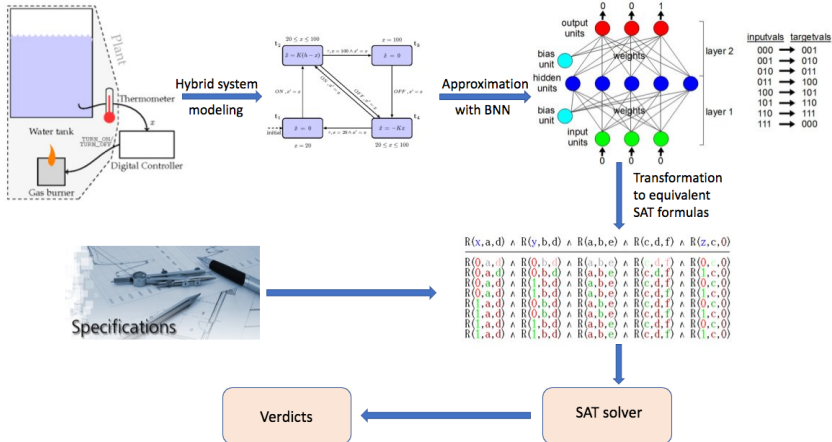


Leveraging SAT and BNN to Design safety-critical systems (LSBD)

05 March 2021

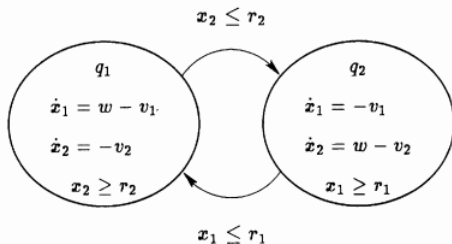
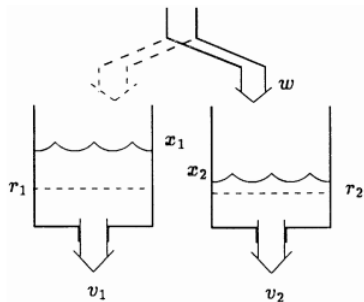
Simple Illustration



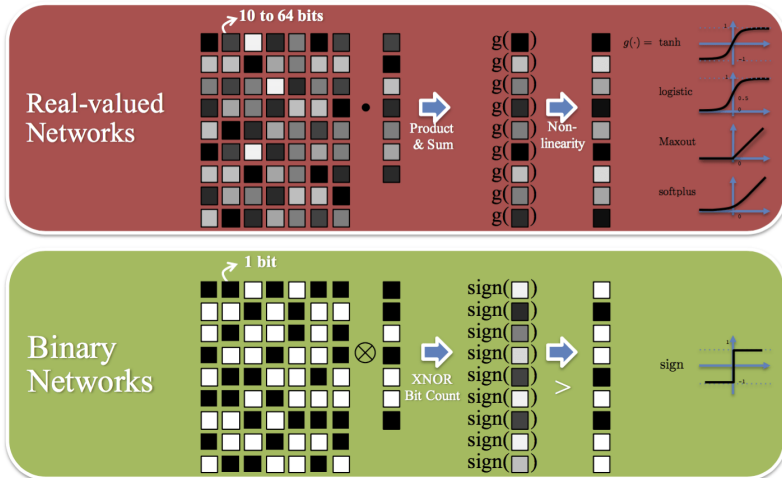
Primary Elements of LSBDD

- Differential equation solution approximated by (binary) NN
 - ▶ One recent very popular NN for this is called PINN (next slides)
 - ▶ Several possibilities for our case: adapt PINN that will be approximated further by BNN; or directly approximate ODE (PDE) by BNN (no related work)
 - ▶ Trade-off between accuracy and complexity
- Interaction between continuous and discrete aspects (formulate an explicit jump relation)
 - ▶ Very few works on this from machine learning community
 - ▶ It seems that neural networks are not suitable to classify the system states with regard to the occurrence of an event (imbalanced data). (see [4])
 - ▶ Other techniques? (directly encoded in SMT?)
- From BNN to SAT (see [5])

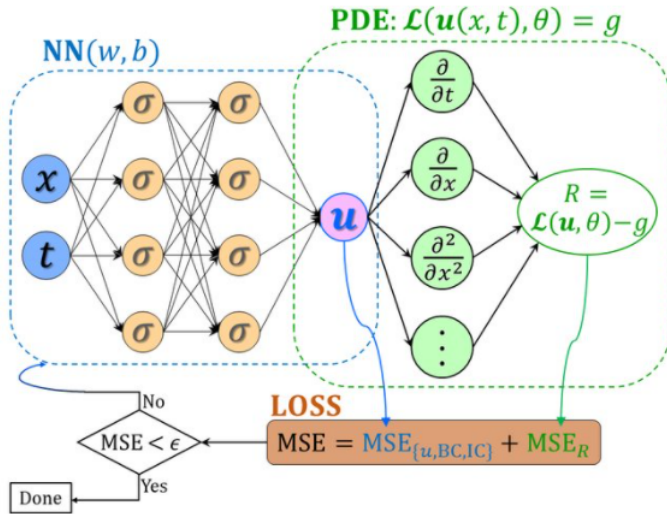
Hybrid Systems [6]



BNN vs. DNN [1, 2]



Physics-informed neural networks (PINN)[3]



Useful references

- 1 Matthieu Courbariaux, Yoshua Bengio, BinaryNet: Training Deep Neural Networks with Weights and Activations Constrained to +1 or -1 (<https://arxiv.org/pdf/1602.02830v1.pdf>)
- 2 Haotong Qin, Ruihao Gong, Xianglong Liu, Xiao Bai, Jingkuan Song, Nicu Sebe, Binary Neural Networks: A Survey (<https://arxiv.org/pdf/2004.03333.pdf>)
- 3 Maziar Raissi, Paris Perdikaris, George Em Karniadakis, Physics-Informed Neural Networks: A Deep Learning Framework for Solving Forward and Inverse Problems Involving Nonlinear Partial Differential Equations
- 4 Stefanie Nadine Winkler, Felix Breiteneker, Neural Network Application for Event Detection in Hybrid Dynamical Systems
- 5 Nina Narodytska, Shiva Prasad Kasiviswanathan, Leonid Ryzhyk, Mooly Sagiv, Toby Walsh, Verifying Properties of Binarized Deep Neural Networks
- 6 Radoslav Ivanov, James Weimer, Rajeev Alur, George J. Pappas, Insup Lee, Verisig: verifying safety properties of hybrid systems with neural network controllers (<https://arxiv.org/pdf/1811.01828.pdf>)

Benchmark collection site

<https://ths.rwth-aachen.de/research/projects/hypro/benchmarks-of-continuous-and-hybrid-systems/>

Expenses

- GPU (NVIDIA GeForce RTX 3090)?
- Else for now?