level and an empirically determined usage fraction as a function of the blood insulin level.

InsulinLevel	UsageFraction
0	0.0075
1800	0.0105
3600	0.0145
5400	0.019
7200	0.0255
9000	0.033
10800	0.0405
12600	0.049
14400	0.0545
16200	0.0575
18000	0.059

- Insulin is produced by the pancreas at a rate described by an empirical function of the blood glucose level:

GlucoseLevel	InsulinProduction
1000	0.0
2000	15
3000	85
4000	190
5000	350
6000	500
7000	665
8000	825
9000	930
10000	975
11000	995

- Assume that the patient eats every 8 hours, increasing his blood glucose level immediately by 1000.

Hint: Use table functions and spline interpolation to represent the empirical functions

Model 2: A type 1 diabetic (intravenous injections)

- A diabetic cannot produce his own insulin and is dependent on regular injections.
- In this model he always injects insulin directly into his bloodstream half an hour before a meal, immediately increasing his blood insulin level by 3000.

Model 3: A type 1 diabetic (subcutaneous injections)

- Insulin is now injected subcutaneously (under the skin, into the underlying tissue), not directly into the bloodstream and therefore only gradually transfers there with a rate proportional to the remaining dose in the injection area.
- Food arrives in the stomach and the glucose within is also only gradually released into the bloodstream with a rate solely proportional to the remaining glucose in the stomach.

If implemented correctly, Models 2 and 3 should also result in the blood glucose level to permanently stay in the healthy range of 4500 to 8000 mg/l. Whenever a type 1 diabetes patient changes his diet (i.e. he increases or decreases the amount of glucose ingested), the amount of insulin to be injected regularly needs to be adjusted.

Your Task:

A person with type 1 diabetes temporarily changes his diet:

1. He travels the United States for some time. During this time, his diet will likely be based largely on fast food an soft drinks, increasing the blood glucose level by 2000 mg/l at each meal instead of the usual 1000 mg/l.
2. Afterwards, to loose the weight gained on the trip, he decides to move to stricter diet resulting only in a 750 mg/l per meal blood glucose increase.

Determine the effect of the change in diet by reducing or increasing the amount of glucose ingested! Determine the resulting need in insulin dosage change to avoid hyper- (too much blood glucose, >8000 mg/l) or hypo-glycemia (not enough blood glucose, < 4500 mg/l).