Qualitative Reasoning - Bathtub Problem

Ioanna Sanida - 2555251

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1 Casual Model

The goal of this assignment is to make use of the given qualitative reasoning rules from class, and blend them with our own assumptions, in order to create a state graph representation. The quantities used are Inflow (of water into the container) $\in [0, +]$, Outflow (of water out of the container) $\in [0, +, Max]$, and Volume (of the water in the container) $\in [0, +, Max]$. Moreover the given dependencies are:

- I+(Inflow, Volume): the amount of inflow increases the volume
- I-(Outflow, Volume): the amount of outflow decreases the volume
- P+(Volume, Outflow): outflow changes are proportional to volume changes
- VC(Volume(Max), Outflow(Max)): the outflow is at its highest value (Max), when the volume is at it highest value
- VC(Volume(0), Outflow(0)): there is no outflow, when there is no volume

We start with an initial state and from this we generate all possible next states, based on the calculations of all possible combinations of derivatives of magnitudes. We then model those states that are reachable from our initial state, in order to prevent possible disconnected states interfering with our model.

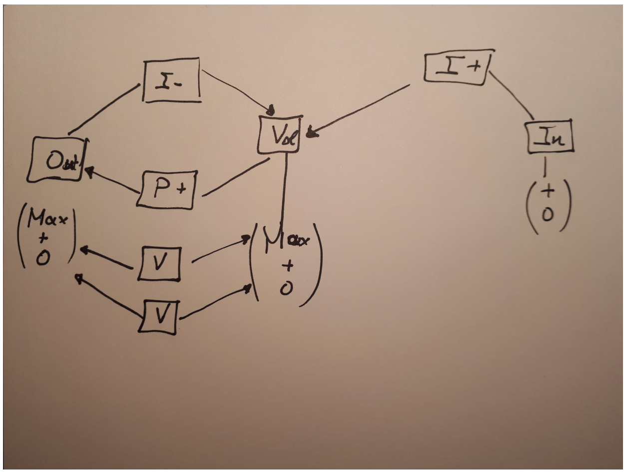

Figure 1: Drawing of the causal model for base problem

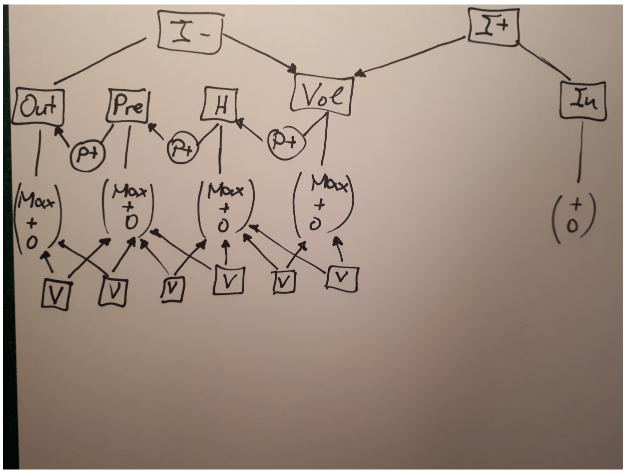

Figure 2: Drawing of the causal model for extra problem

2 Method

The algorithm computes the initial state graph (i.e. the state graph based on an initial state that is given). The steps that follow are searching through all the successors of the current state and add them as children to it in a list. The only successors that are added to the list are the ones that are 'seen' for the first time. We try to find the successive states one after the other, by propagating over all quantities and taking into account all possible derivative combinations of the new state values. After the values of the new state are computed, we need to check if all constraints are satisfied, and keep only the states that do so. They way to check for the new derivatives is through the influences. That means, that for every new state, if the value of the influence stays the same as before, the derivative also stays the same. If there is ambiguity, it is possible to get a derivative of 0. Finally, for every quantity of the model we have to check proportionality among each quantity's derivatives. In case we don't have quantities with proportionate derivatives, the derivative is randomly based, otherwise it is implemented recursively. After all possible derivatives are found for each quantity, new states are created for each state along with the propagation steps.

3 State-graph

The output of the state graph that contains all possible behaviours of the aforementioned system, can be seen here. Nodes represent states and arrows are transitions from one state to the other. We see in each node the value of each quantity and its derivative:

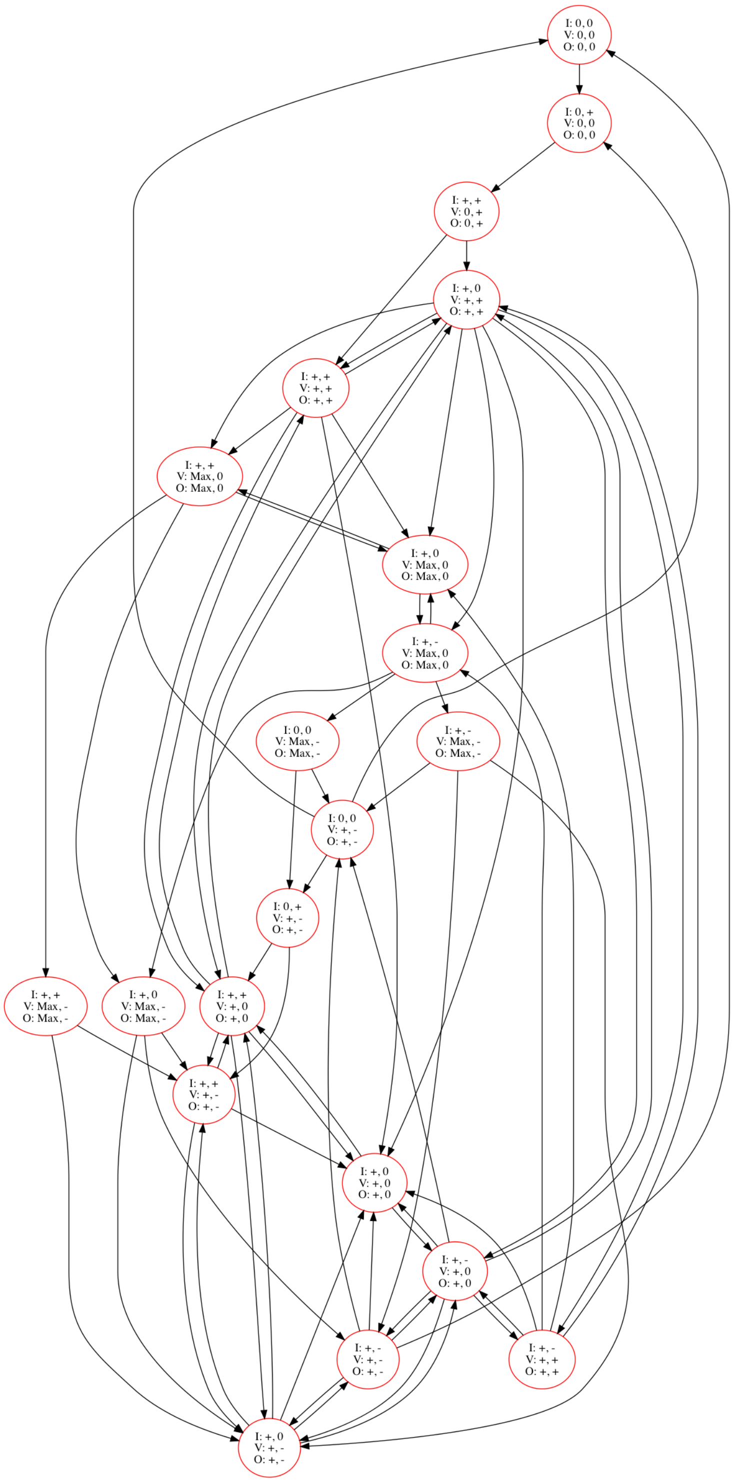

Figure 3: State graph of base problem

4 Extra Problem

For the extra problem the quantities used are Inflow (of water into the container) $\in [0, +]$, Outflow (of water out of the container) $\in [0, +, Max]$, Volume (of the water in the container) $\in [0, +, Max]$, Height (of the water column in the container) $\in [0, +, Max]$, and Pressure (of the water column at the bottom of the container) $\in [0, +, Max]$. The dependencies and the output state graph, are shown here:

Dependencies:

- I+(Inflow, Volume): the amount of inflow increases the volume

- I-(Outflow, Volume): the amount of outflow decreases the volume
- P+(Volume, Height): height changes are proportional to volume changes
- P+(Height, Pressure): pressure changes are proportional to height changes
- P+(Pressure, Outflow): outflow changes are proportional to pressure changes
- VC(Volume(Max), Height(Max)): the height is at its highest value (Max), when the volume is at it highest value
- VC(Volume(0), Height(0)): there is no height, when there is no volume
- VC(Height(Max), Pressure(Max)): the pressure is at its highest value (Max), when the height is at it highest value
- VC(Height(0), Pressure(0)): there is no pressure, when there is no height
- VC(Pressure(Max), Outflow(Max)): the outflow is at its highest value (Max), when the pressure is at it highest value
- VC(Pressure(0), Outflow(0)): there is no outflow, when there is no pressure

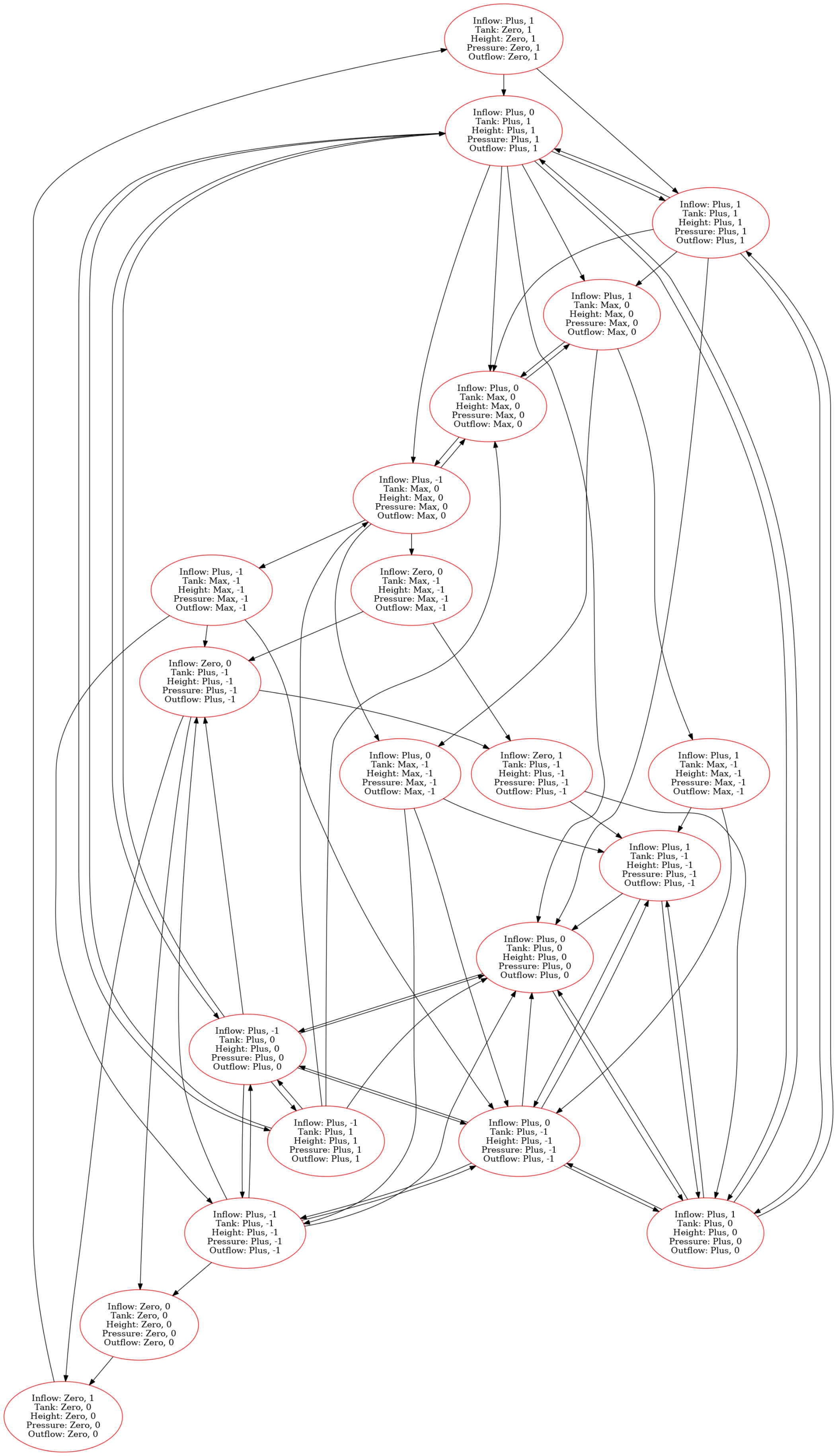

Figure 4: Plot of the state-graph for the extra problem