State manipulation simulation in three-level systems using randomly generated numbers

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Introduction

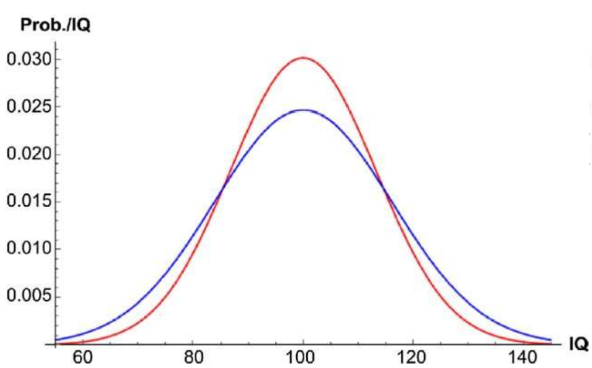
This script is an extension to my previous projects. As could be seen in previous projects, we used a series of randomly generated numbers to identify the population transfer probabilities in a system of two and three level systems. In real world, these systems could be considered as fermionic systems of electrons (two-level) and bosonic (three-level) systems.

In previous approaches, we considered the system in its ground state and assumed that the state transfer is induced via an external magnetic field. Then we introduced the interactions between particles as coupling strength between particles to add a secondary variable to the problem.

Here, we go back to the basics of the project number 1. Here we have a system of three bosonic (three-level) particles and we induce the population transfer using an external magnetic field to study population transfer. Here we consider that the interactions between particles are negligible. The rest of this article includes the data for this experiment, the uncertainty and the variance between data to analyze the original data.

Theory

To generate a distribution of data, we consider that the population transfer experiment is completed many times, so in practice we should expect different data. But like in many other natural phenomenon, the data population is distributed in a Gaussian form. Figure 1-a shows the distribution of IQ level in men and women [1]. This graph clearly says there are no differences between the intelligence level of men and women and is another nail to the coffin to the beliefs of those who think there are differences. In another study, researchers used all the data to figure out the mean age of Nobel laureates. While some win the Nobel prize in really young or old ages, the mean age for Nobel prize winners is about 60 years old [2].



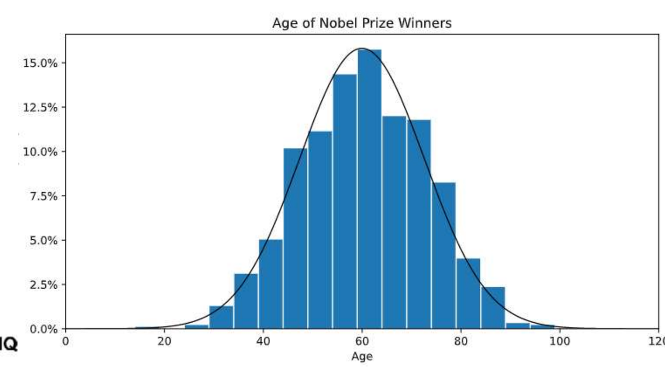


Figure 1: a) IQ grade distribution for men and women, as could be seen the population of data is distributed as a Gaussian function, while **Figure 1-b** represents the mean age of Nobel prize winners, it is never late to win one.

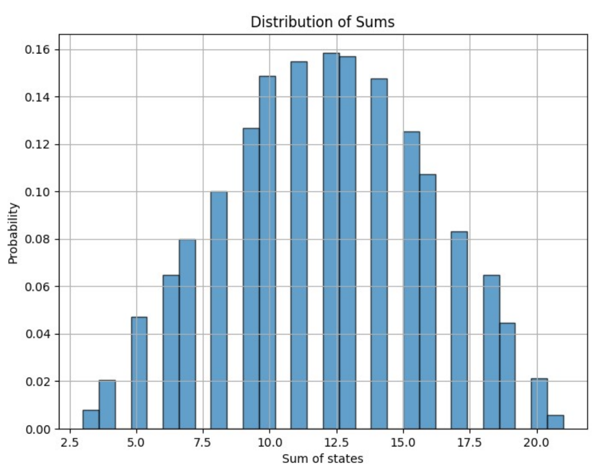
This shows that the Gaussian distribution is the most commonly seen distribution in nature. With that in mind, we assume that this holds true for our experiment. As could be seen in previous projects, using different values for the sweeping rate of the magnetic field (alpha) could change the population transfer and shift the likelihood of finding the system towards the ground state (for low rates of alpha) or one of its excited states (for high rates of alpha). As mentioned before, since we are ignoring the interactions between particles, alpha is the only factor that can change the probability of population transfer.

Results

Figure 2 represents the likelihood distribution of the series of the random numbers we generated. The code that corresponds to this figure could be found in the github repository via the following link named "newmaindata.py" : https://github.com/saarashmn/Project-4. You can also find the code that generates data, under the name of: newdata.py alongside with text files containing raw data.

Figure 3 represents the mean value of population transfer and the sum over excited states, variations and uncertainty could also be observed here. "uncvsal.py" is the code that could be found in the same repository.

In the next step, we included the effect of alpha to make problem more real-life like. The result of this adjustment could be seen in figure 4. Kindly look up the repository for a script named "heatmapanalysis.py" with respect to this figure.



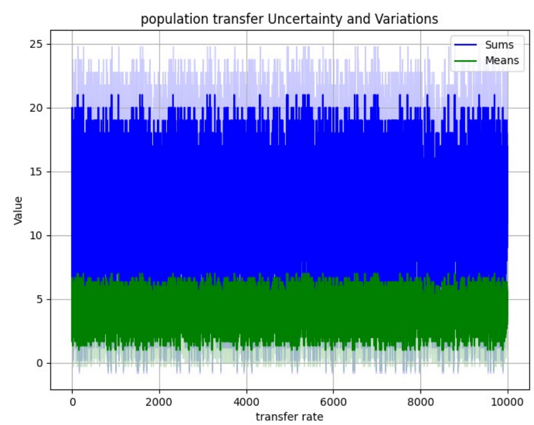
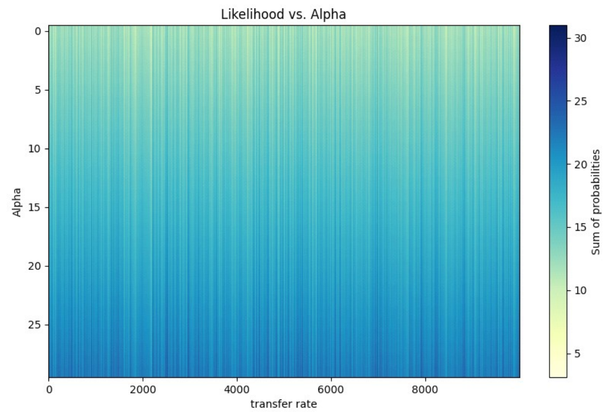


Figure 2 distribution of the sum of the probability of excited states after certain number of iterations for the experiment. **Figure 3** represents the sum of the values and mean value for the sum of excited states for three particles with uncertainty included.

To illustrate how changes in the values of alpha changes population transfer probabilities, we plotted likelihood versus alpha in the range of 0.1 to 10. The result could be found in figure 5. As could be seen in this figure, as the magnitude of alpha increases, the system could be found in desired excited state with lower iterations of experiment. This is in good company with initial results from actual data [3, 4] and project 1, where we indicated that by increasing the magnitude of alpha, there's a higher probability of finding the system in one of its excited states. We also can plot variations and uncertainty versus alpha to find out how changes in alpha can make a difference in uncertainty of the results. In theory it seems that when the alpha (and with respect with that, population transfer rate) increases, the uncertainty in results should increase. That arises from the fact that as a probabilistic system, it should be harder to figure out in which excited state the system is. Though as could be seen from the result, the magnitude of alpha does not change the uncertainty in population transfer, which seems to contradict with actual data.



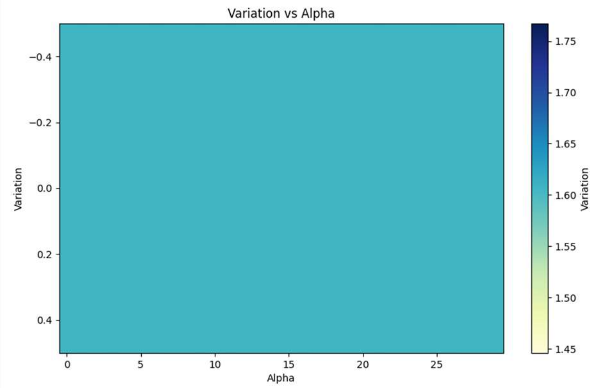


Figure 4: likelihood of population transfer with respect to different values of alpha. **Figure 5** represents the changes in variation and uncertainty with respect to different values of alpha, and as could be seen, the changes in alpha does not affect uncertainty.

Conclusion

In this study we used randomly generated numbers in the form of Gaussian distribution. We used this data to simulate population transfer in a three-particle three-level system. This system could be an example of a bosonic system that was induced by an external magnetic field. As figures two and three represent, this set of random numbers could be a good example to simulate population transfer in such systems. This could work when there are no actual data. The result that is represented in figure four also indicates that this result is relatively close to actual data that indicates when the sweeping rate of the magnetic field increases, the chances of population transfer in this system increases. Although figure five is not in good company with data from actual experiments. As the magnetic field gets bigger and the system is more likely to be found in one of its excited states, the uncertainty increases, mostly because we are less likely to figure out the exact excited states that each particle in the system are. But as could be seen in figure five, changes in alpha will not change the uncertainty in our measurement. Probably there must be a way to include factors in our problem to solve this issue, which sadly is not included in this study.

References

1. 10.4236/am.2020.1110063
2. https://www.w3schools.com/statistics/statistics_normal_distribution.php
3. M. Hosseini, F. Sarreshtedari, "Investigation of the laser controlled Landau-Zener coupled quantum system", JOSA B, 34(10), 2097-2103 (2017). 2) A. Maroufian, M.
4. 4. Hosseini, F. Ahmadinouri, "Effect of next-nearest-neighbor's interactions on population transfer in a four-particle Landau-Zener system", OSA Continuum, 4(2), 290-298 (2020).