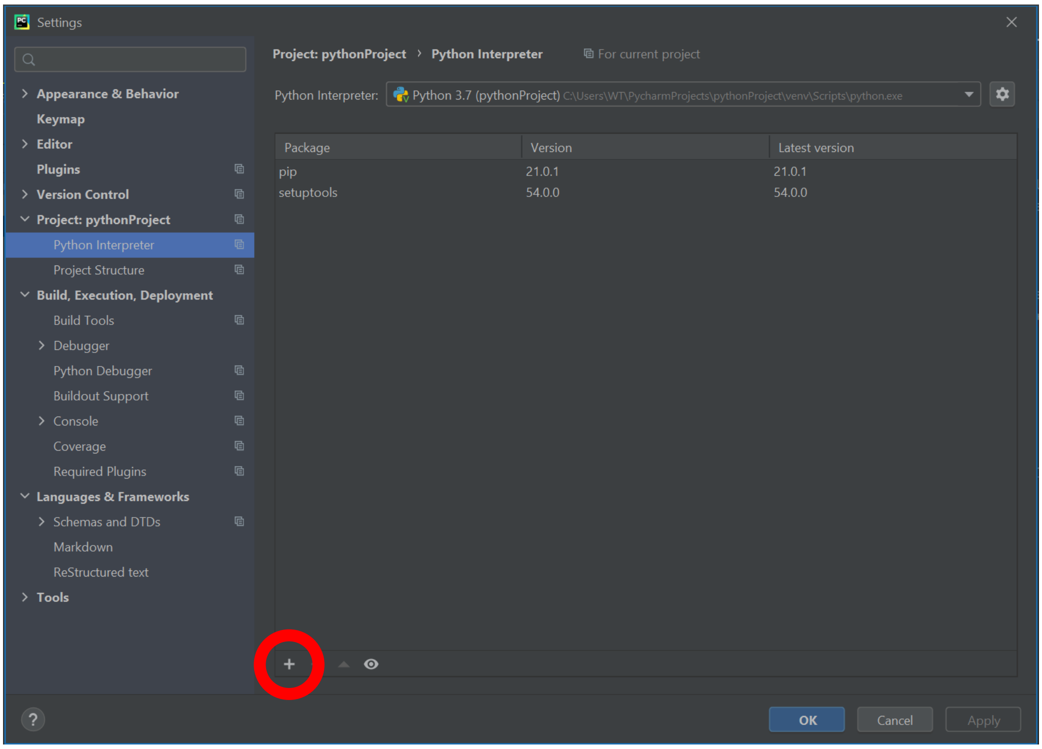
1. Prepare the environment

1. Download and install Python (3.7 or newer) https://www.python.org/downloads/
2. Download and install PyCharm Community https://www.jetbrains.com/pycharm/download/
3. Make new project
4. Install PyMC: File ⟶ Settings ⟶ Project ⟶ Python Interpreter ⟶ +



5. Ensure access to the book: https://nbviewer.jupyter.org/github/CamDavidsonPilon/Probabilistic-Programming-and-Bayesian-Methods-for-Hackers/tree/master/

2. Play with pyplot and distributions

1. Tutorial: https://matplotlib.org/stable/tutorials/introductory/pyplot.html
2. Plot Gaussian probability density function for a couple of different standard deviations in range from 0.2 to 2 (all in one plot). Label the axes appropriately.
3. Plot Gaussian cumulative density function for a couple of different standard deviations in range from 0.2 to 2 (all in one plot). Label the axes appropriately.
4. Plot as in 2 and 3, but make two subplots in one plot: the top containing pdfs, the bottom containing cdfs
5. Plot binomial probability mass function for Bi(10, 0.5) and Bi(10, 0.1). Plot both in one plot (not subplots). Use red dots for the first one, green crosses for the second one. Add legend to the plot.

6. Plot Poisson probability mass function for several values of the parameter, all in one plot. Use continuous line with crosses at data points. Add legend to the plot.

3. Reason backwards

1. Take the COVID-19 example from the lecture as a basis and implement a Python class that enables to reason from a single effect to the cause. Provide appropriate methods to input the required numbers.
2. Play with the class, plot output for different combinations of inputs.
3. Test the class for p(C)=0.2, P(L)=0.001, P(L|C)=0.01. What happened? Why? How to fix it?

4. Reason from multiple evidence

1. Take the burglary example from the lecture as a basis and implement a Python class that enables to reason from any number of pieces of evidence. Provide appropriate methods to define the number of evidence pieces and input the required numbers. Ensure proper operation when some of the pieces of evidence are not present.
2. Play with the class, plot output for different combinations of inputs.
3. Going back to the example, consider situation when the alarm is not silent – it blares horn and flashes light when it goes off. Can computations still be performed in the same manner? Explain.

5. Discover distribution parameter

1. Reproduce example presented during the lecture (anti-viral drug).

6. Compare distribution parameters

1. Using exercise 5 as a basis, develop a model for comparing the parameter of two distributions: the distribution for patients taking anti-viral drug and for patients taking placebo (control group). Use deterministic variable to compare the resulting distribution parameters.
2. Investigate and comment on the difference for the following cases:
    a. treatment group of 100 patients, 70% of which were cured, and control group of 100 patients, of which 50% were cured
    b. as above, but each group consisting of 1000 patients
    c. as b., but with the treatment group consisting of 10 patients.

7. Investigate extreme cases

1. Reproduce example presented during the lecture (drug survey).
2. See what happens when the number of "yes" answers (out of 100) is
    a. 20
    b. 10
    c. 5

    Explain.

8. Generate sample data

1. Modify previous example in order to obtain a sample datasets:
    a. Generate a set of 100 answers for probability of a randomly chosen student taking drugs equal to: 0.1; 0.5; 0.9

   b. Set the probability of a randomly chosen student taking drugs at 0.1, count of the group at 100. The survey was repeated 50 times, generate number of "yes" answers for each attempt.

9. Investigate effect of the loss function

1. Reproduce example presented during the lecture (trade signal)
2. Check what happens when:
   a. The quadratic part of the loss function is disabled
   b. The coefficient by which the quadratic part is multiplied is changed to:
      i. 500
      ii. 1000

   Explain.

10. Make two-part linear model

1. Make your own example that calls for a two-part linear model.
   a. Invent plausible story
   b. Make fake data
   c. Apply a model
2. Check how the model behaves when in the data
   a. The difference between the two parts becomes less pronounced
   b. Noise increases
   c. The switch occurs more gradually

11. Try to beat the Bayesian strategy

1. Reproduce example from the lecture (electronic system production).
2. Implement last three strategies from slide 105 plus one of your own (other than the two remaining in the slide), compare results in a plot.
3. In real life it is possible that the quality of components from a manufacture changes in time. Implement "imperfect memory" in the Bayesian strategy that makes it gradually forget the learned parameters of Beta distribution for each batch. Check using an appropriate example.

12. Obtain and install GeNIe

1. Obtain GeNIe for Academia: https://download.bayesfusion.com/files.html?category=Academia
2. Install and activate according to displayed instructions.

13. Try to construct Bayesian network graph

1. For the following domains and events propose a structure of Bayesian network. Discuss for which domain Bayesian network is useful and for which it is not. Justify.
   a. Respiratory disease. Events: flu, COVID, pneumonia, X-ray result, cough, smell loss, age, cardiovascular disease, vaccination, death.
   b. Plant growth. Events: sun, water, fertilizer, plant growth, pest, fungal diseases, warmth.
   c. Climate change. Events: greenhouse gas emission (e.g., CO_2, water vapour), reflection of infrared radiation back to Earth, temperature rise, loss of ice cover and permafrost, turning forests to desert.

14. Apply serial, diverging and converging principles to your graph

1. For graph from 13.1.a. apply serial, diverging and converging principles to selected sets of nodes. Check whether your expectation of data flow in the graph follow the principles.
2. For the same graph, select two nodes that are far from each other. Are they d-spearated? What data must be observed to change this situation? Is it in accordance with your understanding of the modelled domain?

15. Modify simple structure

1. You were asked to create a simple network for flu diagnosis. You should include two symptoms: coughing and sneezing. You assume that once presence (or absence) of flu is confirmed, observing one symptom does not influence belief in presence of the other symptom.
2. After consulting with a doctor, you learn that the above assumption is not correct. Alter the structure of the network accordingly.

16. Enter some numbers.

1. Using GeNIe, enter numerical specification for the Holmes network (lecture slide 138). Take into account the hints below. Assume the network covers data for 24 hours. Note: some numbers may still be missing! Use your own ideas to plausibly fill the voids.
    a. The monitoring company claims the alarm catches 95% of burglaries.
    b. Someone living in the same neighbourhood said that this type of alarm is triggered by 1 out of 5 earthquakes.
    c. Local radio station is not very reliable, it will sometime report earthquake even if it occurred in another state. On the other hand, they never failed to inform about an earthquake if it occurred in the neighbourhood.
    d. Watson is somewhat deaf, but he is definitely not a prankster.
    e. For the past 2 years, there were 50 house robberies in the neighbourhood. It consists of 1350 houses.
    f. Expect 3 earthquakes each year.

17. Help Mr. Holmes.

1. Help Mr. Holmes decide what action to take regarding burglary in his house. Take into account at least some of the below information.
    a. Assume three possible actions: do nothing, go home, call police.
    b. Each action incurs some cost: for “do nothing” it is 0, going home is greater, as it means having to work after hours to make up for lost time. Calling police is still greater, as Mr. Holmes, being at his spare time a PI, does not like to depend on police.
    c. If someone (Mr. Holmes or police) appears at the burglary site, he/she may catch a thief. There is much higher chance that the police will catch the thief, as they are in the neighbourhood, while Mr. Holmes must drive form work, which takes significant time.
    d. Utility of catching a thief is very, very high (regardless of the fact who catches him/her).

18. Utilise field data.

1. Alarm manufacturer made available data describing operation of its products installed in the neighbourhood (Holmes alarm data.txt). Each record contains state of randomly chosen device, supplemented by information whether burglary or earthquake happened immediately before. Use these data to update the parameters of the Holmes network.
    a. Assume the new data and the data based on which the current network was created are of equal importance.
    b. Remember that only the Alarm node should be updated.
    c. How the parameters of the node changed?