AI CLUB COORDINATOR APPLICATION

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Managerial Questionnaire

1 Essentials:

1.1

Hello guys ! I am Sreeram. I am from elec 23. Beyond Academics, I enjoy playing chess, basketball, listening to music. I like interacting with diverse kinds of people. Exchanging thoughts and discussing creative and innovative ideas with my peers is something which I always love since I get to learn a lot. I also really enjoy teaching cool stuff to people which was the motivation for me to apply for Avanti mentor which was my only POR in my first year and I really loved it. AI/ML is something which I am deeply interested and passionate about and it is exactly what motivated me to apply for this role.

1.2

- AI/ML is something which has fascinated me. Despite my keen interest, I made a deliberate choice of not applying for the role of DC which was because I am a repeater. After my drop year which was extremely challenging, I felt the need to take a break and this was the reason I hadn't applied for any other POR's except Avanti which my saathi mentor (Atreya Vedantam) advised me to apply for, understanding my situation. I was not sure whether I would have been able to do justice to any other POR's in my first semester and this was the reason I hadn't applied for the role of DC. However now I realize its time pursue my interests and with full josh and enthusiasm I contacted my saathi mentor to get to know about the activities of the AI club conducted in the last one year and also to know more about the role of a coordinator.
- My passion for AI/ML fuelled an inner drive within me. I watched last year's summer school lectures conducted by AI club. To enhance my learning, I also watched 3blue 1brown videos on AI/ML and read the textbook which he had recommended in his channel. I also watched some of the CS229 lectures on machine learning and neural networks (from youtube) offered by Stanford University.
- I believe that proficiency in AI/ML opens up a lot of opportunities in various domains, In this modern world, a command in AI/ML would certainly enhance your capabilities to excel in any engineering or even medical field.
- Apart from this I had a course EE1103: Numerical Methods in my first semester where I have the experience of writing a C program for implementing various mathematical models like linear regression, cubic spline etc.

1.3

> "If you want to master something, teach it" — Richard Feynman.

I strongly agree to this quote. Taking sessions and sharing my knowledge is something which I really love to do and I firmly believe that as a coordinator I would get numerous opportunities to take sessions and

interact with great minds which would increase my knowledge and awareness about latest advancements and the cutting edge technology in various domains of AI/ML.

- Roles and responsibilities as a coordinator
  - In the coming tenure, as a coordinator, the first main mission would be Summer School where we will be taking sessions on various topics/domains of AI/ML for the GSB and people outside insti. I believe that the quality of sessions of AI club is something which makes it stand out from other CFI clubs. As a coordinator I would be able to contribute to this strength of the club by taking sessions where the audience would really have some takeaways.
  - As a coordinator we will be having opportunities to share and gain ideas on various topics of AI/ML through the knowledge transfer sessions where we will be researching on some domain of AI/ML by studying various research papers on it and we will be presenting it to the team. This is an exciting opportunity for someone like me, deeply passionate about AI/ML and who desires a high learning curve to both share knowledge and gain insights from my peers.
  - In addition to this, we will be conducting various sessions for the GSB like the epoch sessions which where conducted last year, which will be greatly freshie oriented. As coordinators, we will also have an important role to play in the recruitment of DC's where we will be setting applications for them and also conducting interviews. I believe this would be a great learning experience.
  - As coordinators, we'll also be engaging in PR activities like writing blogs on social media platforms, and designing posters for various sessions of the club. I'm confident that this experience will significantly enhance my creativity skills.
- I have deep passion for AI/ML and I always give my best to the work which I am really interested and excited about. I am an extremely hardworking and a determined person. The fact that I opted to drop for improving my rank despite cracking JEE Advanced the first time is a proof of the same. I believe that my strong work ethic and enthusiasm in the domain of AI/ML makes me fit for this role.
- I believe that communication skills is very important when it comes to the role of a coordinator since we will be the face of the club and we will be responsible for conducting sessions for the GSB and also for the students of other colleges. I believe that I have good communication skills. Well I am an Avanti mentor and in Avanti , when we mentor underpriveleged students preparing for JEE who are at a far away place, communication skills play a huge role in motivating them , helping them out and making them realise their dreams and goals. I feel that good communications skills will help me contribute to the club by taking impactful sessions and also in increasing publicity of the club.
- I believe that I am good at collaborating effectively with my peers and this will help me to contribute to various team events or activities like team projects. I believe I have good leadership qualities like taking right initiatives at the right time, motivating my peers and guiding my peers towards our common goals. Solving practical problems and coming up with innovative solutions is something which I always try to do. I believe these qualities will really help me to contribute to the club.

2 Club:

2.1

- **Summer School 2023**
  - **Strengths:**
    Summer school 2023 event was a big success. It was an online event which essentially covered all the basics of AI/ML and the prerequisites were not much. We also had a very high viewership which helped in increasing publicity of AI club both within insti and also outside insti. A github repository had been made with the presentations and the codes implemented during the session which really helped the viewers in learning. The event was also timed well. It was conducted during the month of July which was a vacation period for a lot of college students. A lot of people

registered for the summer school for the certificates which was a great initiative. The concepts were explained well by the coordinators and the doubts were cleared during the sessions itself. After the sessions, the viewers were also given tasks which for sure increased their involvement in the sessions and also helped them get a grip in practical implementation of the concepts of AI/ML.

- **Weaknesses:**

  The content discussed in the sessions could have been planned better. Some sessions just had too much content to be covered within a short time hence sometimes coords had to rush through some topics. Also the slides could have been designed better and we could have brought in some animations which would have helped the viewers in visualising the concepts and get a better understanding of them. Also sometimes we faced network issues and some other technical glitches from our side which we should be trying to minimize from next time as much as we can.

- **Opportunities:**

  Well coming to opportunities, we could have selected some top 5 or 10 best task finishers and post their names in our insta handle. This would have motivated the viewers further. It also might have addressed the threat of losing viewership session after session to a descent extent. This would have brought a competitive spirit among them and would have accelerated their learning. Yes its indeed true that the codes are scammable. But it would have certainly encouraged a lot of the viewers to actively participate in the program.

- **Threats:**

  There was a drastic decrease in viewership over time. To address this threat, We have to figure out ways to maintain the enthusiasm in our viewers. One way is as suggested in opportunities to post the top task finishers names in insta handle which will be a great motivation for them. We should also try to make the sessions less math intensive so that people don't give up in between. Its definitely challenging as many concepts of AI/ML require a lot of math but we can select those interesting topics which require less math and more of conceptual understanding. I believe these are some of the ways in which we can solve this issue.

- **Epoch**

  - **Strengths:**

    The event was great. The turnout was overwhelming for the initial lectures (The CRC was full). Also the domains Quantum machine learning and Generative AI is extremely interesting and fascinating. The lectures were excellent and the coordinators were very enthusiastic in clearing the doubts from the audience. This certainly created enthusiasm among the freshies and fuelled motivation within them to explore such domains of machine learning hence the objective was met, making this event a success.

  - **Weaknesses:**

    It was certainly mathematically intensive which made some section of people loose interest and give up in between. Well its true that domain itself is like that and we cannot get a greater picture without understanding the math behind it.

  - **Opportunities:**

    The topics Quantum Machine learning and Generative AI are the currently trending topics and these are domains of AI/ML which has high scope for research and innovation. Considering these facts, it might be a good idea to increase the number of sessions that we conduct on these domains which would help in increasing the enthusiasm among the students especially freshies.

  - **Threats:**

    The threat is that if the sessions become too mathematically intensive then the turnout would drop significantly and also some of the students might lose interest in this topic. It is our duty as presenters to cultivate interest among our viewers and the ideas suggested in opportunities might help in tackling these issues to a certain extent.

2.2

What distinguishes our club from other CFI clubs is the quality of our sessions and our events. As coordinators of the club, it will be our responsibility to conduct sessions on various topics of AI/ML and cultivate interest in our audience.

- Bringing more interesting and less math intensive topics to target a wide audience would be a good idea so that people don't give up in between the sessions and also don't lose interest in the topics.
- Organising sessions by collaborating with other CFI clubs is certainly going to help in increasing the turnout because people will have fun through the process and they would enjoy the session. The a_i to AI contest conducted last year in collaboration with the maths club was a great success.
- Another initiative can be releasing various problem challenges and announcing rewards (if possible) and their names on the our instagram handle would be a great idea. This would fuel motivation and build a competitive spirit among the students which would also help in increasing our club's publicity and reputation.
- As coordinators I think we should focus on trying to conduct sessions in such a way that people without any background in AI/ML are also able to follow the content. It may not be always possible especially when it comes to certain trending and advanced topics of AI/ML but as coordinators we should always try to bring in better pedagogical methods for explaining concepts.

2.3

- The projects taken by the club this year have immense scope for research. A.I.Rahman, Project Nightvision and SunCast. A.I. Rahman is a project which aims to use AI to create fusion music by generating music in different genres together. Project Nightvision aims to enhance low light video using deep learning techniques which has a wide variety of applications such as satellite imaging. SunCast is a project where we are collaborating with the Horizon club and the aim of this project is predict solar flares emitted by sun using time series forcasting using ML and it can have great applications like helping satellites to activate defence mechanism to mitigate the effect of solar flares. All these projects have a great scope of research in them and also their practical applications make it even more interesting.
- The project which interests me the most is Nightvision. In this project we aim to enhance low light video using Computer vision and Deep learning techniques. This involves application of Deep learning models like CNN's (Convolutional Neural Network) as powerful tools for enhancing the visibility and the appearence of the low lighted footage. This also has several applications in various domains such as surveillance, cinematography and autonomous driving.

2.4

- During my tenure I would like to explore Quantum Machine Learning and Robotics and Autonomous systems.
- Quantum Machine learning is an interdisciplinary domain which explores the intersection between Quantum computing and Machine learning. The use of quantum computers to perform machine learning algorithms like optimization, pattern recognition more efficiently makes this an interesting domain to me for exploring.
- Robotics and autonomous systems is yet another interesting domain of AI/ML where machine learning techniques are applied to robotics and autonomous systems for performing various tasks navigation and decision making in various environments. I also believe this is a domain in which an effective collaboration with iBOT club will be great.

3 Publicity and PR:

3.1

- Public relations plays a pivotal role in the operations of any club. Currently AI club is the most reputed club in insti and it has the highest number of applicants for any role compared to the other CFI clubs. This is because of the great publicity and PR that our club has. This is what attracts the talented people in insti to apply for various roles hence increasing publicity and maintaining reputation of our club is extremely important.

- For bringing in new faces to the club , its important to get a lot of people to know about the club, its initiative and its activities. For example considering freshies, some of the coordinators / PM's of AI club would certainly be applying for the role of Saathi mentor. So being saathi mentors , we can increase the publicity among freshers by explaining our saathi mentees about the club, its initiatives, reputation and cultivate interest among them. Now once they are interested they would spread this information to their friends and may be they would enquire about AI club to their saathi mentors and figure out stuff.

- I believe that youtube is an untapped resource when it comes to our club. The only set of videos we have in our youtube channel are the videos of Summer School 2023. I think its important to make our youtube channel active by creating some videos on hot topics may be related to our project works or may be some hot topics in the domain of AI/ML. Then sharing these links in various Whatsapp groups and in our instagram stories will increase the publicity and awareness among people about AI/ML and also of our projects.

- If there is something which makes our club stand out compared to other CFI clubs, its our impactful sessions and events. This is something which we are anyway doing, but we certainly have a scope of improvement in coming up with more interesting topics of AI/ML which can increase the participation of our audience. Bringing topics which are less math intensive and conducting more sessions on hot topics which are math intensive like Quantum Machine Learning might be a good idea. Conducting various events, tasks, hackathons and announcing the names of the winners in our social media platforms like Instagram will for sure increase the publicity and involvement of the students in insti. It would also bring in enthusiasm and motivation in students to explore various domains of AI/ML and as Coordinators this is exactly our job being the face of the club.

- Last year we had collaborated with the Mathematics club and organised an a_i to AI contest which was a great success. This is a proof of the fact that collaborating with other clubs increase publicity and also the events are likely to be a success because combination or intersection of various disciplines or fields can attract a wide variety of audience. This year we are collaborating with the Horizon club on a project SunCast and I am sure that it has increased awareness and publicity of our club. Hence Conducting events by collaborating with other clubs might be great idea.

3.2

- It is true that the turnout for our first session is overwhelming and then it decreases quite rapidly in the subsequent sessions. There are many reasons for this. Well one reason is some sessions that we conduct are math intensive. For example the Epoch session on Quantum Machine learning had a huge turnout for the first session. The CRC was full. But in subsequent sessions the turnout dropped drastically because the session started becoming math intensive and people kind of give up in between. So trying to conduct sessions on interesting topics which are more conceptual and less math intensive is something we should try out.

- As coordinators , it is our responsibility to try to make the sessions engaging, fun and also presenting the ideas in such a manner that a person with no background of ML/ any prerequisites can also benefit from our sessions. For example when if we conduct a session on Neural networks, the back propagation is going to be math intensive (not for college students since they are well versed with basic calculus.

taking this just as an example to illustrate the point). We should at least try to make sure that they get intuitive understanding of the concept and they have fun in the process of understanding. As coordinators I believe this is something which we should work on.

- Another initiative can be releasing some challenging problem statements with concepts based on our sessions and announcing rewards (if possible) and the name of the winners in our instagram handle.I think this might motivate people to attend subsequent sessions and may be through the process they might gain interest and certainly learn a lot.

4 Commitments / POR's:

4.1

I am not applying for any other POR's in my second year. Currently I am an Avanti mentor and my tenure as a mentor will be ending by August 2024. I am not applying for any other POR's because of the fact that I don't believe in doing things which I am not really interested about. AI/ML is something which I am genuinely interested in and teaching cool stuff is something which I love to do. This is exactly why I am applying for the role of a coordinator. I believe following your passion and genuinely loving what you do are the most critical things in achieving excellence. I believe that if I get selected as a coordinator, I will be able to devote enough time to this POR and more than a POR I will get to do what I really enjoy.

4.2

Considering the fact that I will not be having any other POR's in my second year and my motivation to apply for this role, practically speaking I would say 7-8 hrs weekly. It might change a little here and there due to various reasons but I feel on an average 1 hr a day is something which I would certainly be able to commit to AI club.

Technical Questionnaire

5 Navigating the Network

5.1

a) **Weights and biases :**

- Weights refer to the parameters of a neural network which determine the strength of the connections between a neuron and the neurons of the previous layer. There are multiple inputs coming into a neuron. Since some transmissions are more important than the other we assign weights to each connection. Higher the weight of a connection, higher the influence of the corresponding neurons of the previous layer on the value of the current neuron.
- Biases are the parameters assosiated with each neuron of a network which help in shifting the activation function and this along with weights help the neural network in learning more complex mappings and brings in flexibility in learning.

b) **Loss function :**

Loss function gives the error between the predicted value of the output and the true value of a single data point. Summation of the loss function for all the input data points gives the cost function.

Mean Square Error is a good example of a loss function. The advantage of Mean Square Error is that it is a convex function with a single minima (the global minima). This makes it extremely beneficial while implementing Gradient Descent algorithm.

c) **Activation functions :**

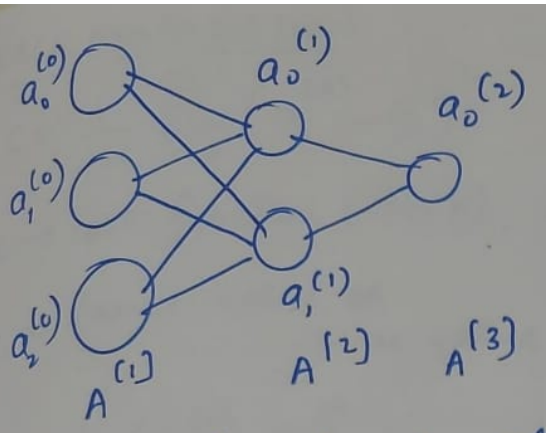
These are the mathematical functions applied to the sum of the weighted inputs and the biases to bring in non linearity into the neural network. This non linearity brought in by the activation functions helps especially the hidden layers of the neural network in complex feature extraction to a greater extent. Some examples od the activation functions are given below

- **Sigmoid function** : $\sigma(x) = \frac{1}{1+e^{-x}}$
- **Hyperbolic Tangent function** : $\tanh(x) = \frac{e^{x}-e^{-x}}{e^{x}+e^{-x}}$
- **ReLU function** : $\text{ReLU}(x) = \max(0, x)$

d) **Learning rate :**

It is a hyperparameter that controls the step size while training a model. A very high learning rate leads to overshooting the minimum and and a very low learning rate leads to many iterations/ steps to be taken to reach the global minimum of the cost function. Hence it is essential to have an optimal learning rate for achieving fast convergence.

5.2



given:

$$W^{[1]} = \begin{bmatrix} 0.1 & 0.2 \\ -0.3 & 0.4 \\ 0.5 & -0.6 \end{bmatrix}$$

$$W^{[2]} = \begin{bmatrix} 0.7 \\ 0.8 \end{bmatrix}, \quad B^{[1]} = \begin{bmatrix} 0.1 \\ -0.2 \end{bmatrix}, \quad B^{[2]} = [0.3]$$

learning rate $\alpha = 0.1$, all activations are sigmoid and loss function is Mean square error.

$$A^{[1]} = \begin{bmatrix} 0.5 \\ 0.3 \\ -0.2 \end{bmatrix}, \quad Z^{[2]} = W^{[1]T} A^{[1]} + B^{[1]}$$

$$Z^{[2]} = \begin{bmatrix} 0.1 & -0.3 & 0.5 \\ 0.2 & 0.4 & -0.6 \end{bmatrix} \begin{bmatrix} 0.5 \\ 0.3 \\ -0.2 \end{bmatrix} + \begin{bmatrix} 0.1 \\ -0.2 \end{bmatrix}$$

$$\boxed{Z^{[2]} = \begin{bmatrix} -0.04 \\ 0.14 \end{bmatrix}}, \quad A^{[2]} = \sigma(Z^{[2]}) = \begin{bmatrix} 0.49 \\ 0.535 \end{bmatrix}$$

$$\boxed{A^{[2]} = \begin{bmatrix} 0.49 \\ 0.535 \end{bmatrix}}$$

$$\boxed{\sigma(z) = \frac{1}{1+e^{-z}}}$$

$$Z^{[3]} = W^{[2]T} A^{[2]} + B^{[2]} = \begin{bmatrix} 0.7 & 0.8 \end{bmatrix} \begin{bmatrix} 0.49 \\ 0.535 \end{bmatrix} + [0.3]$$

$$\boxed{Z^{[3]} = [1.071]}$$

$$A^{[3]} = \sigma(Z^{[3]}), \quad \boxed{A^{[3]} = [0.7447]}$$

After forward propogation, we get

$$A^{[2]} = \begin{bmatrix} 0.49 \\ 0.535 \end{bmatrix}, \quad A^{[3]} = [0.7447]$$

BACK PROPAGATION

$$C = \frac{1}{2N} \sum_{i=0}^{N-1} \left(a_i^{(2)} - y_i\right)^2$$

$C \rightarrow$ cost function (MSE), $a_i^{(2)} \rightarrow$ neurons of the output layer (here there are only 3 layers, hence, $a_i^{(2)}$)

$y_i \rightarrow$ target value or true value

$$C = \frac{1}{2}\left(a_0^{(2)} - y_t\right)^2$$

$y_t = 0.6$ (given)

$$\frac{\partial C}{\partial w_{00}^{(2)}} = \frac{\partial C}{\partial a_0^{(2)}} \times \frac{\partial a_0^{(2)}}{\partial w_{00}^{(2)}} = \left(a_0^{(2)} - y_t\right) a_0^{(1)} = (0.7447 - 0.6)(0.49) = 0.0709$$

$$\frac{\partial C}{\partial w_{01}^{(2)}} = \frac{\partial C}{\partial a_0^{(2)}} \times \frac{\partial a_0^{(2)}}{\partial w_{01}^{(2)}} = \left(a_0^{(2)} - y_t\right) a_1^{(1)} = (0.7447 - 0.6)(0.535) = 0.0774$$

$$\frac{\partial C}{\partial w_{00}^{(1)}} = \frac{\partial C}{\partial a_0^{(2)}} \times \frac{\partial a_0^{(2)}}{\partial a_0^{(1)}} \times \frac{\partial a_0^{(1)}}{\partial w_{00}^{(1)}} = \left(a_0^{(2)} - y_t\right) w_{00}^{(2)} a_0^{(0)} = 0.0506$$

$$\frac{\partial C}{\partial w_{01}^{(1)}} = \frac{\partial C}{\partial a_0^{(2)}} \times \frac{\partial a_0^{(2)}}{\partial a_0^{(1)}} \times \frac{\partial a_0^{(1)}}{\partial w_{01}^{(1)}} = \left(a_0^{(2)} - y_t\right) w_{00}^{(2)} a_1^{(0)} = 0.0304$$

$$\frac{\partial C}{\partial w_{02}^{(1)}} = \frac{\partial C}{\partial a_0^{(2)}} \times \frac{\partial a_0^{(2)}}{\partial a_0^{(1)}} \times \frac{\partial a_0^{(1)}}{\partial w_{02}^{(1)}} = \left(a_0^{(2)} - y_t\right) w_{00}^{(2)} a_2^{(0)} = -0.0203$$

$$\frac{\partial C}{\partial w_{10}^{(1)}} = \frac{\partial C}{\partial a_0^{(2)}} \times \frac{\partial a_0^{(2)}}{\partial a_1^{(1)}} \times \frac{\partial a_1^{(1)}}{\partial w_{10}^{(1)}} = \left(a_0^{(2)} - y_t\right) w_{01}^{(2)} a_0^{(0)} = 0.0579$$

$$\frac{\partial C}{\partial w_{11}^{(1)}} = \frac{\partial C}{\partial a_0^{(2)}} \times \frac{\partial a_0^{(2)}}{\partial a_1^{(1)}} \times \frac{\partial a_1^{(1)}}{\partial w_{11}^{(1)}} = \left(a_0^{(2)} - y_t\right) w_{01}^{(2)} a_1^{(0)} = 0.0347$$

$$\frac{\partial C}{\partial w_{12}^{(1)}} = \frac{\partial C}{\partial a_0^{(2)}} \times \frac{\partial a_0^{(2)}}{\partial a_1^{(1)}} \times \frac{\partial a_1^{(1)}}{\partial w_{12}^{(1)}} = \left(a_0^{(2)} - y_t\right) w_{01}^{(2)} a_2^{(0)} = -0.0231$$

$$\frac{\partial C}{\partial b_0^{(1)}} = \frac{\partial C}{\partial a_0^{(2)}} \times \frac{\partial a_0^{(2)}}{\partial a_0^{(1)}} \times \frac{\partial a_0^{(1)}}{\partial b_0^{(1)}} = \left(a_0^{(2)} - y_t\right) w_{00}^{(2)} = 0.1013$$

$$\frac{\partial C}{\partial b_1^{(1)}} = \frac{\partial C}{\partial a_0^{(2)}} \times \frac{\partial a_0^{(2)}}{\partial a_1^{(1)}} \times \frac{\partial a_1^{(1)}}{\partial b_1^{(1)}} = \left(a_0^{(2)} - y_t\right) w_{01}^{(2)} = 0.1158$$

$$\frac{\partial C}{\partial b_0^{(2)}} = \frac{\partial C}{\partial a_0^{(2)}} \times \frac{\partial a_0^{(2)}}{\partial b_0^{(2)}} = \left(a_0^{(2)} - y_t\right) = 0.1447$$

Updating weights and biases after back propagation.

$(w_{00}^{(1)})_{new} = w_{00}^{(1)} - \alpha \frac{\partial C}{\partial w_{00}^{(1)}} = 0.1 - 0.1(0.0306) = 0.09494$

$(w_{01}^{(1)})_{new} = w_{01}^{(1)} - \alpha \frac{\partial C}{\partial w_{01}^{(1)}} = -0.3 - 0.1(0.304) = -0.3304$

$(w_{02}^{(1)})_{new} = w_{02}^{(1)} - \alpha \frac{\partial C}{\partial w_{02}^{(1)}} = 0.5 - 0.1(-0.0203) = 0.50203$

$(w_{10}^{(1)})_{new} = w_{10}^{(1)} - \alpha \frac{\partial C}{\partial w_{10}^{(1)}} = 0.2 - 0.1(0.579) = 0.1421$

$(w_{11}^{(1)})_{new} = w_{11}^{(1)} - \alpha \frac{\partial C}{\partial w_{11}^{(1)}} = 0.4 - 0.1(0.0347) = 0.3965$

$(w_{12}^{(1)})_{new} = w_{12}^{(1)} - \alpha \frac{\partial C}{\partial w_{12}^{(1)}} = -0.6 - 0.1(-0.0231) = -0.59769$

$(w_{00}^{(2)})_{new} = w_{00}^{(2)} - \alpha \frac{\partial C}{\partial w_{00}^{(2)}} = 0.7 - 0.1(0.0709) = 0.69291$

$(w_{01}^{(2)})_{new} = w_{01}^{(2)} - \alpha \frac{\partial C}{\partial w_{01}^{(2)}} = 0.8 - 0.1(0.0774) = 0.79226$

$(b_0^{(2)})_{new} = b_0^{(2)} - \alpha \frac{\partial C}{\partial b_0^{(2)}} = 0.3 - 0.1(0.1447) = 0.28553$

$(b_0^{(1)})_{new} = b_0^{(1)} - \alpha \frac{\partial C}{\partial b_0^{(1)}} = 0.1 - 0.1(0.1013) = 0.08987$

$(b_1^{(1)})_{new} = b_1^{(1)} - \alpha \frac{\partial C}{\partial b_1^{(1)}} = -0.2 - 0.1(0.1158) = -0.21158$

5.3

Suppose we assign all weights to 0. Now we do forward pass and the value of neurons in the neural network will be equal to the corresponding bias terms and now we compute the loss and to minimize the we do back propagation. The problem with this approach is that after we do back propagation we end up with same value for all the weights. This is going to severely affect the learning process of our model. The whole point of introducing weights was the fact that some neural network transmissions are more important than the other, so the connection with a higher weight will have higher influence on the value of the neuron and the one with lower weight will have lesser influence on the value of the neuron. This problem can be avoided by assigning random numbers as weights to the neural network.

6 Image Processing

6.1

As per the given approach, we are undersampling the given 512 X 512 image to get a 256 X 256 image. When we undersample, we are actually using fewer pixels than required to represent the original image. Due to this fact, we fail to capture fine details of the original image leading to loss of information and low resolution of the output image.

6.2

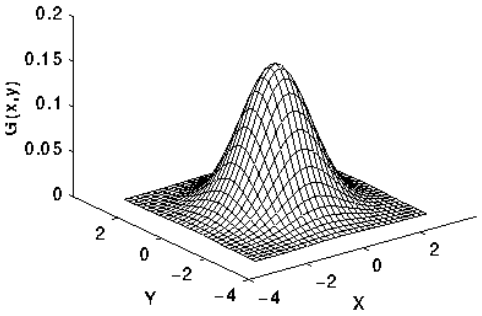
- By Nyquist-Shannon Sampling theorem, a continuous time signal can be reconstructed from its samples only if the sampling frequency is greater than or equal to twice the maximum frequency present in the input signal ie. $f_s \geq 2f_{max}$ where f_s is the sampling frequency and f_{max} is the maximum frequency component of the input signal. The Shannon theorem gives the minimum sampling rate required to capture all the information of the signal accurately.
- When undersampling is done, the sampling frequency is less than the required sampling frequency as per Nyquist theorem and this leads to phenomenon like Aliasing and loss of the high frequency components of the input signal (in this case the input image). Aliasing refers to the phenomenon where high frequency components of the input image is distorted and this happens when the sampling theorem condition is not met.
- This is precisely the reason for the lack of clarity or resolution of the output image since there is loss of information/fine details due to undersampling.
- This issue can be solved by passing the input image to a low pass filter before the sampling process is done. A low pass filter, as the names suggests, only allows the low frequency signals to pass through and blocks the high frequency components. This prevents aliasing by making sure that no high frequencies are able to alias into the lower frequencies during the sampling process. This makes sure that the high frequency components of the input image are removed before sampling and hence ensures that the Shannon theorem is followed. With this modification, we can ensure that the new image still looks like the original painting.

6.3

- **Gaussian filter** : It is a low pass filter widely used in image processing for blurring, smoothening and reducing noise. The Gaussian function in 2D is given by

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

  where x and y represent the vertical and horizontal distances from the center of kernel respectively and σ refers to the standard deviation of the Gaussian function. Higher the value of σ, more broader the Gaussian function becomes which leads to greater smoothening of the input image. The 3X3 and 5X5 kernels of the Gaussian filter are shown below.



(a) Plot of the 2D Gaussian function.

$$\frac{1}{16} \times \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} \qquad \frac{1}{273} \times \begin{bmatrix} 1 & 4 & 7 & 4 & 1 \\ 4 & 16 & 26 & 16 & 4 \\ 7 & 26 & 41 & 26 & 7 \\ 4 & 16 & 26 & 16 & 4 \\ 1 & 4 & 7 & 4 & 1 \end{bmatrix}$$

(b) 3x3 and 5x5 kernels of the Gaussian filter.

Figure 4: Gaussian function and kernels of the Gaussian filter

- **Sobel filters** : These are the high pass filters used in image processing particularly for tasks like edge detection. They emphasize regions of rapid pixel intensity changes like edges or boundaries by calculating the gradient of the image intensity. Sobel filters consist of two seperate kernels, one for computing the gradient along x axis (horizontal direction) and the other for computing the gradient along y axis (vertical direction).

$$S_x = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix}$$

$$S_y = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix}$$

Figure 5: The Sobel filter kernels for the x and y directions respectively

- **Box filter** : also known was mean filter is a low pass filter used for smoothening or blurring the input image. It substitutes the every pixel in the image with the average value of the surrounding pixels and the pixel itself. They are more effective than Gaussian filters when it comes to blurring the image but may not preserve edges and boundaries like Gaussian filters. This is due to the difference in distribution of weights in the kernel. In Gaussian filter the weights are high close to the centre of the kernel and decrease as you move away but in box filter it is basically averaging of all the pixel values within the region of the kernel (the weights are uniform).

$$\frac{1}{9} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Figure 6: 3x3 box filter kernels

7 An Ant's journey

7.1

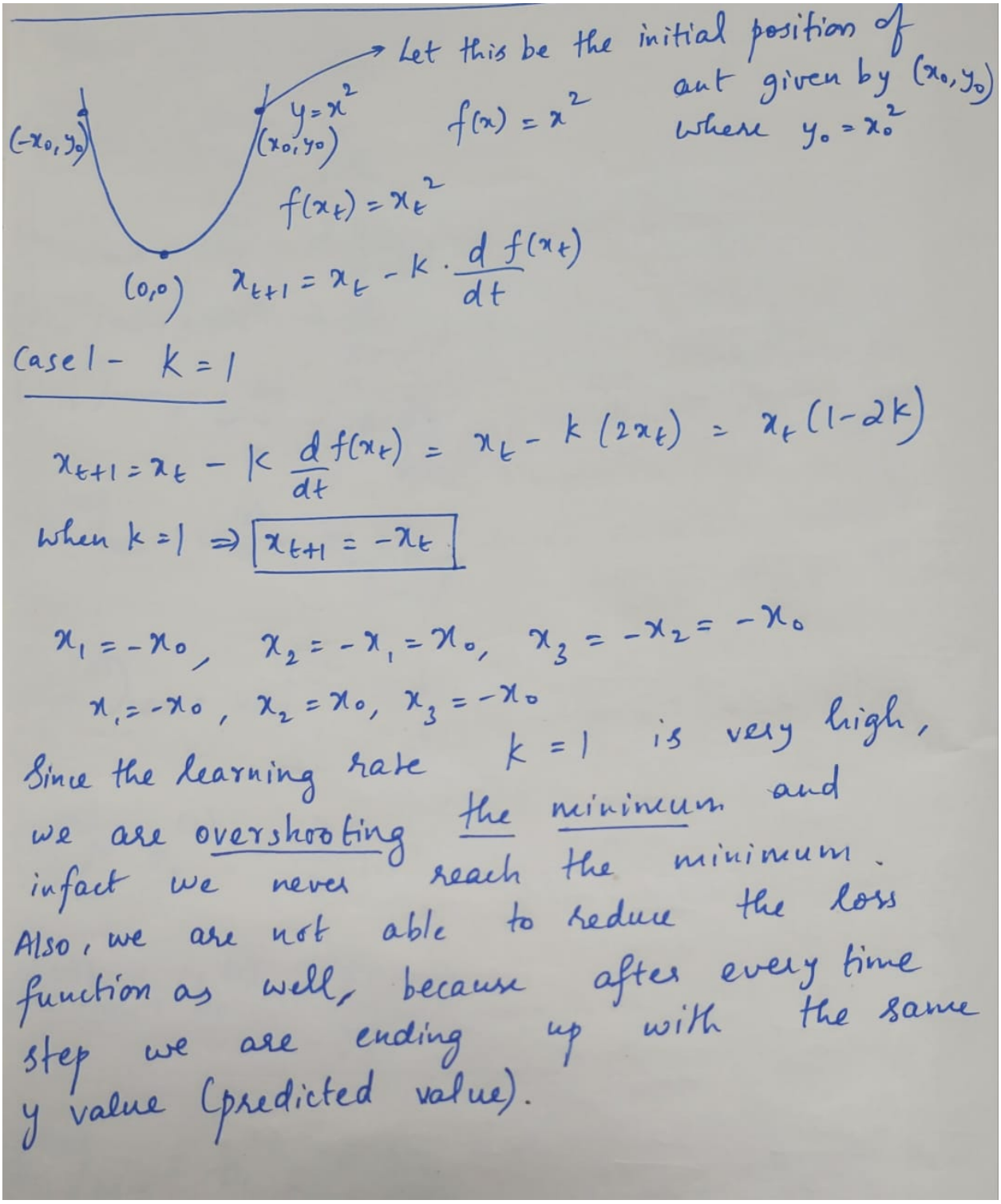


Figure 7: Analysis of the case where learning rate =1

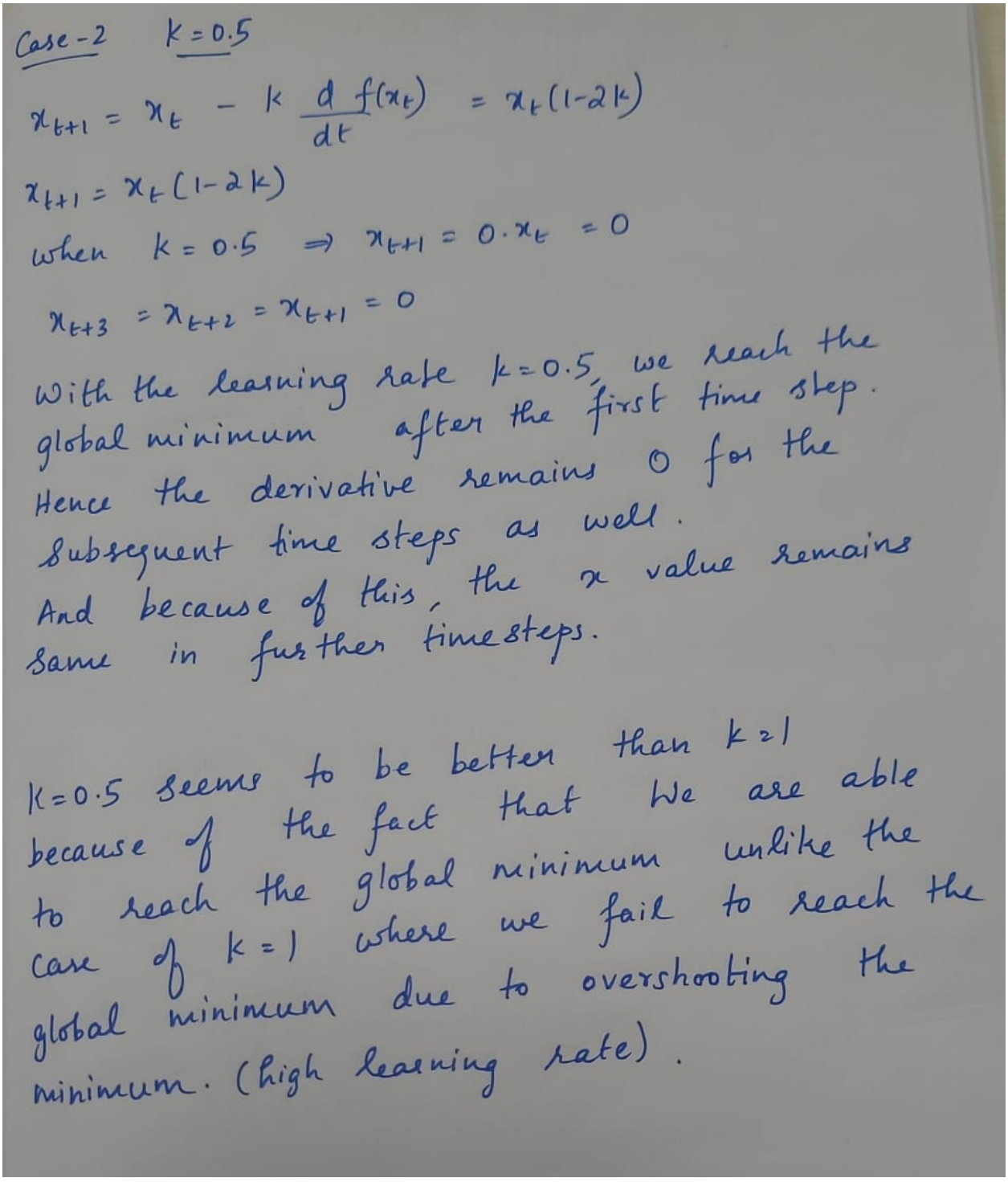


Figure 8: Analysis of the case where learning rate =0.5

7.2

- The first strategy mentioned is stochastic gradient descent with momentum. These are the equations proposed for the first strategy

$$v_{t+1} = \mu v_t - \kappa \nabla f(x_t, y_t, z_t) \tag{1}$$

$$(x_{t+1}, y_{t+1}, z_{t+1}) = (x_t, y_t, z_t) + v_{t+1} \tag{2}$$

- In the first equation,
  - v_t refers to the momentum vector at iteration t, that is the moving average of the gradients.
  - ∇ refers to the gradient of the 3D function at the point (x_t, y_t, z_t).
  - μ and κ are adjustable constants.
- The second equation is the update step where the location of the ant on the 3D terrain is updated.
- This is a better strategy than the strategy proposed in the first part of the question (gradient descent). In the update equation, the position of the ant is being updated by a momentum vector which can be interpreted as an exponential moving average of the gradients.
- While implementing gradient descent we come across oscillations while updating parameters which leads to slower convergence and leads to a lot of computational effort whereas when we implement gradient descent with momentum, it dampens the oscillations and helps in achieving faster convergence. This is a better strategy compared to gradient descent for the ant since it will help the ant to reach its food faster.
- The second strategy is RMSProp. These are the equations proposed for the second strategy.

$$S_{t+1} = \gamma S_t + (1-\gamma) \nabla f(x_t, y_t, z_t)^2 \tag{3}$$

$$v_{t+1} = -\kappa \frac{\nabla f(x_t, y_t, z_t)}{\sqrt{S_{t+1} + \epsilon}} \tag{4}$$

$$(x_{t+1}, y_{t+1}, z_{t+1}) = (x_t, y_t, z_t) + v_{t+1} \tag{5}$$

- In the third equation,
  - S_t refers to the accumulated square gradients.
  - ∇ refers to the gradient of the 3D function at the point (x_t, y_t, z_t).
  - γ refers to the decay parameter.
  - ϵ is a constant to avoid division by zero.
- The fifth equation is the update step where the location of the ant on the 3D terrain is updated.
- The second strategy proposed is RMSProp optimization algorithm. It help in achieving faster convergence than both Gradient Descent and Gradient Descent with momentum. In RMSProp algorithm, moving average of square of gradients is computed and the learning rate is effectively divided by the square root of this moving average. Hence comes the name Root mean square propagation. This dampens oscillations further by scaling the learning rate which helps in achieving faster convergence. Hence this is the best among the proposed strategies for the ant to reach the food !
- In the case of neural networks, the goal is to come up with weights and biases such that the loss function is minimum. For this we first do forward pass and then compute the loss function , then through back propagation we update the weights and biases till we minimize our cost function. Optimization Algorithms are used to minimize the cost function and for example if we consider the cost function as Mean Square Error then the scenario becomes similar to the ant problem. The goal in the ant problem was to help the ant reach the food at the global minimum whereas the goal in Neural networks is to minimize the Cost function. Among the proposed algorithms RMSProp helps in achieving faster convergence compared to the other two due to the reasons explained above.

8 RNNs

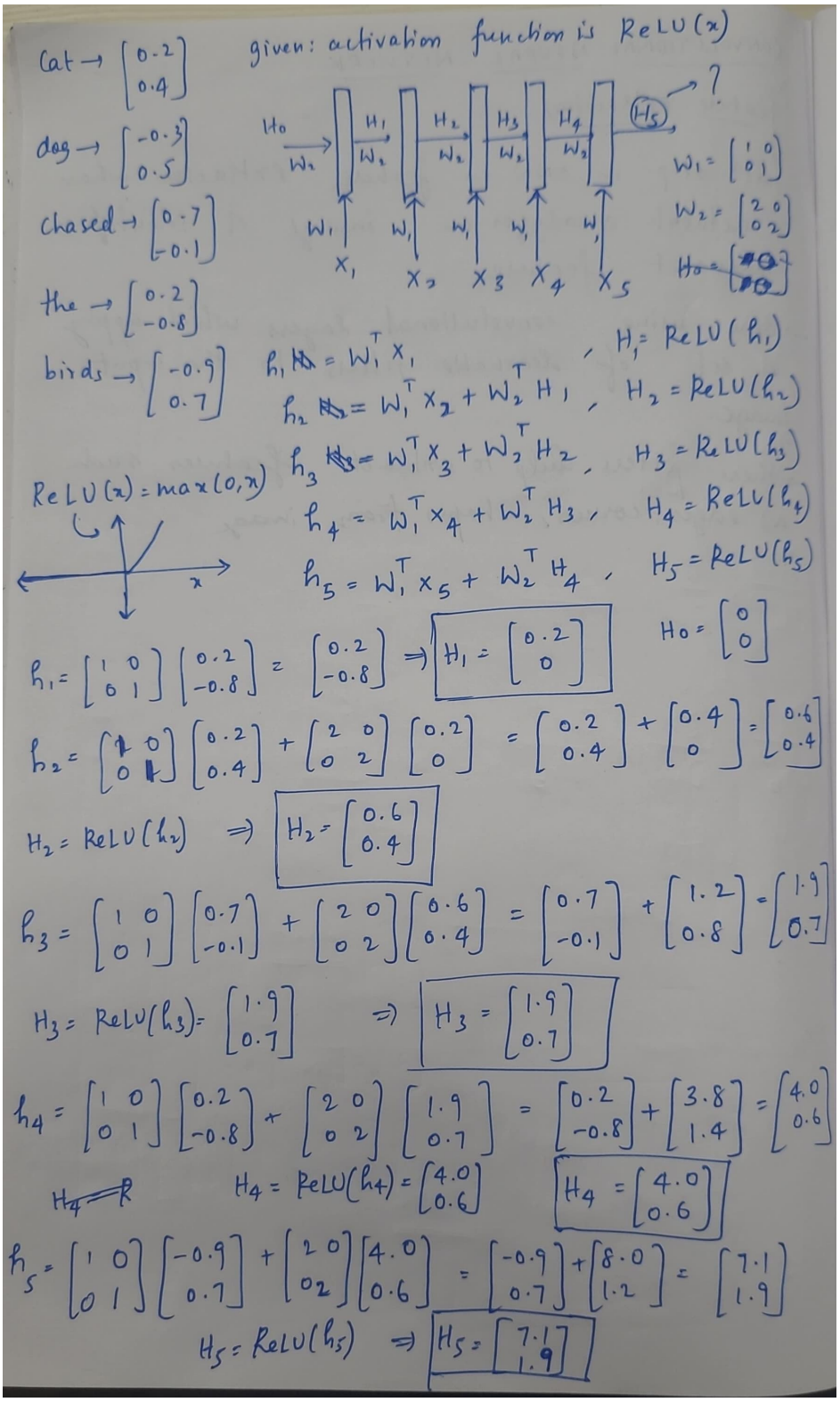


Figure 9: Calculation of the hidden states of the RNN