School of Engineering and Applied Science (SEAS), Ahmedabad University

B.Tech(CSE) Semester IV: Probability and Stochastic Processes (MAT 277)

- Group No : sb15
- Name (Roll No) : Group Members
  AU1940275 : Anshul Mehta
  AU1940160 : Chirayu Vithalani
  AU1940114 : Harsh Patel
  AU1940126 : Kavan Desai
  AU1940217 : Nihal Aggrawal
  AU1940176 : Sarthak Bharad
  AU1940156 : Jeenal Shah
- Project Title: Multiscale Approach for Ion-beam Therapy

1 Justify how probabilistic model/PSP concept is used in your project. How uncertainty is modeled?

- Modeling of physical/real-time uncertain Problem, Study of any existing probability based models etc., MSA has an advantage over LQ that it can predict quantitatively survival chances of cells in a tumor theoretically. LQ model took into consideration only dose given whereas MSA includes biological factors like genome size of cell, conversion of SSBs to DSBs, number of base pairs and physical factors as well like energy of the ion beam.
  The main parameter for calculating the probability of cell survival is damage yield. This yield is derived by calculating the number of lethal lesions in the tumors which follows Poisson distribution.

  $Y_l = \frac{\pi}{16}\sigma N_g \frac{1}{S_e} d$
  Y_l is number of lethal lesions
  N_g is the genome size
  Se is the stopping potential
  d is the dose

  Finally, a parameter χ , is introduced which is the probability of successful repair of a lesion. The probability of cell survival is certainly not purely exponential and there is a deviation up to certain

quantity of dose up to which cell repair is possible, after which the relation follows a purely exponential behavior.

$\chi = (\chi_0 Y_l)\theta(\chi_0 - \chi_1 Y_l)$

$\pi_{surv} = exp[-(1 - \chi_0 Y_l - \chi_1 {Y_l}^2)]$

$\pi_{surv} = e^{-Y_l}$

2 Clearly enlist the new things done in the coding part, excluding the shared code. [If no new code is written/added/modified, then please write NA]

1. Code change-1

   We showed the decreasing exponential nature of cell survival and also derived the increasing exponential damage that is done as we increase the dose. The cell Survival and Cell Damage are both plotted against dose and both Yield desired Exponential Results as dose is directly proportional to Yield.

2. Code change-2

   We were given one method to calculate the Survival Curve. We enhanced the Method to derive results for All the 6 Cell Lines that were described in the Paper We Moreover derived the Values of Yield and then iterated to tweak the method and derive more accurate and informative results.

   We also used other methods to derive parameters that were directly provided to us hence making the code more comprehensive.

3. Code change-3

   We showed the deviation in the same curve by Changing the LET Values in Accordance with OER Ratio and then we Plotted to show the change from the Normal Curve.

4. Code change-4

   We used the Poisson PMF to show the cell repair which is given as a formula to show the cell repair and the deviation that is caused by the Hypoxic Conditions and this was illustrated by Poisson PMF Modelling which is Modelling the Uncertainty of Cell Repair in this Case.

5. Code change-5

   The same set of results have been able to provide Justification for the LQ model that has been a semi empirical model and the results of MSA are pretty much Similar when Shouldered to LQ.

6. Code change-6

   We have implemented a functionality from the user perspective of a medical professional/doctor where inputs are Cell Line and LET . The output gives a value for dose after which there is no cell repair and also gives the user an idea after what dose there are no chances of repair.

3 Any innovation done considering the society/neighborhood problem?

- Innovation 1

  We have implemented a small innovation that helps the doctors to estimate the number of Double Strand Breaks caused per cell and also the number of DSBS caused per particle.

- Innovation 2

  We have given the doctor the function to input the cell line and the LET to estimate at what dose there will be 0 cell repair. This will help the medical professional in planning dosage for the treatment for optimal efficacy.

- Innovation 3

  By making the dose time dependent and by increasing the dose in a linear fashion, we observed a significant decrease in relative cell survival. As we have decreased the dose in a pattern 0.96, 0.93, 0.90, 0.88, 0.85(3/(3+i/10) ; i=1,2,3,4,5) as parameters. We assumed a linear relation between dose and time that implies dose is directly proportional to time. Making dose time dependent we also found the exponential nature of survival curves which suffice the inclination of curves towards Linear quadratic equation and multiscale approach. We took a total time interval of 8 minutes and 1 minute is divided into 100 fractions which makes the plot more efficient.

4 Enumerate the inferences derived from user-centric perspective.

MSA takes into consideration key biological factors to calculate survival chances of cells in a tumor. Hence, this approach can be extended to predict radiobiological effects of other cell lines as well. The graph of survival fraction with dose helps the user decide the quantity of the dose to be given, adjust the energy of the ion beam in accordance with the area of tumor. This will also help users to determine the relationship between various biological parameters such as genome size, number of base pairs and physical factors like energy. Researchers can try to study these relationships and build up further theories of MSA.

1. Derived inference-1 from the work. We can observe that Chi1 (X1) is negatively proportional to Cell Repair Function. Which makes it Negatively Proportional to the Cell Survival. This means that larger the value of CHi1(X1), lesser will be the Cell Repair. This means that the Surviving Fraction will decrease when we increase the value of CHI1(X1).

2. Derived inference-2 from the work. We also observe that CHI0(X0) is directly proportional to the Cell Repair Function. Which means a larger value of CHI0(X0) will result in a larger cell repair which in turn will increase the surviving fraction of cells.

3. Derived inference-3 from the work. By making the dose time dependent and by increasing the dose in a linear fashion, we observed a significant decrease in relative cell survival. cell repair which in turn will increase the surviving fraction of cells.

4. Derived inference-4 from the work. From Our Small Innovations part we derive that there exists a dose value after which cell repair is 0 which is mentioned as the critical value. So we derive the Critical Value for the input of Se and Cell Line. This Critical Value might be of some help in dose planning as doctor firsthand knows about the value of dose after which there is no chance of cell repair.

5 Contribution of team members

5.1 Technical contribution of all team members: Tables 1 and 2

5.2 Non-Technical contribution of all team members: Tables 3 and 4

Tasks	Anshul Mehta	Chirayu Vithalani	Harsh Patel	Kavan Desai	Nihal Aggrawal
Task-1	Coding- Innovation of Max Dose for Cell Repair	Coded the derivation of average length of cell traverse through diameter	Coded the deviation between expected curve and actual curve. Plotted	Coded the cell survival with using the condition ratio of x0/x1	Coded the parameters of alpha and beta for incorporating the LQ model.
Task-2	Coding- Innovation for number of DSBs and lesions	Coded the function of calculating number of base pairs and genome size with various biological factors	Done some improvement in damage curve	Coded the Innovation of time dependent dose. Plotted various survival curves dependent on time.	Coded and Debugged improvements in Survival Curves and Damage Curves.
Task-3	Coding Part - Main and Main extension Code	Defined all these functionalities for all types of cells	Code the Equation of cell survival without repair factor of cell	Coded the plots varying CHI values	Coded the above parameters for all types of cells.
Task-4	Monte Carlo Simulations for parameters 7 and 6		Helped in finding correct linear relation between time and dose	Coded the plots with Various ratios of CHI0/CHI1	Helped in coding the cell survival probability by assimilating the empirical parameters of LQ Model
Task-5	Reproducing Figures 1.			Coded the plots keeping ratio constant of CHI0/CHI1	

Tasks	Sarthak Bharad	Jeenal Shah
Task-1	Coding - Yield for different cells	Structuring the code
Task-2	Coding - values for stopping potential	Commenting the code
Task-3	Coding - inclusion of equations 13,14 and 15	Coding Multiscale Approach to Linear Quadretic model
Task-4		

Tasks	Anshul Mehta	Chirayu Vithalani	Harsh Patel	Kavan Desai	Nihal Aggrawal
Task-1	Hand- Written Analysis	Contributed in deciding the order of equations of the model	Concept map = Contributed in condition part	Report- Enlisted Inference regarding our code	Concept Map - Reproducing Mathematical Methods
Task-2	Inference Drawing	Modelling of experiments and results	Defining the flow of all the equations for the modelling	Modelling - Beginning with modelling and analyzed the flow over modelling	Modelling: Explaining the LQ model with specification of empirical parameters
Task-3	Concept Map - Maths Part	Summarized the modelling for the report	Mathematical modelling and writing inference about equation 4 and 5	Concept Map - MSA part	Modelling- Specifics for N(r), Criterion for Lethality and total RVs
Task-4	Report Writing- Part 2 and Part 4	Derived inferences of the MSA approach in the report.	Report innovation part =Contributed in finding number of DBS and number of lesions	Report - Enlisted Inference regarding Innovation	Incorporating formulas for modelling and concept map
Task-5	Mathematical Modelling Eqn 3 to 6			Incorporating Two-lesian-Kinetic Model and time dependent Dose as innovation	

Tasks	Sarthak Bharad	Jeenal Shah
Task-1	Concept Map - Results and Discussions part	Concept map's format and MSA part
Task-2	Modelling - Steps 8 to 10 equation and their explanations	Introduction, mathematical part and inferences in modeling
Task-3	Report Writing in LaTex, question 1	Report writing in LaTex
Task-4	clicking snapshots of plots generated	Finding innovation methods