Visualization of Loss Landscapes in Neural Nets to identify minima of loss functions
CS 529: Visual Data Science

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Project Manager: Varunya Yanamadala

Client: Dr. Sathya Narayanan Ravi, Assistant Professor, Department of Computer Science, University of Illinois at Chicago

Data Links:
https://drive.google.com/file/d/12oxkvfaKcPyyHiOevVNTBzaQ1zAFlNPX/view
https://drive.google.com/file/d/1eUvYy3HaiCVHTzi3MHEZGgrGOPACLMkR/view

Project Idea:
The idea of the project is to understand the geometry of the loss function landscape in terms of sharpness or flatness and to estimate on the loss function values.

Project Proposal Slides:
https://drive.google.com/open?id=13vaPc7azUNvtaluHBUDyk5rkUbvEfPpD

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Requirement Analysis

1. Humans

- Machine Learning Researchers
- Machine Learning Engineers
- Machine Learning Modelers
- Architects or Designers of Neural Networks
- The usage frequency ranges from at least a couple of times a day and should be up until all observations can be studied.
- Access is available 24x7
- User could use anywhere.

2. Tasks

High Level:
Select a particular algorithm and different parameters of that algorithm are displayed. A visualization is displayed to understand the local minima values that can be attained at different parameter values.

Questions Prioritized:

- Can by any means a user compare one or more algorithms of interest?
- Can a representation of one algorithm be overlaid on the other for comparison?
- Could we have an indicator to show the global minimum for the model?
- Can the stability of predictions in parameter space be studied?
- Can the user get to any conclusion the complexity of the model selected?
- Could few parameters be changed to see its effect on the overall loss landscape?
- Can we compare the parameter set values for the similar loss function value in a network?

3. Data

- Network models information:
  This multivariate data contains information related to the network architecture parameters - number of layers, the width of each layer, edges – connectivity, biases, skip connections, etc.,
- Loss function values:
  This data contains the loss function values for parameter set of a model.

4. Flow

The flow of the system is as follows:

- The user lands on the main page where he could see the types of algorithms.
- The user could select an algorithm, the visualization depicting the loss function values is shown.
- The user could hover over a point of interest to see the values.
- Since the visualization is a representation of non-convex loss function, the user could select the wireframe option to observe the descent in any local space.
- A representation of how the architecture looks is also displayed to the right to help the architectures understand the neural network model.

5. Non-functional Requirements

Performance
The system should have faster response times

Scalability
The developed system should have great adjustability from laptops, desktops to larger displays.

Accessibility
Cross-platform and preferably should be able to run using an executable file. This is not hosted on any server and is not viewed on browser.

Reliability
There is no server downtime, as it's a standalone application. It should be accessible at all times for the users.

Security
No need of data security.

Privacy
No restriction on data accessibility.

User Experience
No training should be required, should be understandable by the user how to operate through and the user should be able to navigate through the flows easily.

6. Probes

Rationale for visualization

Visualization wasn't used in this field of identifying the loss function values in neural networks. It is a novel approach to help the researchers to identify the minimizers and global minimum for an algorithm of interest.

Alternative tools

There is no tool present which is publicly available. A base version of the selected paper was released by Telesens. We intend to improvise the visualization so that the above objectives are achieved.

Other possibilities

Could be integrated with data residing on a server increasing the scope for integrating more up-to-date algorithms, making the visualization system dynamic.

Work Plan of the project

Week1 – Week2: Understand the data background on how its generated and check for the ways of converting the data as required for visualization. Prepare functional requirements document.

Week3 – Week4: Produce prototypes using Five Design Sheet methodology and take approval from the client. Develop alpha phase of the visualization and present to the client.

Week5 – Week7: Corrections (if any) of the existing system and continue with other requirements of the project; be ready for beta release.

Week8: Get a final approval of the client. Prepare the final abstract, and for presentation and demonstration of the project.

Tools

Github: https://github.com/VarunyaY/CS-529-NN_Loss_Function_Visualization

Bug Tracker:
https://github.com/VarunyaY/CS-529-NN_Loss_Function_Visualization/issues

Calendar:
https://calendar.google.com/calendar/b/1/r?cid=NHBxbzE0amY5b3VtNjVwMHBob2gzbnJrdGtAZ3JvdXAuY2FsZW5kYXIuZ29vZ2xlLmNvbQ

Communication: Slack

Data and Tasks Abstraction

Data Abstraction

The dataset has data related to 4 models each corresponding to a neural network architecture.

Dataset Type:

Table (Multivariate, Information Visualization)

All the data available is static

Attributes:

Model Name

- Name of the neural network (Categorical)

X - Direction: Quantitative (ordering direction: diverging, range: -1 to 1)

Y - Direction: Quantitative (ordering direction: diverging, range: -1 to 1)

- X - direction and Y - direction are random filter normalized directions

Train loss: Quantitative (ordering direction: sequential)

- Indicates the training loss of the model

Train Accuracy: (ordering direction: sequential)

- Indicates the training accuracy of the model

Test Loss: (ordering direction: sequential)

- Indicates the testing loss of the model

Task Abstraction

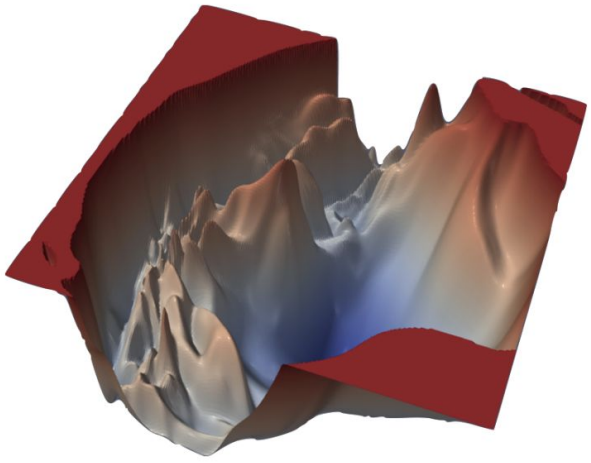
Analyse	**Consume**	**Present** • Loss values for different values of parameters.
	Lookup	• The other objective is to lookup for both global and local minimum values.

Search	**Browse**	• Should be able to search for values less than a particular value by the visual encoding.
Query	**Identify**	• Should help identify the local minima and the global minima of each model considered.
	Compare	• Allows to compare the global minima of models
	Summarize	• Gives an overall view of the minima values as per directions.

State of the Art Report

1) Existing Tools/ Systems

- 3D Visualizer: A base version of the proposal developed using the idea from the research paper - *Visualizing the Loss Landscape of Neural Nets*. NIPS, 2018.
- It has a landscape visualisation. But does not let the user view the X, Y random filter normalized directions at a particular level of loss. No other encodings were used to make the system more explorative. Our system aims to add these features thereby making it more effective in terms of drawing conclusions.



2) Visual Encodings of the dataset types

- 3D landscape, bubble plots, heatmaps or other encodings for static tabular data:overview of loss and accuracy.

- Position: To indicate the random filter normalized directions of both X and Y.
- Color (hue): To indicate local and global minima of different models.
- Position or Color: To indicate loss and accuracy values.

3) Interaction techniques/systems for the tasks

The interactions with the systems will be mostly clicking and hovering.

- Buttons and drop down menu to select a model
- Hovering on the loss function visualization will display the corresponding random filter normalized directions. (X - direction and Y - direction)
- Filter the loss values using a slider

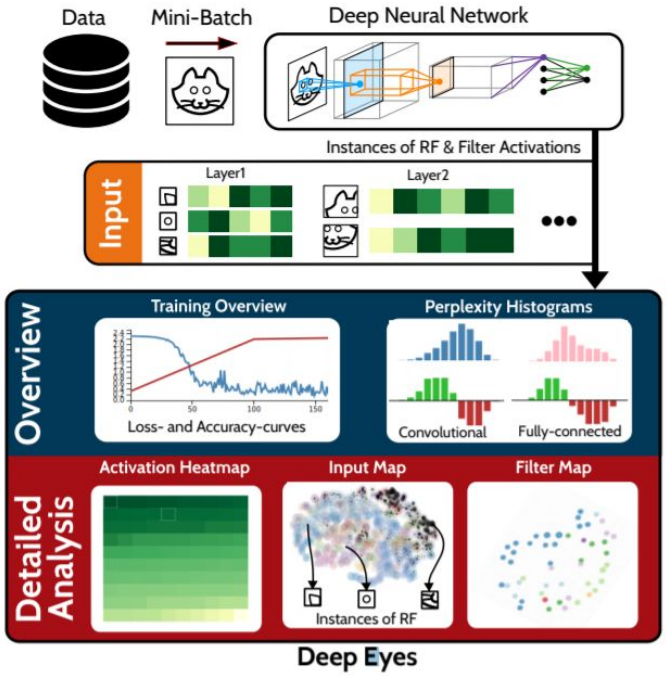
Highlighting

- To indicate loss values only above a particular threshold

4) Comparison with related works

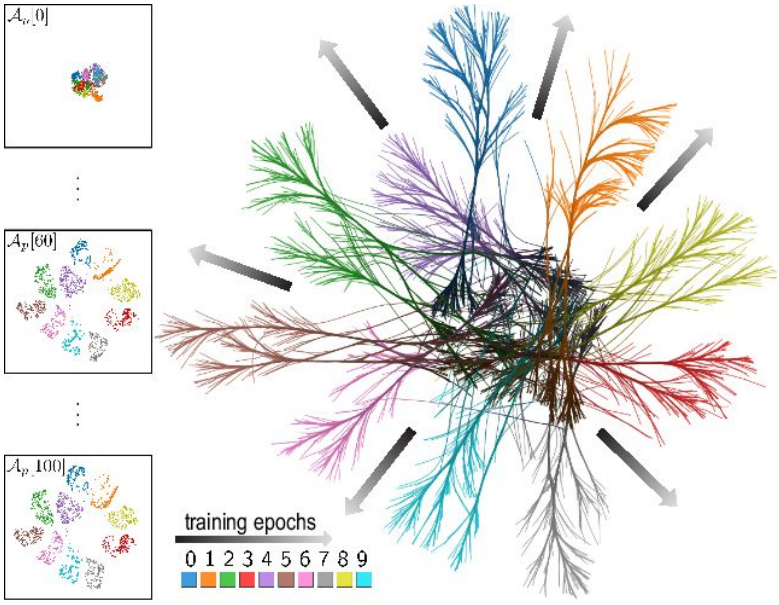
i) DeepEyes: Progressive Visual Analytics for Designing Deep Neural Networks: Link

- The system facilitates the identification of problems, such as superfluous filters or layers, and information that is not being captured by the network
- The system doesn't emphasize on loss function with reduced parameter space.
- The paper uses a line chart to indicate loss values of a neural network.



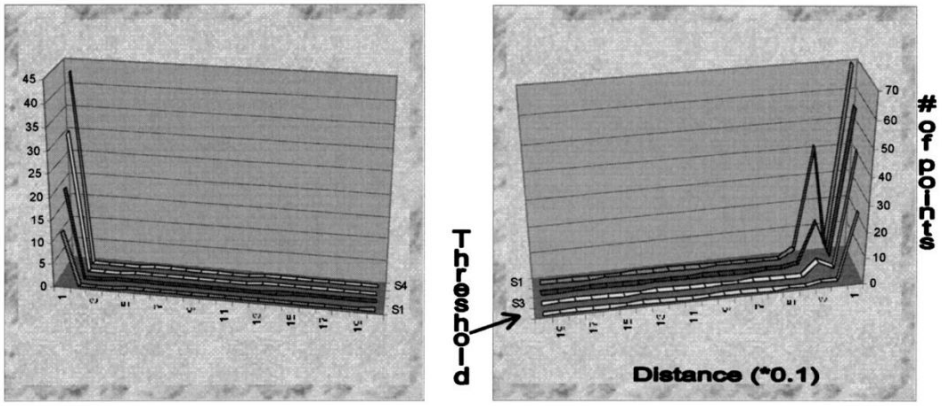
ii) Visualizing the Hidden Activity of Artificial Neural Networks: Link

- The paper shows we show how visualization can provide highly valuable feedback for network designers.
- The paper does not focus on the losses and accuracies of the said hidden activities.
- The encoding used for clustering in the paper can be used to indicate the X and Y directions for a particular loss value.



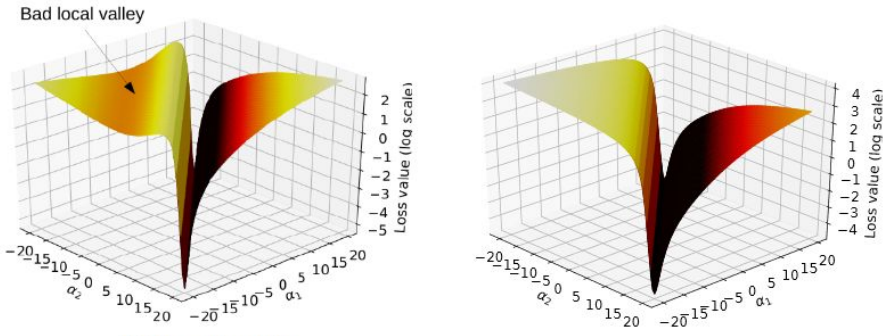
iii) Visualization of neural-network gaps based on error analysis: Link

- Presents a methodology for detection of neural-network gaps (NNGs) based on error analysis and the visualization that is applicable to the n-dimensional I/O domain.
- There is no emphasis on errors caused specifically due to losses.
- The paper uses a 3D bar chart to indicate loss values for different thresholds. This may be used for our project to visualize loss values of different models. But, usage of a 3D bar chart is not suitable since it causes visual occlusion and hinders drawing of conclusions. Hence, we rule out 3D bar chart as a viable encoding for our data.



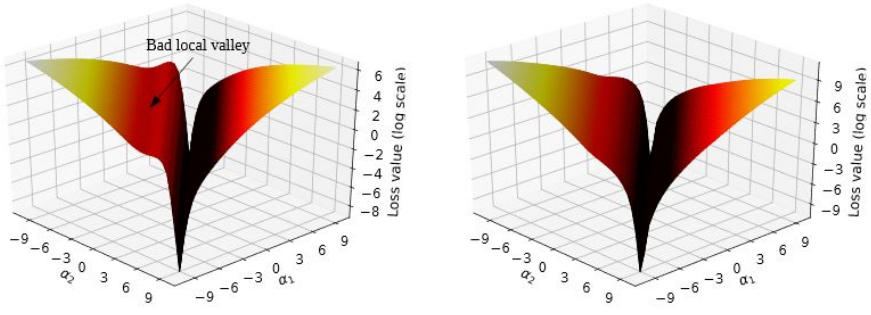
iv) On the loss landscape of a class of deep neural networks with no bad local valleys: [Link]

- The paper identifies a class of over-parameterized deep neural networks with standard activation functions and cross-entropy loss which probably have no bad local valley.
- The paper shows loss can be visualised in 3D as a landscape which makes it easy to identify local, global minima and maxima



(a) Sigmoid, no skip (b) Sigmoid, with skip

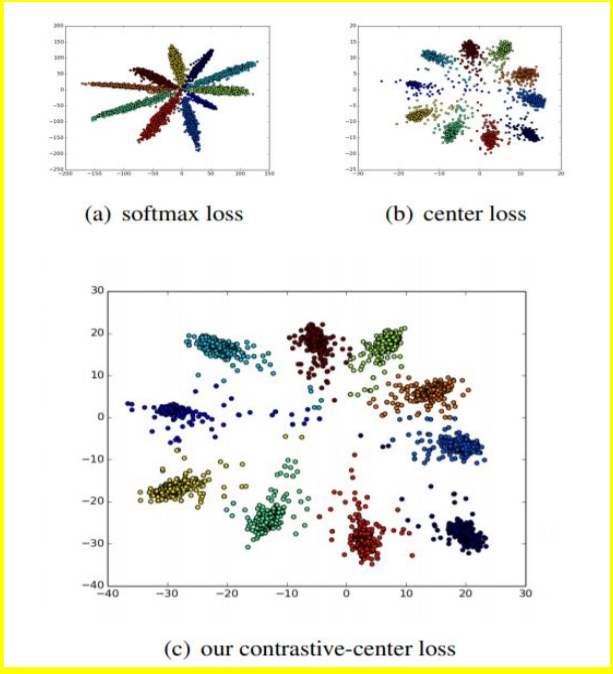
Figure 3: Loss surface of a two-hidden-layer network on a small MNIST dataset.



(a) Softplus, no skip (b) Softplus, with skip

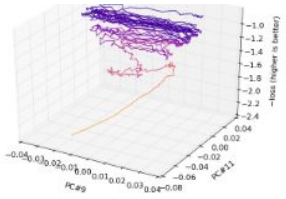
v) Contrastive-center loss for deep neural networks: Link

- This paper proposes a novel auxiliary supervision signal called contrastive-center loss, which can further enhance the discriminative power of the features.
- The paper visualises loss as a scatterplot which can be extended to our case.

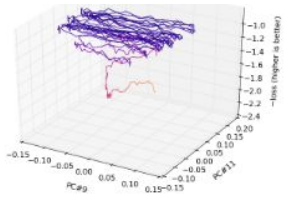


vi) Visualizing Deep Network Training Trajectories with PCA: Link

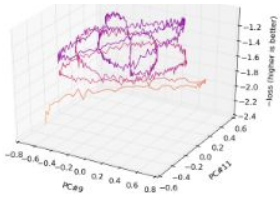
- The paper aims to visualize training trajectories.
- The author uses principal component analysis (PCA) reduce the dimensionality of the parameter trajectory.
- The paper tries to visualize loss in 3D. This method can be used to visualize loss as a landscape in 3D.



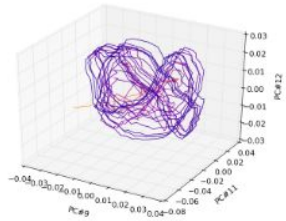
(a) $\mu = 0.5$; neg loss vs. PCs 9 and 11



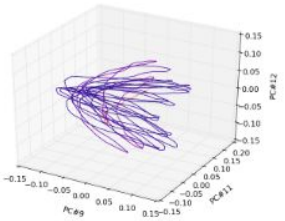
(b) $\mu = 0.9$; neg loss vs. PCs 9 and 11



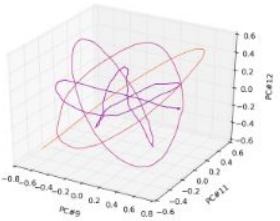
(c) $\mu = 0.99$; neg loss vs. PCs 9 and 11



(d) $\mu = 0.5$; PCs 9, 11, 12



(e) $\mu = 0.9$; PCs 9, 11, 12



(f) $\mu = 0.99$; PCs 9, 11, 12

vii) Visualization methods for neural networks: [Link]

- The authors propose a framework for visualization methods suited for feed forward neural networks. The basic idea is to use the spatial information available outside the network to arrange the data to be visualized (weights, activations of units) in the spatial domain of the display.
- The work does not specify methods to visualize losses and accuracy.
- The heatmap given in the paper(weight visualisation) can be used as an encoding to indicate the loss values for different X and Y filter normalized directions.

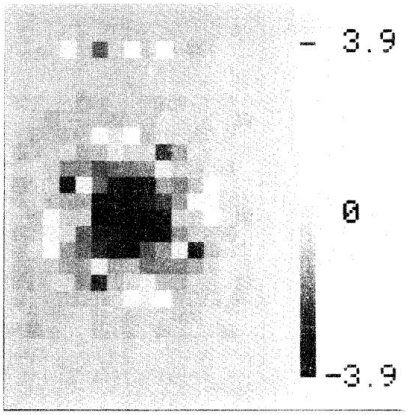
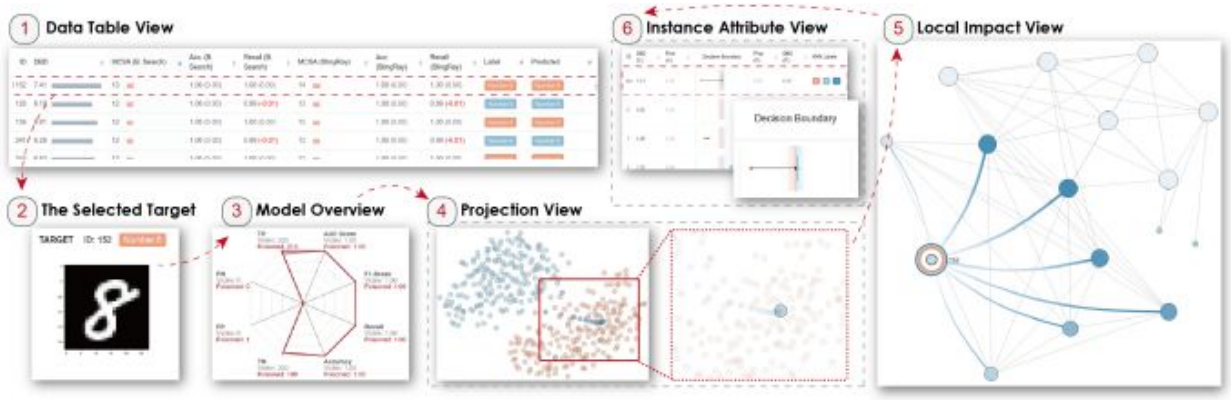


Fig. 4 *WV-diagram for one hidden unit*

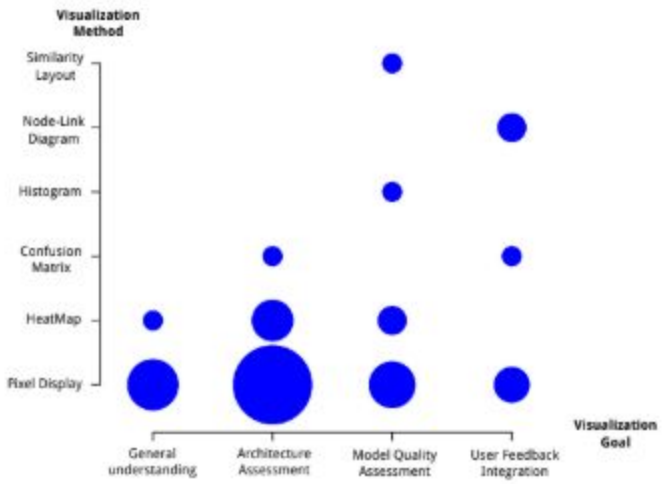
viii) Explaining Vulnerabilities to Adversarial Machine Learning through Visual Analytics: Link

- The radar chart shown in the paper is useful to convey both loss and accuracy without any visual occlusion.
- The cross-sectional view of a part of the points shown below from the paper can be applied to the project to indicate the X and Y values having a particular loss level. This interaction gives the user details about similarity in loss values in relation to X-direction and Y-direction.



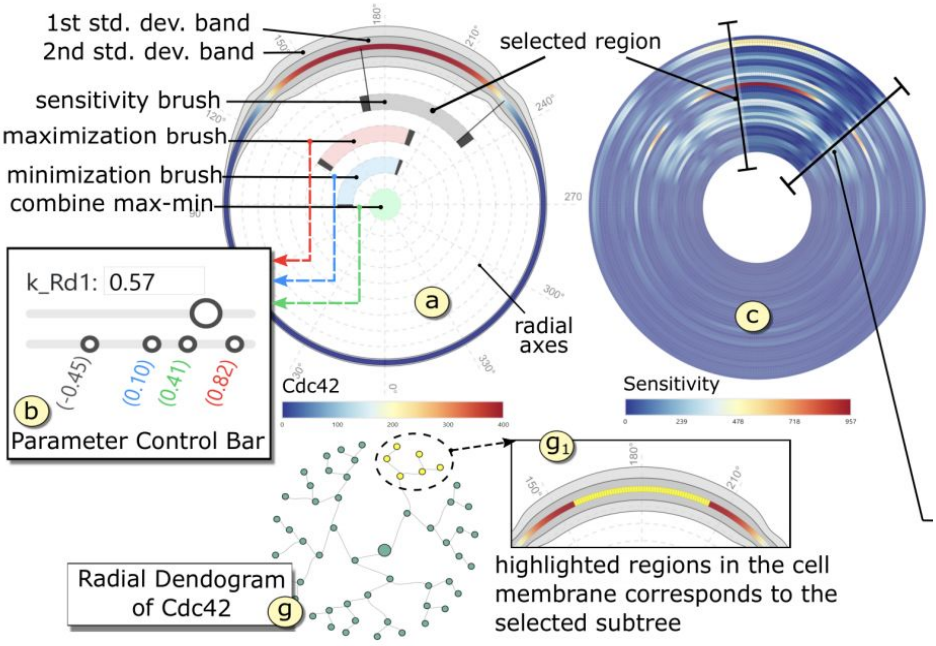
ix) Visualizations of Deep Neural Networks in Computer Vision: A Survey link

- The bubble plot shown below from the paper is a good representation for loss and accuracy of two or more models. The size of circle would be a good indicator for the loss/accuracy values at a given X and Y filter normalized direction. In order to distinguish between loss values of various models the circles can be given different colors. However, indicating loss and accuracies at all the values of different models will still result in an occlusion.



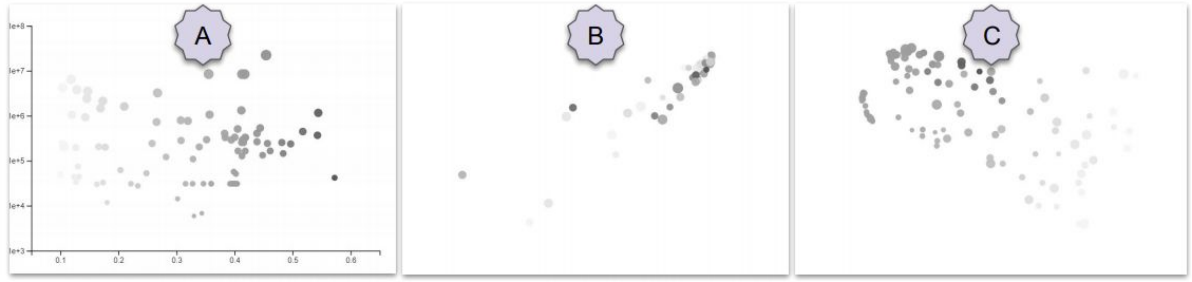
x) Neural Network Assisted Visual Analysis of Yeast Cell Polarization Simulation: Link

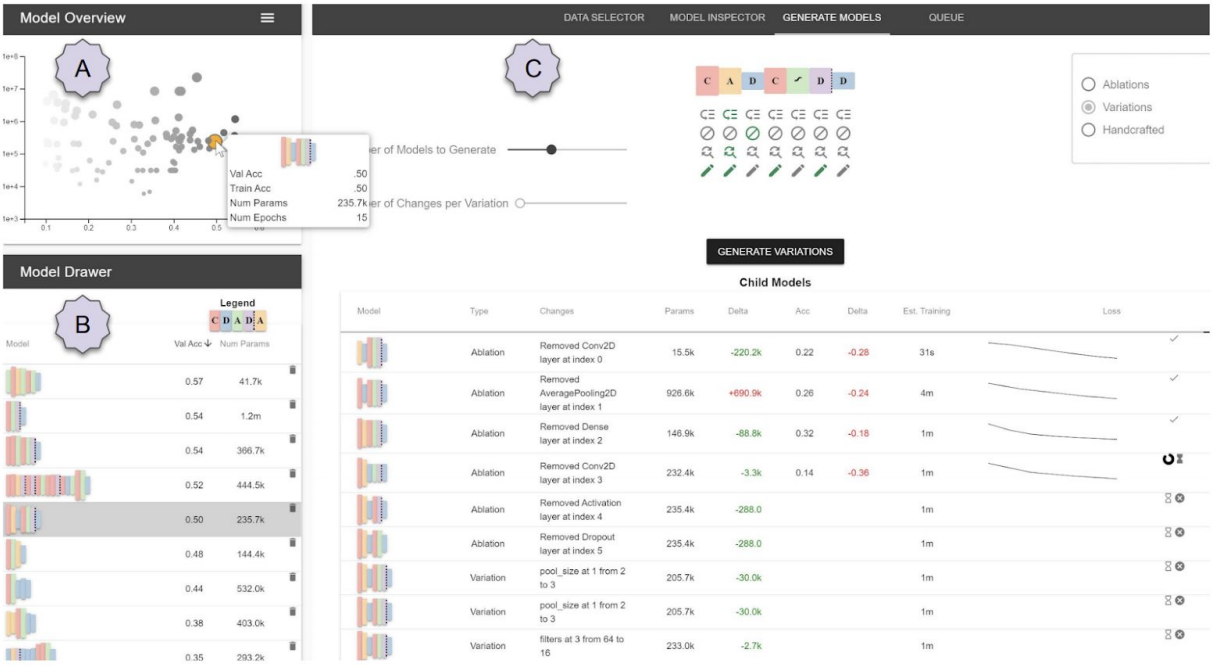
- The radial chart in a could be leveraged for model comparison, highlighting the same loss value ranges and study the spread of x, y values.



xi) Ablate, Variate, and Contemplate: Visual Analytics for Discovering Neural Architectures: Link

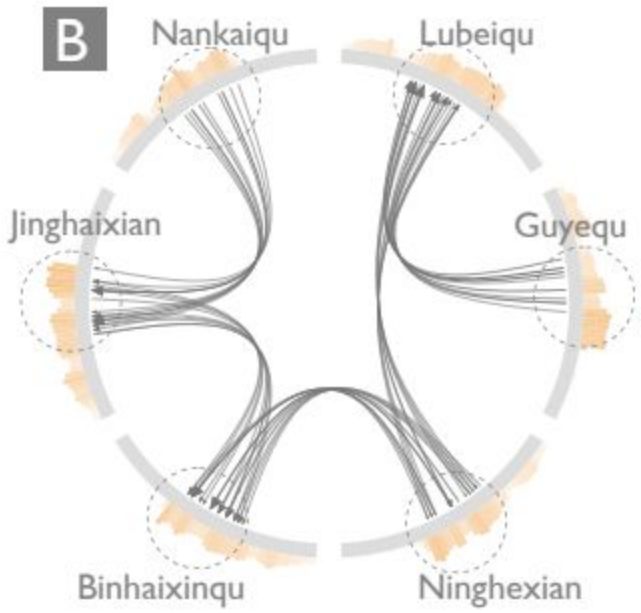
- The future scope of our project is in high similarity to the problem discussed in the paper. A user could model a network and view the results of the network before hand to know its accuracy vs log of parameters.





xii) AirVis: Visual Analytics of Air Pollution Propagation : [Link]

- The idea is to incorporate different network models as arcs and for a x, y pair, the loss or accuracy value could be highlighted.
- Or for a loss value what are the corresponding x, y values in other network models.



Functional Specifications

This spec is complete, to the best of our knowledge, but if we forgot something, please tell us. This functional spec provides several scenarios to be reviewed by the domain experts, as well as what the system will *not* do, given the constraints of this course.

Author: Varunya Yanamadala

Scenario 1: Load an existing model, explore the values at each individual point, and observe descent in any local space. [Sai Aakarsh Reddy Koppula]

Tony Stark, apart from his other responsibilities is also a machine learning modeler. Mr. Stark wishes to learn more about the loss function of a neural network. He opens the visualization of loss landscape in neural nets, where he sees options of pick algorithms and options to compare the results of the algorithms by overlapping them on each other. He selects an algorithm to observe it closely, he hovers the mouse over various points on the visualization and sees the values corresponding to those points displayed on the screen. He is also able to observe the descent in any local space and is happy to see a representation of architecture on the right.

Scenario 2: Load an existing model, explore all the possible minima associated with the architecture selected. [Varunya Yanamadala]

Bruce Banner, an aspiring PhD browses through the outcomes he received in his “Conundrum Of Network Losses”. He decides to see the values in graphical representation and opens the visualization on the browser. He selects ResNet in the options available. He sees a landscape of values. He selects the region of a valley to see more details. Amazed by the details, he spots a deepest valley. He realizes that it’s the global minimum value. He now understands that ResNet is better than the network he is working on and continues to enhance his work.

Scenario 3: Load two models simultaneously in an overlaying fashion to compare them. [Ramana Rao Akula]

Steve Rogers, a Machine Learning enthusiast and researcher has enrolled in the fall class on Neural Networks. Once in his class he gets an assignment to study two Neural Networks and compare them. Running deep in his thoughts on how to complete his assignment he opens the visualization and selects DenseNet and ResNet.

The system shows the visualizations of loss functions of both models on top of each other. Denser then quickly identifies which model has higher global loss. He writes this observation in the assignment. But, he suddenly finds that the model which has higher loss is better than the other one in some regions. Denser then notes this fact in his assignment. This way the system helps him compare various Neural Networks.

Non functional specifications:

Performance
The system should have faster response times

Scalability
The developed system should have great adjustability from laptops, desktops to larger displays.

Reliability
It should be accessible at all times for the users.

Security
No need of data security.

Privacy
No restriction on data accessibility.

User Experience
No training should be required, should be understandable by the user how to operate through and the user should be able to navigate through the flows easily.

Non-goals:
The visualisation system doesn't support dynamic data presentation.
The visualisation system currently supports data related to four neural networks.

Goals and Targets

Targets

Low Target:

- Show the global minimum of a neural network so that it can be differentiated easily from the local minima
- Show detailed view at various levels of loss as per user's requirement

Desirable Target:

- Overlay visualizations on top of each other
- Compare one or more neural network models

High Target:

- An understanding on stability of the minima

Extras:

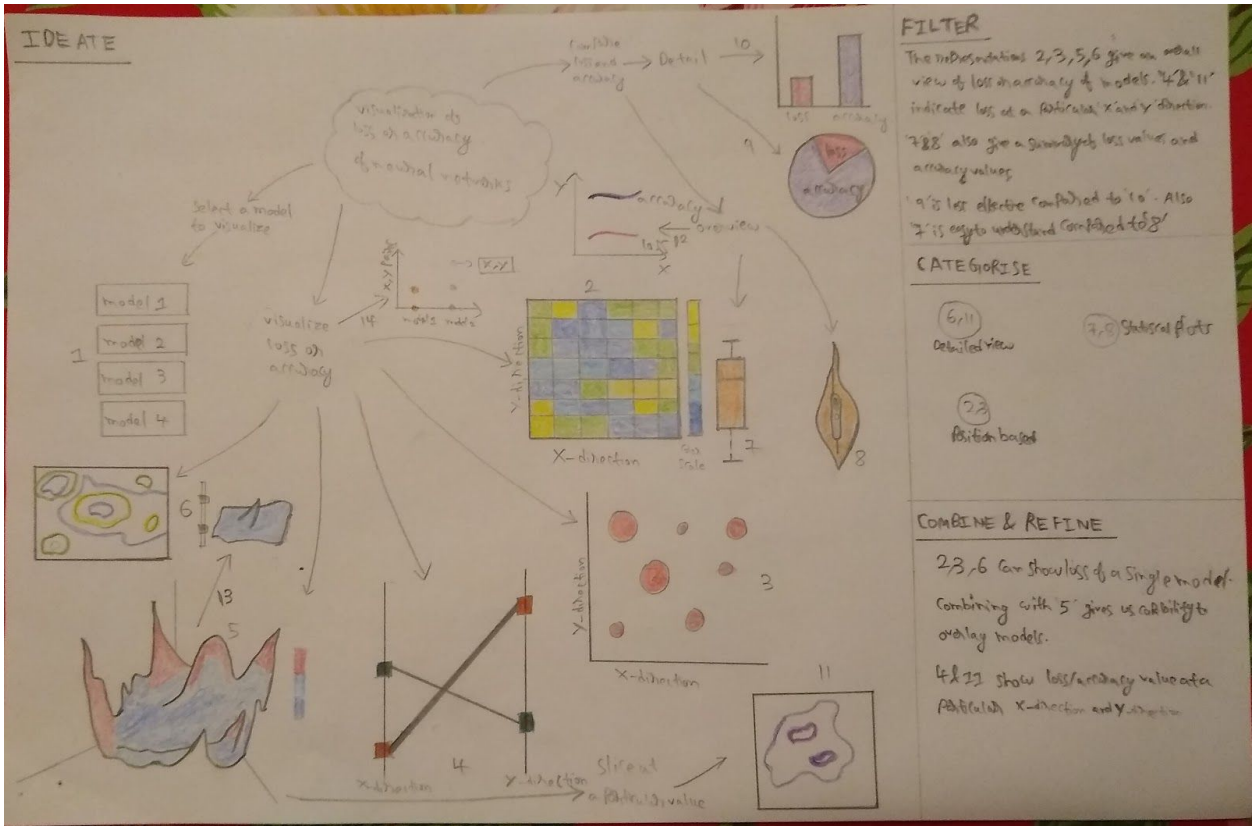
- Include additional neural network models
- Make it a stand alone application
- Create visualizations for additional data which can be obtained using Pytorch

Goals

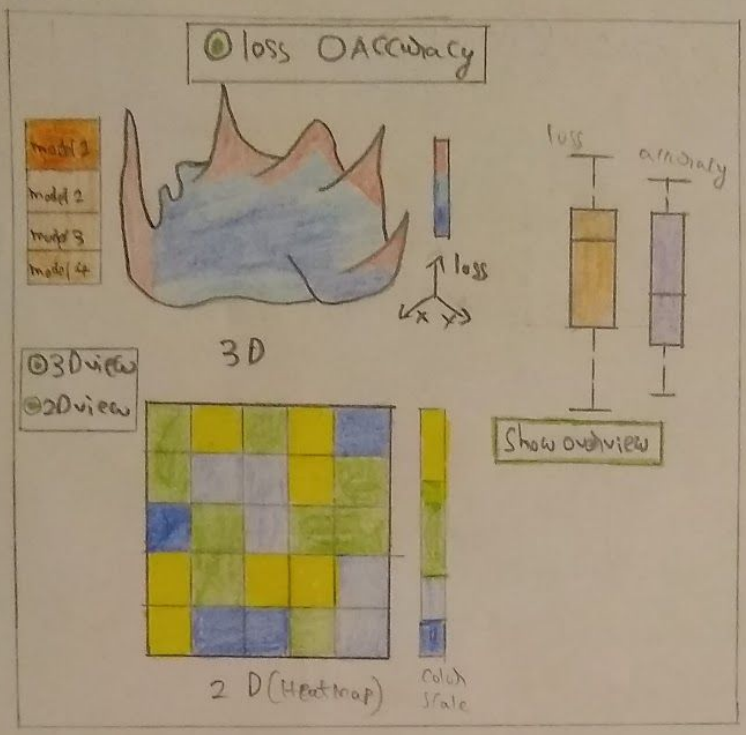
Varunya: Add the details of two models and bind the related visualization of each model.
Ramana: Indicator of global minimum, overlay visualizations of different models
Aakarsh: Indicate the values at arbitrary points on mouse hover, show descent in any local space.

Prototypes

Ramana Rao Akula



LAYOUT



TITLE: MAIN PAGE
AUTHOR: RAMANA RAO
DATE : 11/6/19
SHEET : 2
TASK: visualize loss/accuracy of a model

OPERATIONS

The buttons on the left allow the user to select a model.

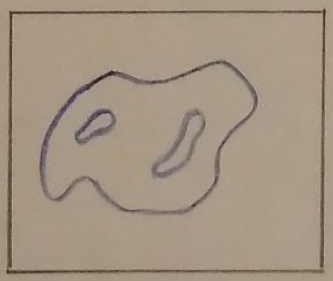
Radio buttons allow the user to select 2D or 3D view.

'Show overview' button shows a statistical overview of loss and accuracy of the model

loss, accuracy radio buttons show only the required values when enabled

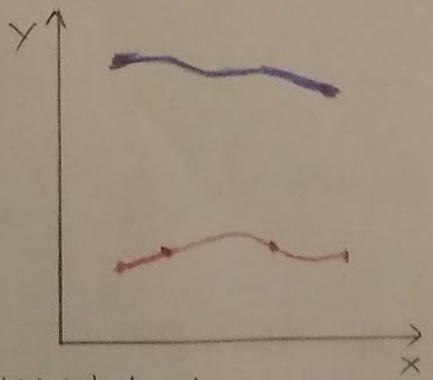
Hovering on the heatmap gives a tooltip showing the loss value at that particular point.

FOCUS



loss value = 10.1

Cut view after brushing the 3D view indicating a particular loss/accuracy value.



Line chart indicating loss & accuracy (both values) 'x' and 'y' directions for a model.

DISCUSSION

The 3D view supports overlay of two or more models ✓

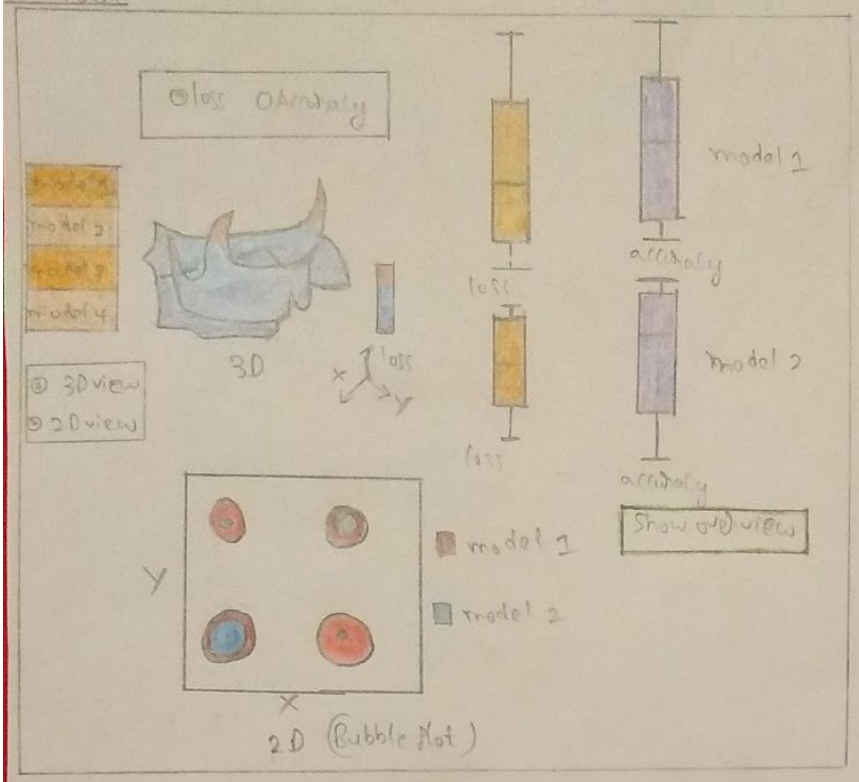
But the 2D Heat map allows only side by side comparisons. ✗

The line charts indicate a summarized plot of the loss and accuracy ✓

The cut view shows a cross section ✓

The heat maps if overlaid on top of one another cause visual occlusion ✗

LAYOUT



TITLE : MAIN PAGE
AUTHOR RAMANA RAO
DATE: 11/6/19
SHEET: 3
TASK: visualize loss/accuracy of model. Compare two models

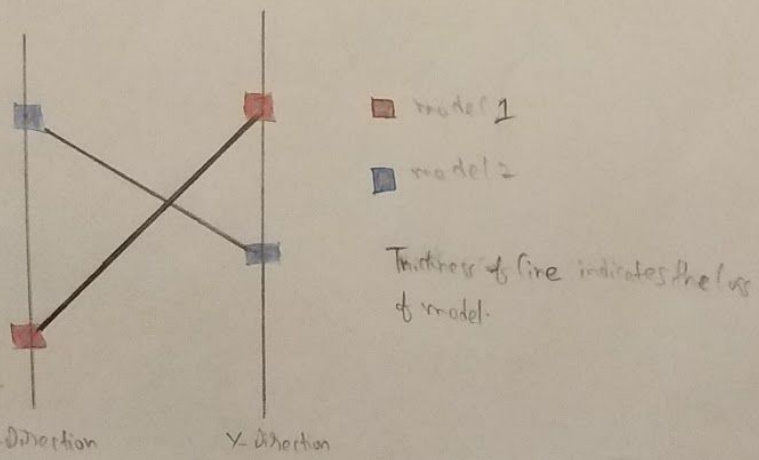
OPERATIONS

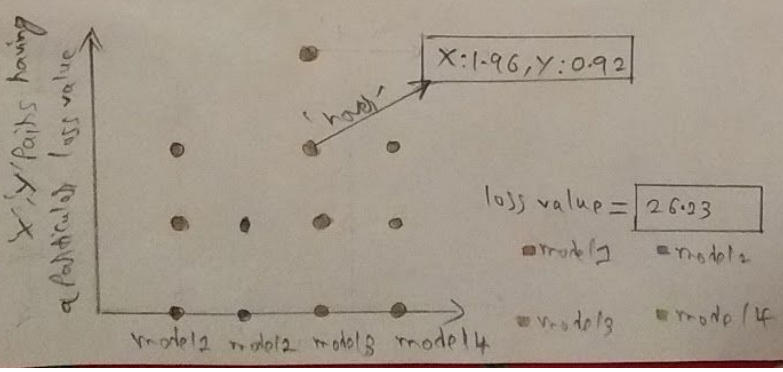
When more than one model is selected, the models are shown in an overlaying fashion

Clicking on a particular X,Y coordinate shows a focussed view of two models and their loss values.

The sliders can be used to adjust the X, Y values of the loss function of different models

Focus





DISCUSSION

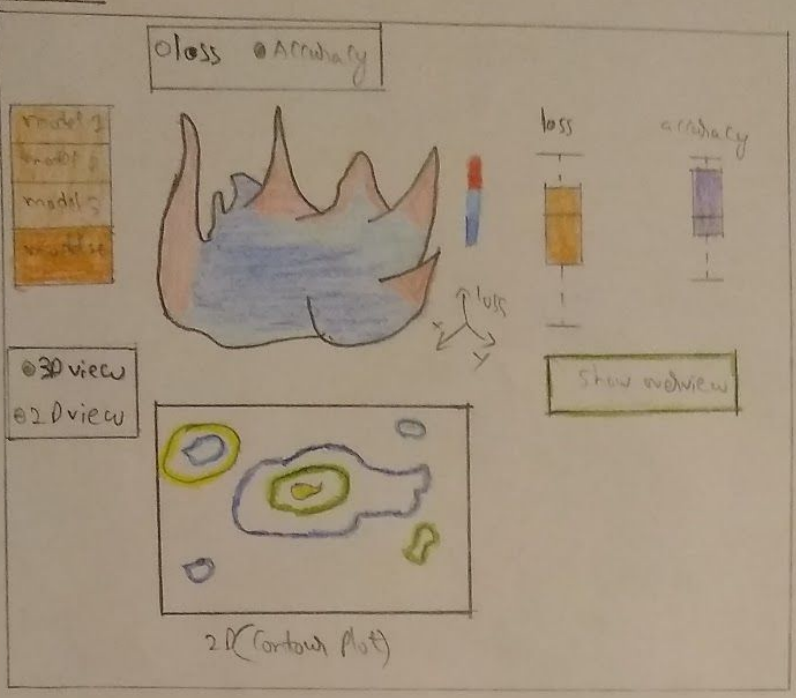
The bubble plot allows overlays of models. ✓

The 3D view also supports comparison of more than one model. ✓

The plot shown in the focus area is a nice way to visualize loss values of two models via thickness of the lines and hue of the sliders. ✓

The bubble plot in focus section allows comparison of X,Y for different models ✓

LAYOUT

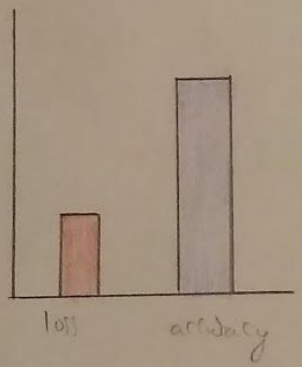


TITLE: MAIN PAGE
AUTHOR: RAMANA RAO
DATE: 11/6/19
SHEET: 4
TASK: visualize loss/accuracy of a model

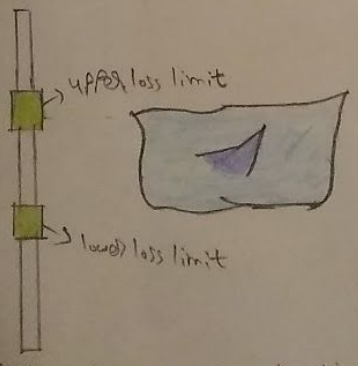
OPERATIONS

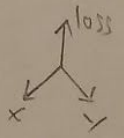
clicking at point on the 2D contour plot plots both chart indicating both loss and accuracy for the corresponding x and y filter normalized directions.

FOCUS



To indicate loss & accuracy for a particular x and y filter normalized directions.





Sliders to control the loss limits. The plot shows a brushed view of the original 3D plot

DISCUSSION

The 3D plot of the loss values supports comparison of different models ✓

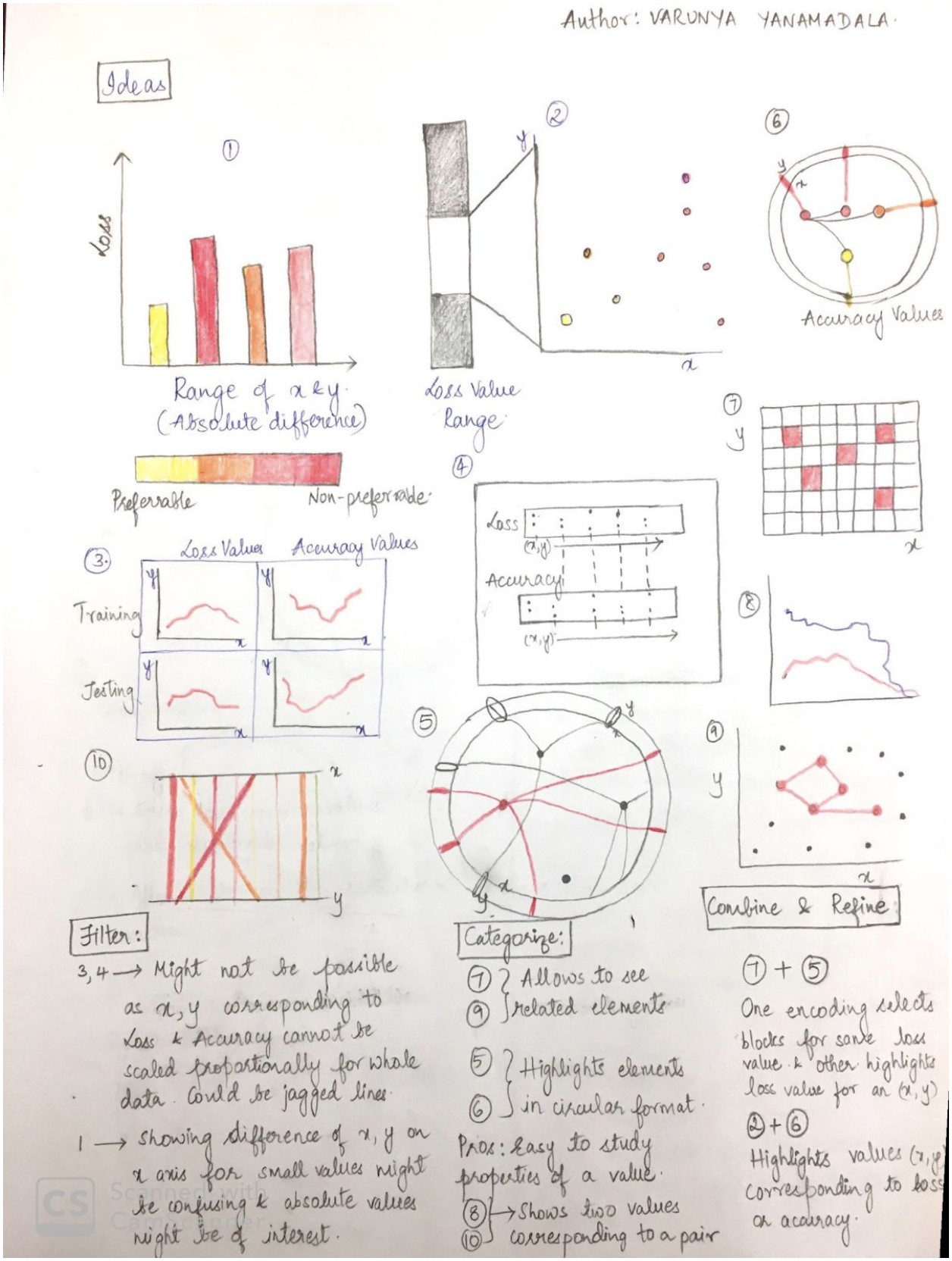
The contour plot gives a visualization that is similar to a compressed version of the 3D plot but is difficult to understand ✗

Clicking on a point in the 2D (contour plot) gives a bar chart as a detailed view indicating both ✓

Contour plot is overlaid caused occlusion and makes comparisons harder ✗

The brushed view allows to focus only in areas of interest ✓

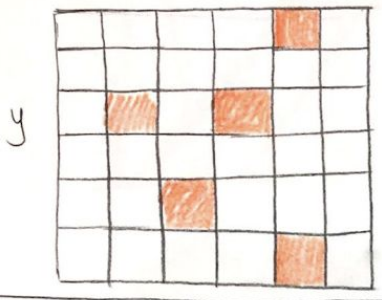
Varunya Yanamadala



Title: HeatMap.
Author: Varunya Yanamadala
Date : NOV 1, 2019.
Sheet : (2)
Task : Vizualising loss & accuracy values corresponding to x & y directions

Model

Loss Value Range :

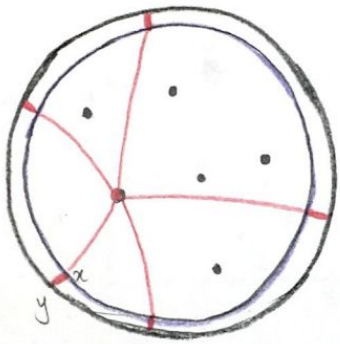


Layout

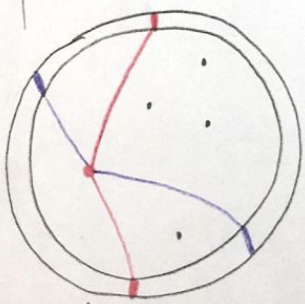
Focus

● Loss Values

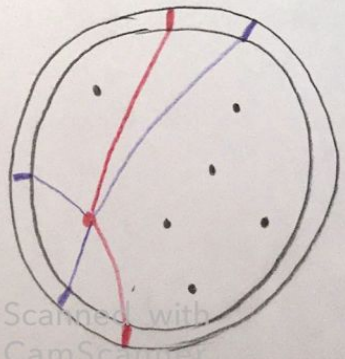
○ Accuracy Values.



Comparison:



Model 1



Model 2

Operations

1. The vizualization to the top left encodes a (same) loss value of different (x, y) pairs after selecting a model
2. Slider at the top indicates the range of value to be highlighted in the below grid.
3. The below diagram (chord) highlights the (x, y) values for a loss value selected (by hover over).
4. Comparison of models can be made by selecting one or more models and selecting a loss value.

Discussion:

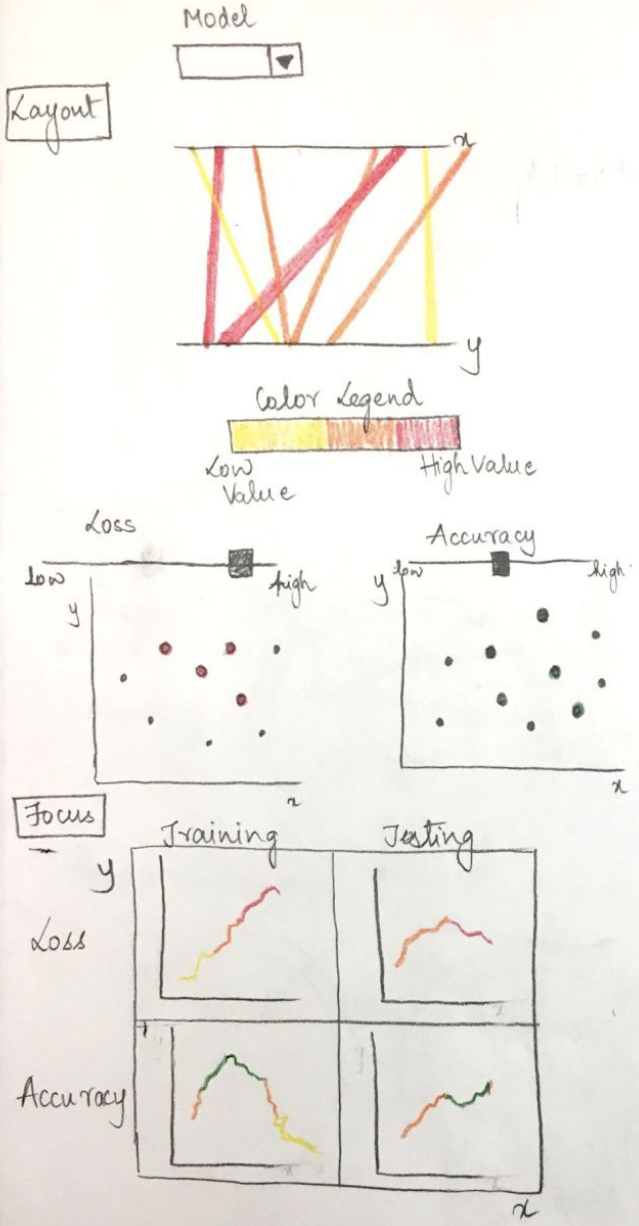
Advantages:

1. Since a range of loss can be selected, user gets to view many x, y pairs which might be helpful
2. By comparing two models for same loss & (x, y) pairs the similarity of models can be selected.

Disadvantages:

1. As the model selection increases, the diagrams might be hard to compare.

Title: Parallel Co-ordinates
Author: Varunya Yanamadala
Date : Nov 7, 2019
Sheet : (3)
Task: Vizualising loss & accuracy values corresponding to x & y directions



Operations:

1. For the model selected, the parallel co-ordinate graph updates with different widths (indicating the loss value) & color (to easily locate the higher loss values or vice versa).
2. The slider lets user select loss value & another for accuracy and all such (x,y) values are highlighted.
3. Allows getting an estimate of x,y pairs for some loss & accuracy.

Discussion:

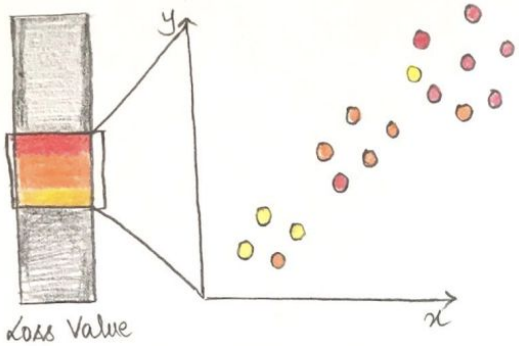
a) Advantages:

1. Allows comparison of models in a matrix way.
2. Parallel Co-ordinates might get cluttered as the data increases.

b) Disadvantages:

1. As the models increase, the scatterplot matrix gets widened and readability might be difficult. It should be handled by enlarging selected portions.

Model



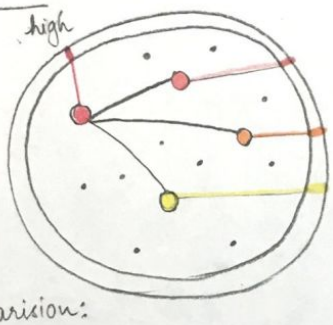
Loss Value Range

Layout

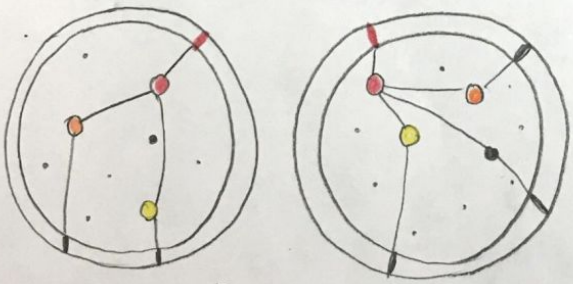
low (scale) high

- Loss
- Accuracy

Focus



Model Comparision:



Disadvantages:

1. As the nodes increase, bundling has to be done for values
2. If (x,y) varies a lot or if there are more (x,y) points for a value, the diagram might get cluttered.

Title : Sliding Window Sheet : (4)
Author: Varunya Yanamadala
Date : Nov 6, 2019
Task : Vizualising loss & accuracy values corresponding to x & y directions.

Operations:

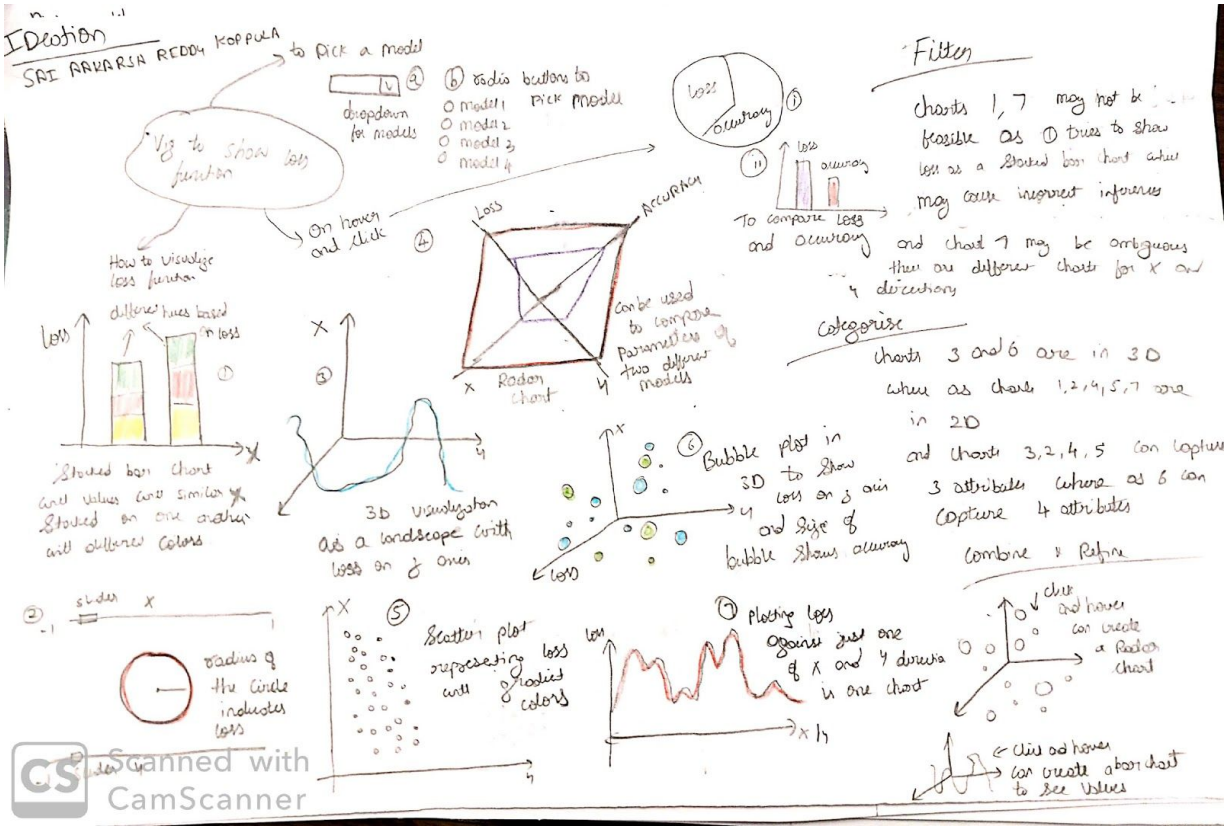
1. From the loss value range to the left, a scatterplot indicates the x,y pairs of the range.
2. The color coding indicates the values of the loss.
3. The chord diagram below updates based on the loss value selected at the scale above.
4. The nodes at the center are highlighted which sum up to the selected value highlighting corresponding x,y values. Color of the nodes indicates the loss intensity.

Discussions:

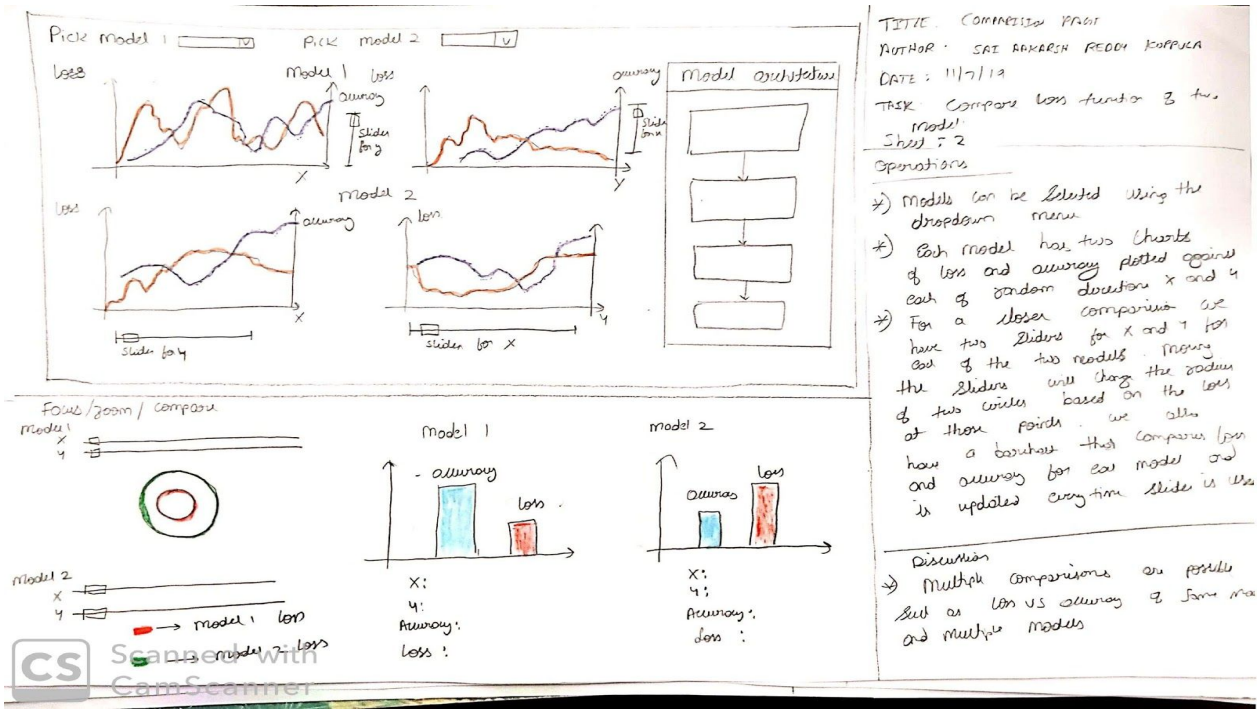
Advantages:

1. For a model simultaneous comparison of x,y's for a loss range.
2. Shows group of nodes which sum up to a value. Helps in avoiding few xy values.

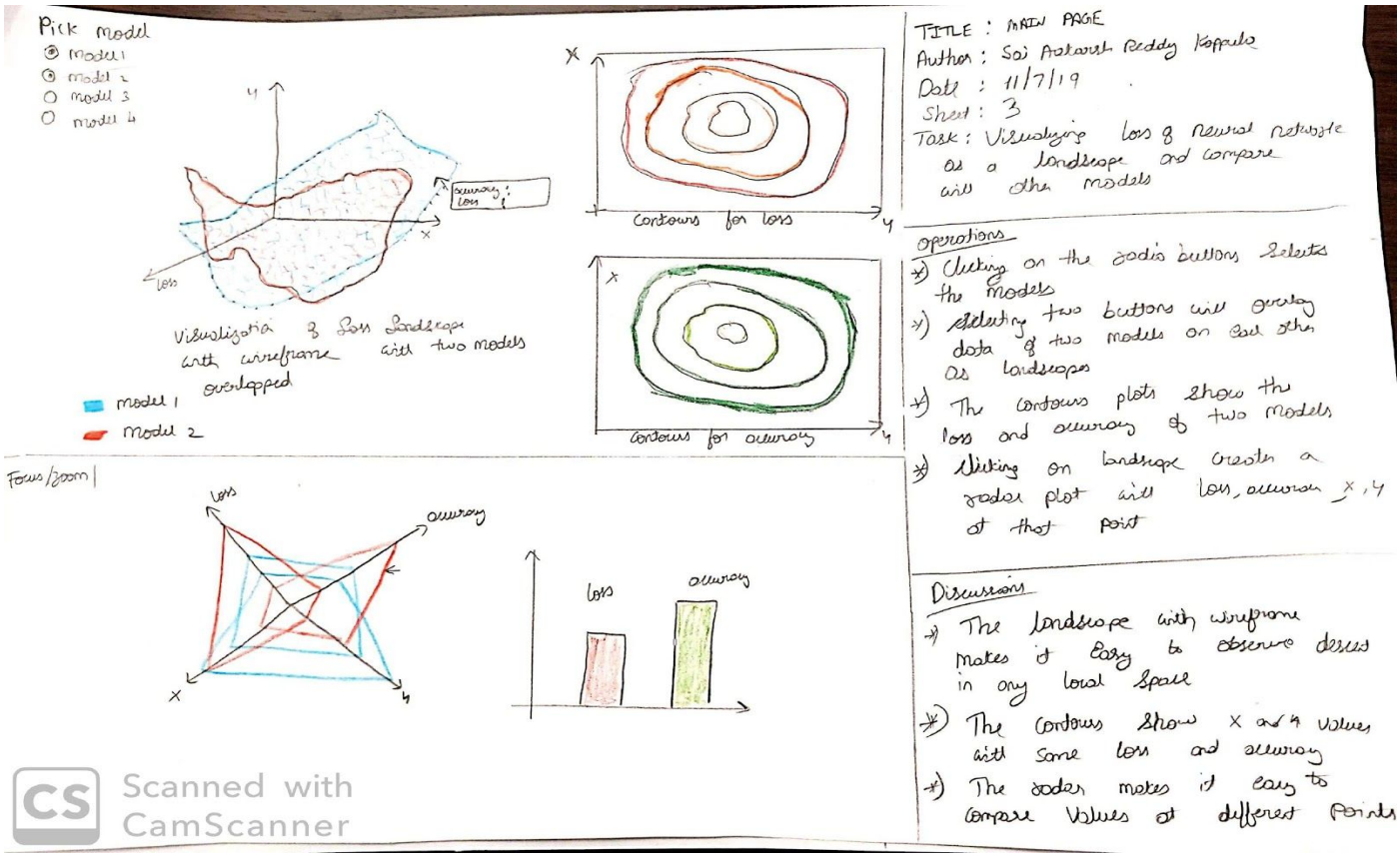
Sai Aakarsh Reddy Koppula



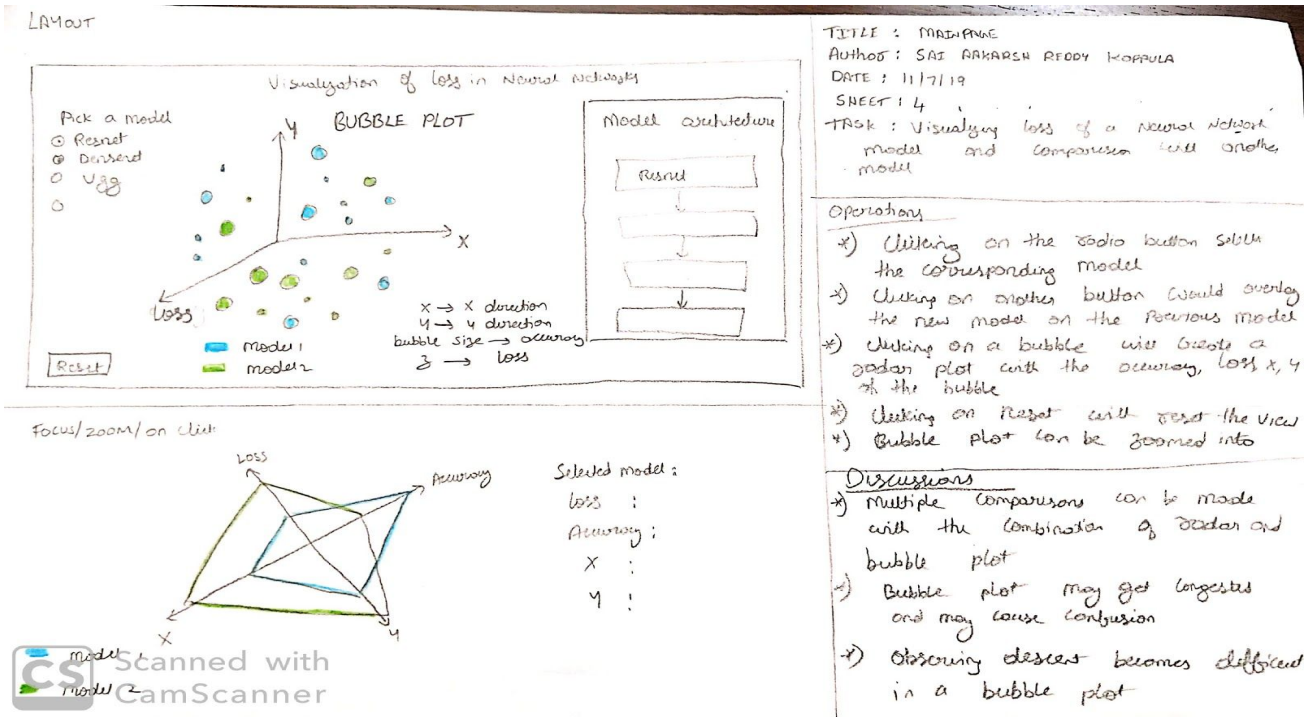
Sheet2


Pick model 1
Pick model 2
loss
accuracy
Model 1
Model 2
Model architecture
slider for y
slider for x
Focus / zoom / compare
Model 1
Model 2
accuracy
loss
X:
Y:
Accuracy:
Loss :
TITLE : COMPARISON PAGE
AUTHOR : SAI AKARSH REDDY KOPPULA
DATE : 11/7/19
TASK : Compare loss curves of two models
Steps :
Operations
Discussion
Scanned with CamScanner

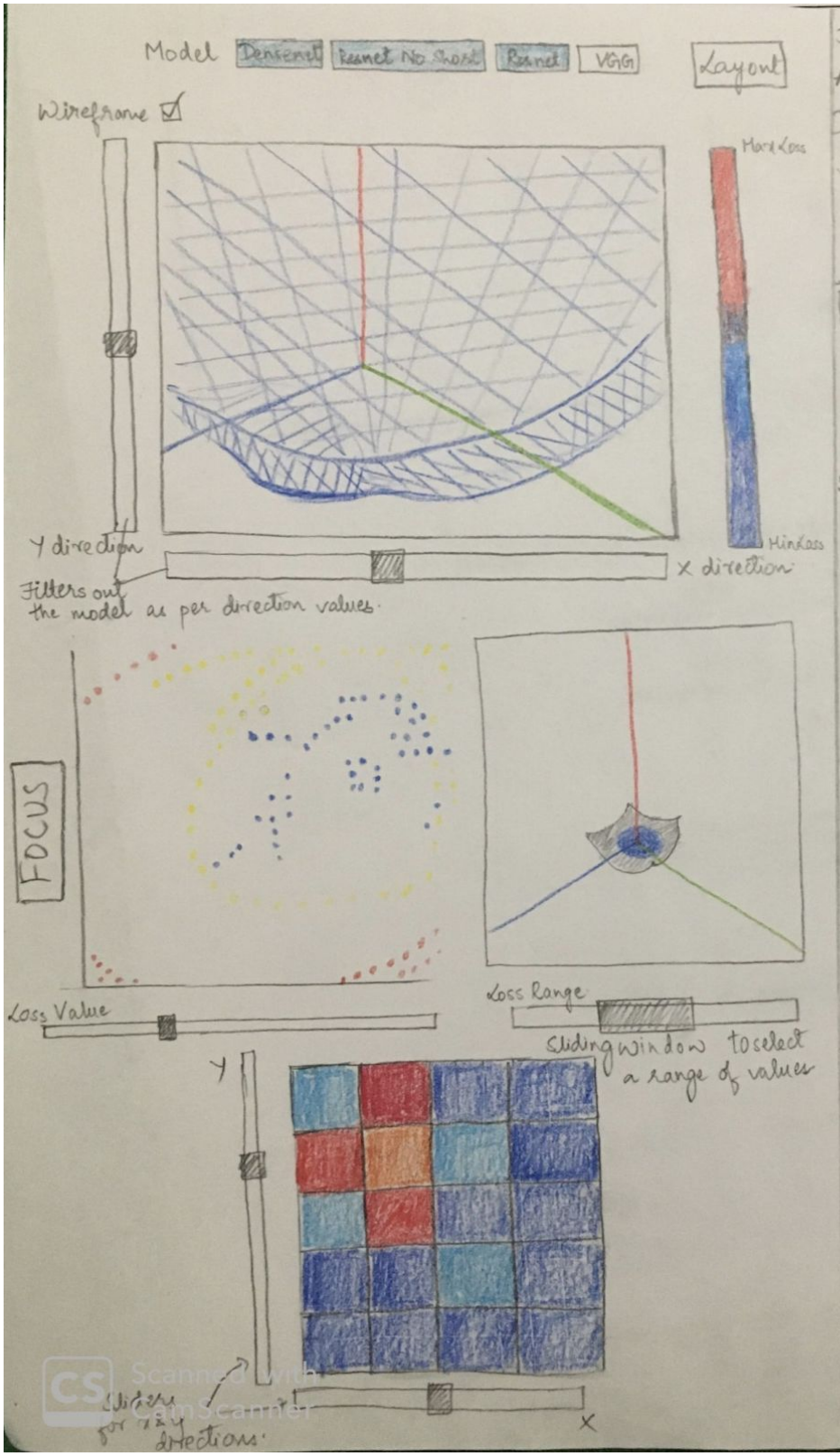
Sheet3



Sheet4



Final Design Sheet: Sheet 5



Title: Final Design Sheet

Author: Varunya Yanamadala

Date: Nov 13, 2019

Task: Visualizing loss values corresponding to random normalized x, y directions.

Operations

1. The scene shows the loss as a landscape in 3D with a color scale.
2. The landscape is linked to scatterplot with a slider to select loss value.
3. There are buttons to select the models to be rendered on screen.
4. Clicking the wireframe will render the model in wireframe mesh.
5. A slider to select range of values will filter (grayout) the non-applicable particles.
6. There is a heatmap with sliders to show the loss values.

Discuss points:

1. The landscape viz makes it easier to study the non-convex regions of the loss functions.
2. It helps the user study the stability at a minimum value through the sharpness/flatness curvature.

Alpha Release

Layers Completed

1. Data transformation: The data was in hdf5 file format and segregated in different dimensions. The files are now transformed into a single file that contains the X, Y random filter normalized directions and also the loss values for each pair of these X, Y values for easy maintainability. Similar work is done for all the four models.

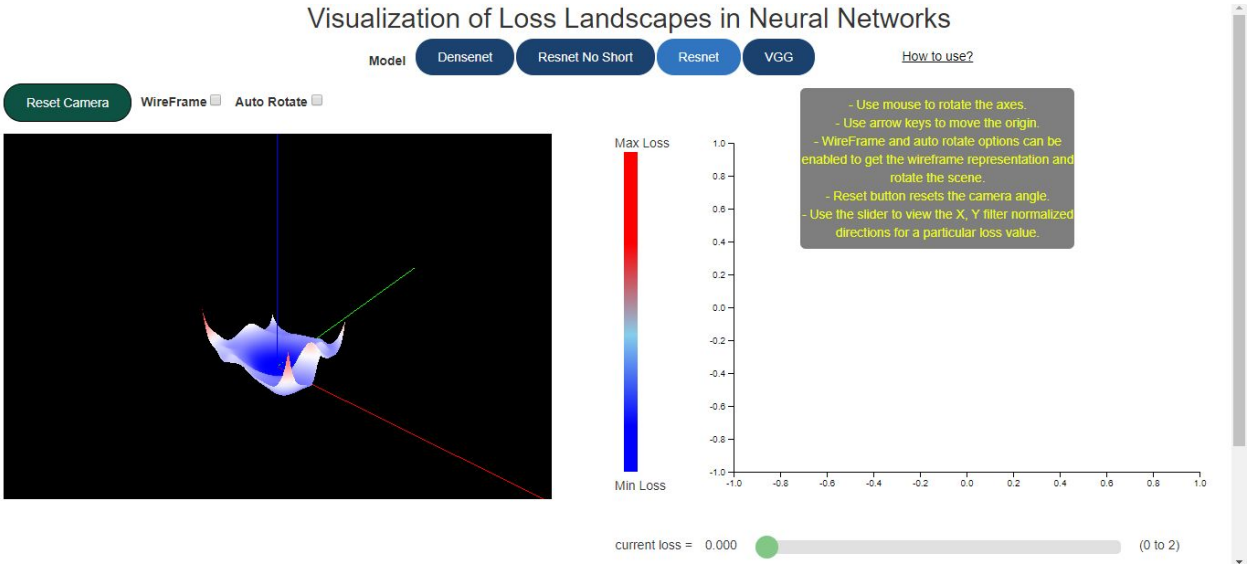
2. Initial Layout Setup: The initial layout with html and css has been developed and pushed to git repository during P01.

3. Tasks achieved for alpha release:
    a. As per the ideation sheets developed by each member, the applicable ones are selected for alpha release. Visual encoding corresponding to showing the global minimum of different models, simultaneously understanding the non-convex nature of the model (selected by the user) was implemented.
    b. For a given a loss value range and for the models selected, a cross section of the 3D loss landscape encoding is displayed to the right. This would enable the user to get an overview on the sudden spikes and troughs through the x, y random filter normalized directions.
    c. The desirable target of overlaying loss surfaces of the different models is implemented.
    d. The above encodings were implemented in a way to compare multiple models selected by the user.

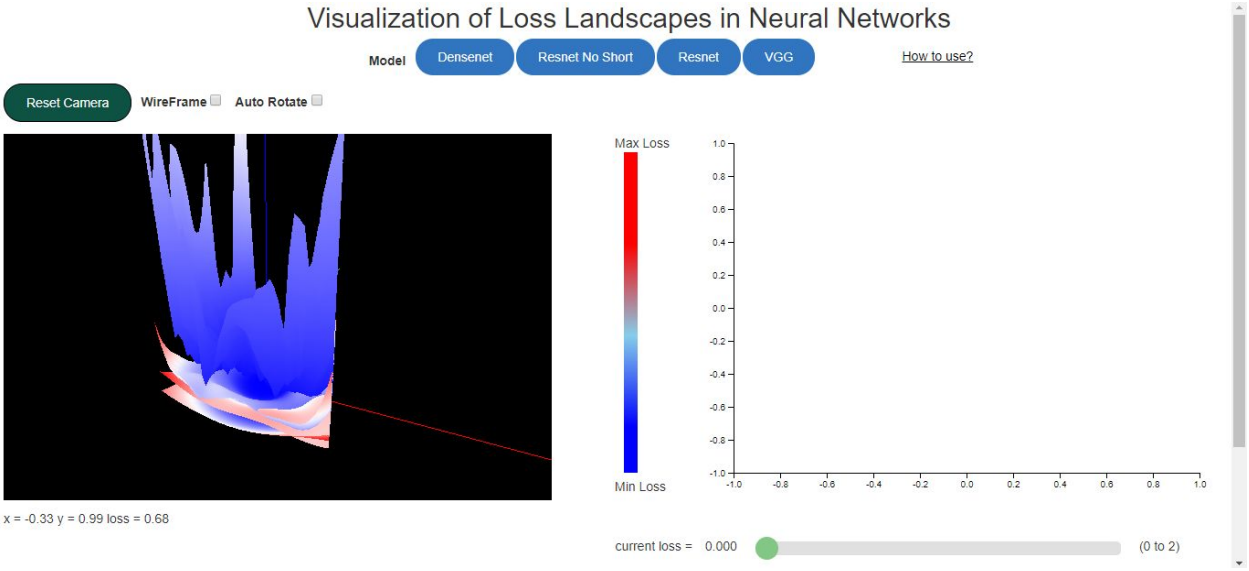
Note: Since, the data (loss values) for all the models isn't within the same range, the loss values of all the models are scaled down to 5% of their original loss values for easier viewing and comparability.

Screenshots of the alpha release

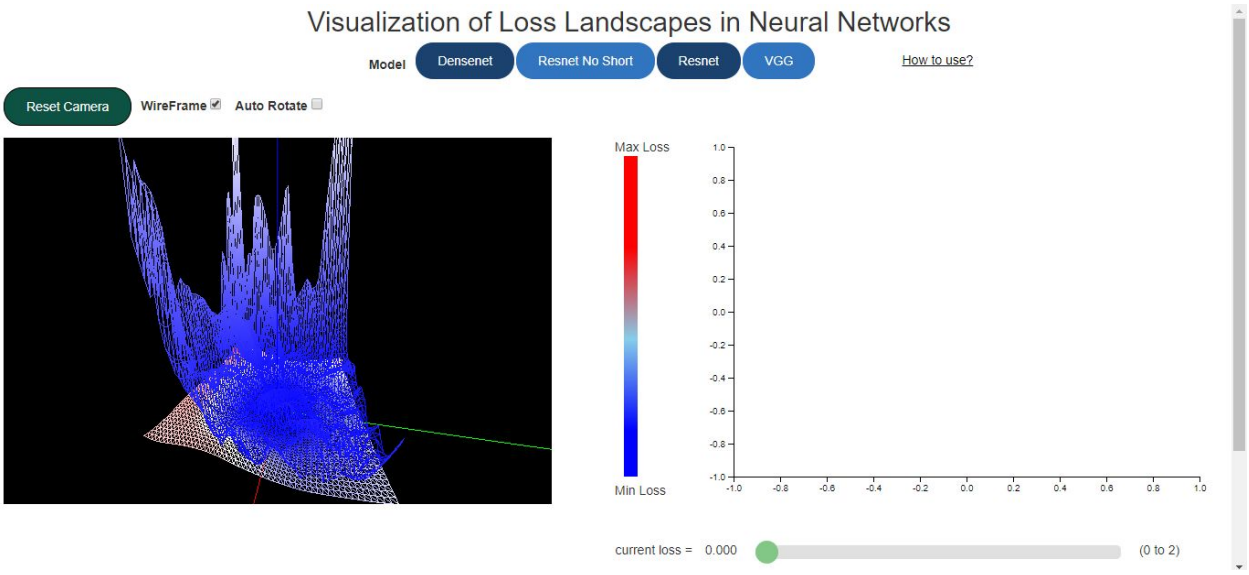
1) Layout



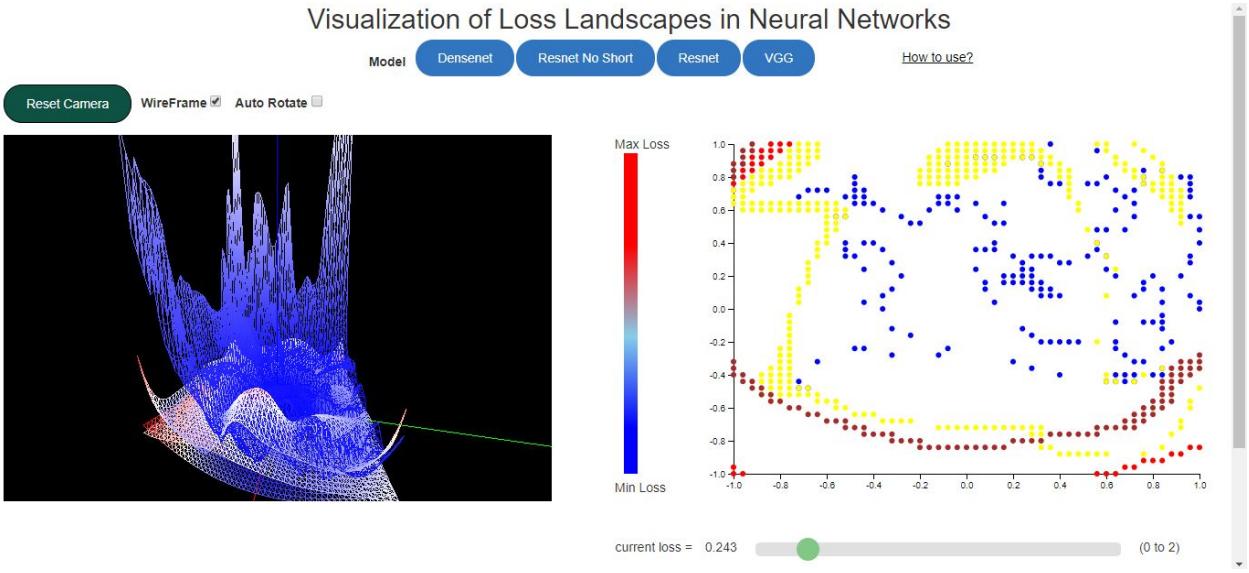
2) Overlay of models



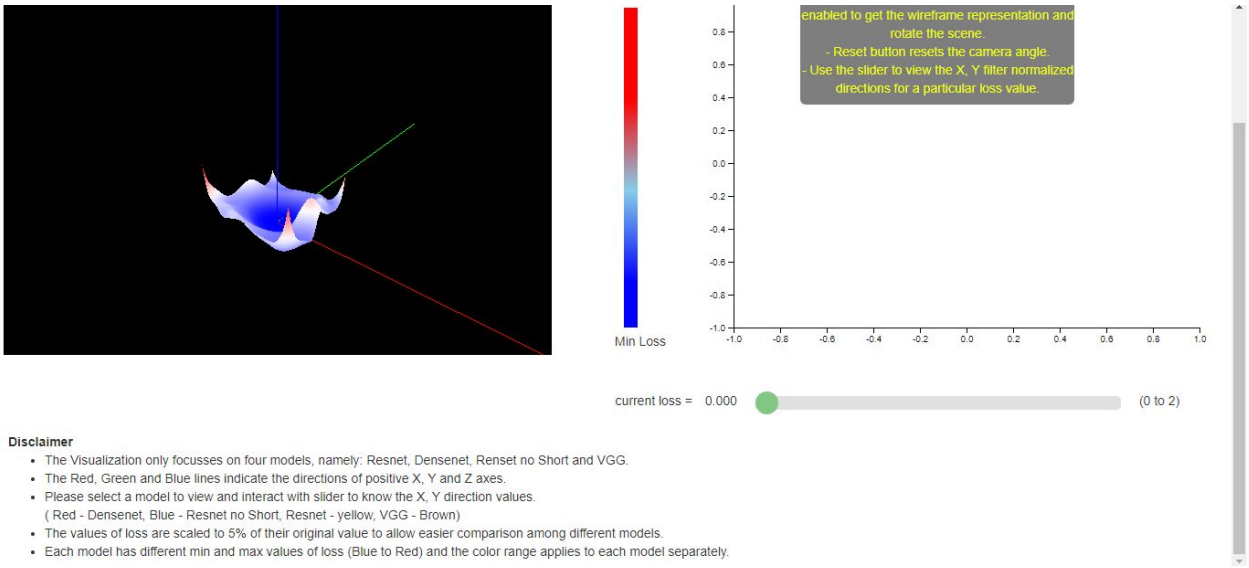
3) Wireframe Representation



4) Cross sectional view at a particular loss value



5) Disclaimer



Accomplished vs Not Accomplished

Accomplished:

1. The targets aimed under low target were achieved.
2. The targets aimed under desirable target were also achieved.
3. Learnt setting up the tasks within the layers milestone wise among the team members.

Would make it better if we (Not Accomplished):

1. Allowed the user to view the part of the 3D loss surface.
2. Brushing the loss surface to highlight only the selected loss range. We would include this in the Beta release.
3. Included additional 2D encodings under focus to support more comparisons.

We aimed at building the bare bones first and enhancing the built later which would help user draw better conclusions corresponding to the normalised directions. We were successful at achieving the targets but due to challenges faced during alpha build's testing process, we could make corrections and structure the project code.

Testing

We incorporated manual testing by jotting down the issues which failed in testing. As a takeaway, we would incorporate the scenarios which passed as well by the Beta release.

S.No	Module	Issue Description	Scenario to replicate	Functionality Effected	Priority	Fixed
1	Loss surface encoding	The dots (loss values given in the data) don't indicate a landscape surface.	1. Click on the densenet button. 2. View the dots on the encoding to the left. To try: Come up with a way to create a smooth surface by joining the dots plotted for the model.	Yes	High	Yes
2	Multi model comparison	When two models are laid over one another, unable to view the minima of both.	1. Click on densenet button and resnet no short button at the top. 2. Two models would overlap on one another in the left pane. When a user selects densenet and resnet no short, the minima are close to each other and these cannot be differentiated well. To Try: A wireframe might help to some extent.	Yes	High	Yes
3	Densenet loss surface visualisation	When densenet is selected, the loss surface doesn't appear all the time.	Select densenet, if it works deselect it and select all other models. Now, select densenet - the loss surface doesn't appear. To Try: Try adjusting the scalability factor and	Yes	Very High	Yes

			moved the x, y direction values to csv.			
4	color scheme for each model.	If a common color scheme is not used for all the models, making comparisons would be very difficult. Also if the color scale is applied directly across loss values of all the models, maxima and minima of some models may not be identifiable.	1. Repeat steps in scenario 2. 2. The viz seems to be a mass of surfaces, making it difficult to differentiate the highest value of a model. Select any two models (the max loss value of one is more than the other model). The surfaces cannot be viewed with good understandability. To Try: Apply a common color scale to all the models such that the maxima are indicated by one color and the minima are indicated by another color. This scheme applies individually to all the models.	No	Mediu m	Yes

Tasks

1. Identify the global minimum of a model.
2. View various levels of loss as per user's requirements.
3. Compare one or more models in terms of loss values.

Questionnaire

1. Do you find it easy to understand the interface? (Yes/No/Maybe)
2. Could you complete the tasks that were stated? (Yes/No/Maybe)
3. If there is one improvement we have to do, what would that be?
4. Any other improvements?

Report (after Alpha testing)

Three participants completed the testing of our alpha build.

Measures for each tester:
1) All the testers were able to complete the tasks successfully.
2) The overall time spent by each tester to complete all the three above mentioned tasks was in between 2 minutes and 2 minutes 15 sec.
3) No errors were reported by the testers during the above tasks.

Observations (cumulative):

1. The system was easy to understand and the testers could complete the tasks within a reasonable amount of time.
2. A tester found it difficult to compare the models after overlaying. He zoomed in the face to the screen but could complete the task. Overall, the ease with which the task was completed could be improved.

Suggestions from the testers (cumulative):

1. A way to blend the left scene into the background, to lesser the effect of background on the visualization.
2. A tester needed some additional information of the model selected to enrich the overall visualization experience.
3. Scatterplot, doesn't have a labels associated with it and for some loss values, the scatter plot doesn't show up any results. We need to think of a way to let the user know of this.
4. On initial screen load, no model is shown in the scene. A tester suggested to load one model initially so that it would convey what the system would do in general.
5. A tester felt that the left scene could be made bigger so that models are represented at a reasonably zoomed in state. This would make the system more user-friendly.

Take Away from testing:

1. Document a complete set of test cases, so that we could re-run them after few milestones are achieved and to make sure current functionality isn't affected.
2. To layout the instructions in a better way.

3. Incorporate implementable suggestions from testers, which would help in improving the usability of the system.

Beta Release Feedback

Layers Completed

Apart from the layers completed for alpha release the following layers have been included

1. The layout has been adjusted to eliminate the need for scrolling and extra tabs.

2. A Heatmap has been added to the visualization. The heatmap makes it possible to identify regions of stability of different models.

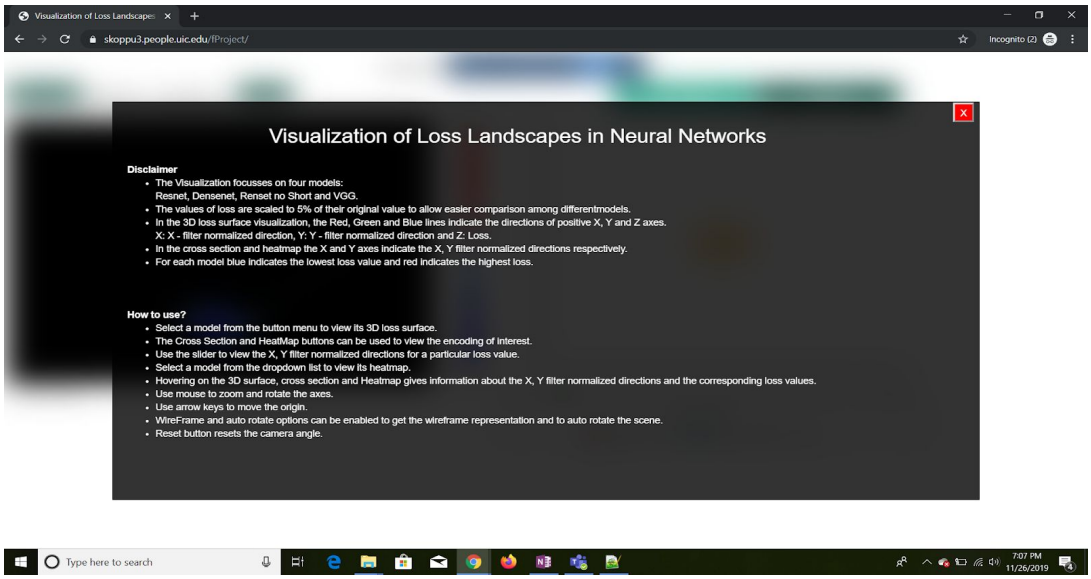
3. The disclaimer has been added as a pop-up when the page is loaded/reloaded. It can also be accessed using the 'Info' button.

4. Tooltips were added to scatterplot and heatmap that show the X,Y and Loss information on mouse hover.

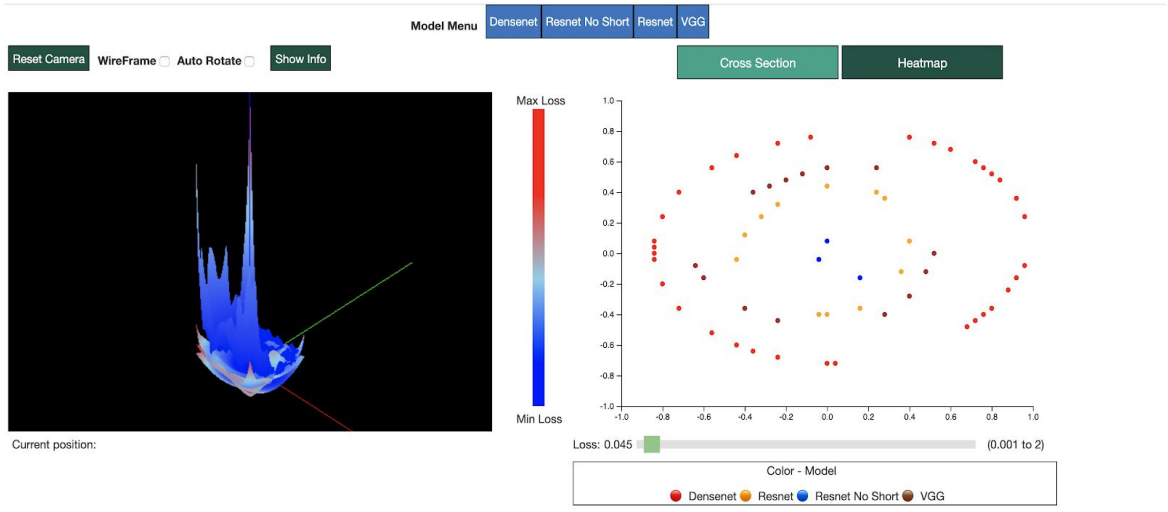
5. Feedback received during alpha release was analysed and incorporated suitably into the Beta version.

Screenshots of the Beta release

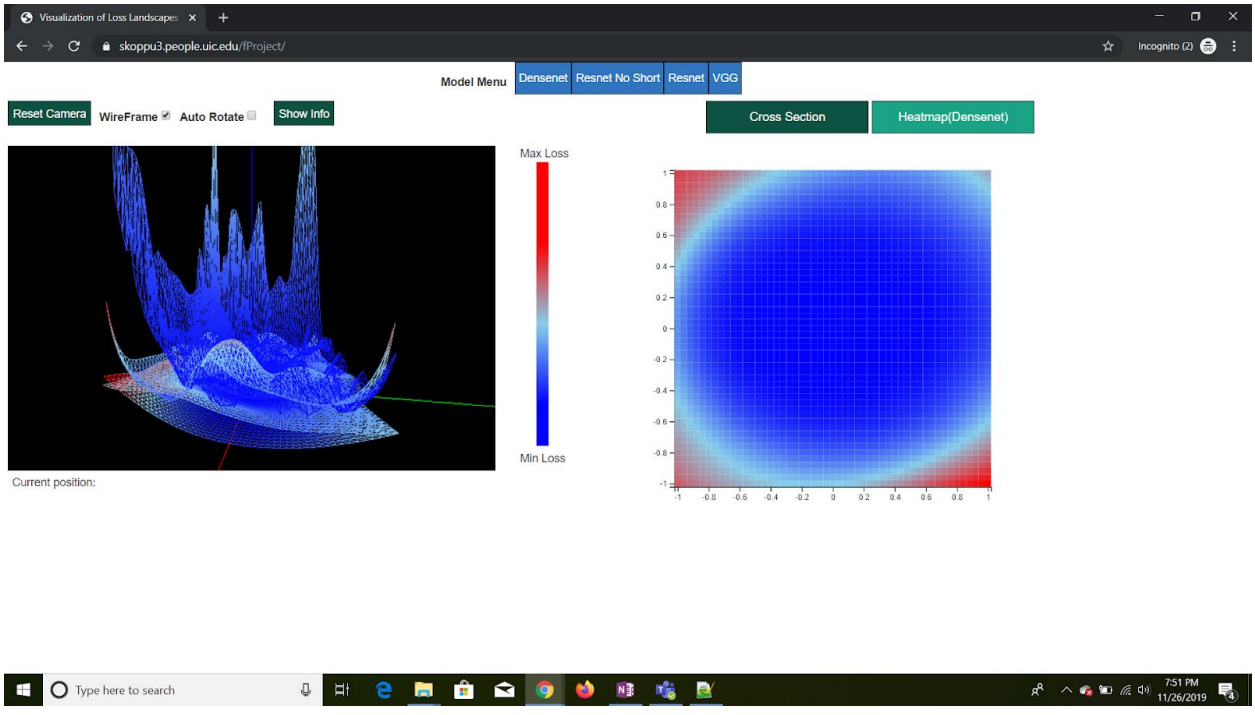
1. Screenshot of the disclaimer when the page is loaded.



2. Screenshot of 4 models visualised as a landscape in wireframe and their cross section.



3. Screenshot of the heatmap of one of the models(DenseNet). Model can be selected from the dropdown menu provided in the heatmap button.



Accomplished vs Not Accomplished

Accomplished:

1. The targets aimed until high level target were achieved.

Would make it better if we (Not Accomplished):

1. Allowed the user to view the part of the 3D loss surface.
2. Brushing the loss surface to highlight only the selected loss range. We would include this by the final release.

Testing

S.No	Module	Issue Description	Scenario to replicate	Functionality Effected	Priority	Fixed
1	Heatmap	The markings on the axis of the heatmap were overlapping on each other	Click on heatmap button and select a model	Yes	High	Yes
2	Heatmap	Using the same color scale for all models caused ambiguities	Click on heatmap button and view two different models	Yes	High	Yes
3	Formatting of the webpage	Having the disclaimer and the visualization in the same view involved scrolling	Open the visualization	No	Low	Yes
4	Formatting of the webpage	Having the heatmap and scatterplot on the same view involved scrolling	Open the visualization	No	Low	Yes

Tasks

1. Identify the global minimum of a model.
2. View various levels of loss as per user's requirements.
3. Compare one or more models in terms of loss values.
4. Identify the stable regions in a model.

Questionnaire

1. Do you find it easy to understand the interface? (Yes/No/Maybe)
2. Could you complete the tasks that were stated? (Yes/No/Maybe)
3. Do you think the encodings are appropriate? (Yes/No/Maybe)
4. If there is one improvement we have to do, what would that be?
5. Any other improvements?

Report (after Beta testing)

Five participants completed the testing of our beta build.

Measures for each tester:
1) All the testers were able to complete the tasks successfully.
2) The overall time spent by each tester to complete all the above mentioned tasks was in between 5 to 6 minutes.
3) No errors were reported by the testers during the above tasks.

Observations (cumulative):

1. The system was easy to understand and the testers could complete the tasks within a reasonable amount of time.
2. A couple of testers found it difficult to figure out the controls for the loss landscape without any guidance from team.

Suggestions from the testers (cumulative):

1. The rotations of the landscape should be restricted and X,Y,Z labels to the axes.
2. Use better colors and increase the dot sizes in scatter plot.
3. The Scatterplot and heatmap could be made collapsible and the landscape could be made larger if scatterplot and heatmap are collapsed.
4. Add a note to the users in the disclaimer to use arrow keys to move the landscape in the scene.

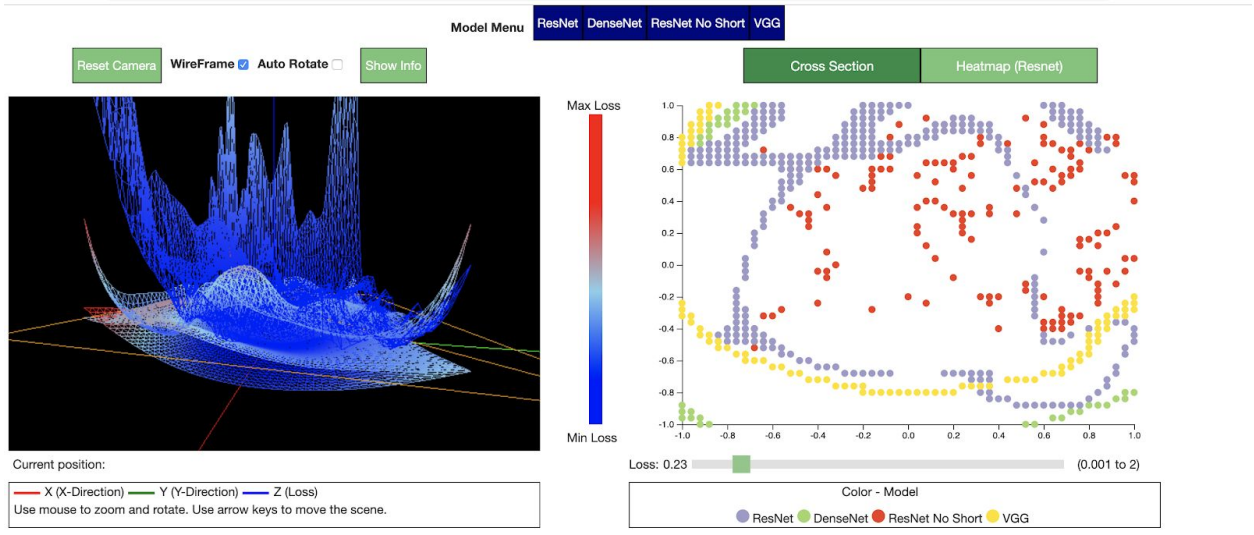
5. Button should become darker after selected not the other way around.
6. The color legend could be placed better.

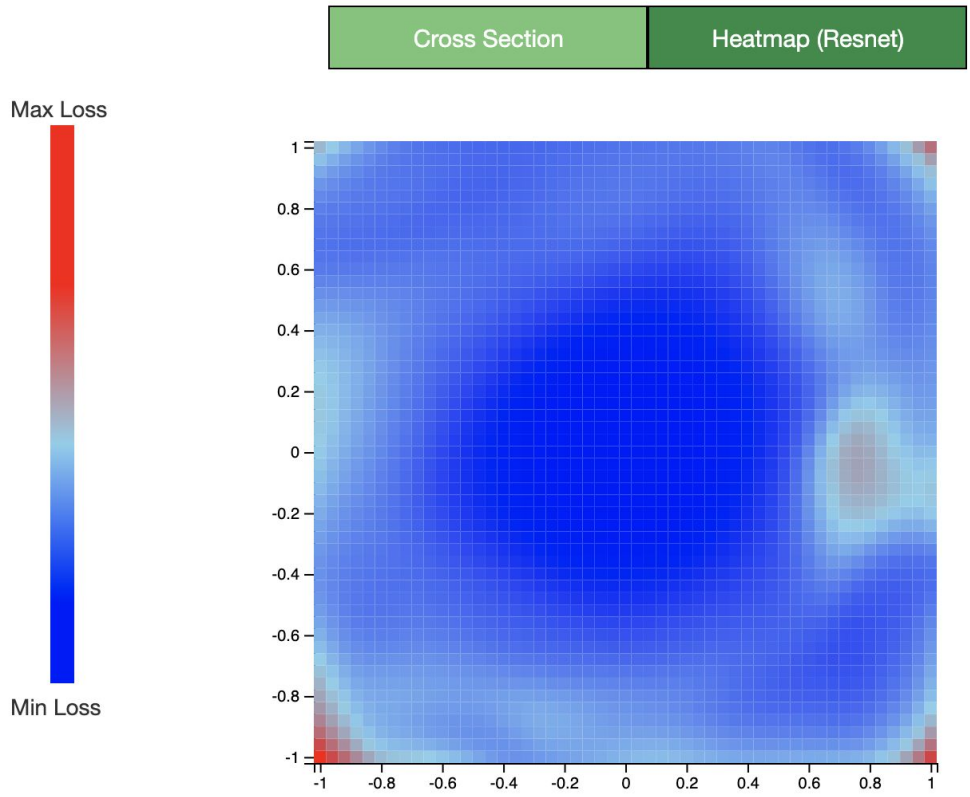
Public Release

Current state of the UI

As of today the interface consists of a landscape, a scatterplot, a heatmap and buttons and sliders to navigate and modify the views.

- The landscape can render one or more models in the same scene and helps in comparing the minima of different models. The landscape has options of wireframe and auto rotate that help in a thorough analysis of the models.
- The scatterplot shows the cross-section of the landscape at a certain value of loss, the scatterplot comes with a tooltip that shows the model name, x and y filter normalized directions at each dot. Below the scatterplot is a slider that can be used to pick a value of loss. The scatter plot helps in studying the convexity of a model.
- The heatmap can be rendered by using the heatmap button and picking a model from the dropdown. The heatmap also has a tooltip to show loss, x and y filter normalized directions at the position of the mouse pointer. The heatmap helps us to identify the stable regions of a model.
- Legends and disclaimers are also included.





Presentation Slides

https://docs.google.com/presentation/d/1TAIaAsvlD0UNKTGC5mlCAm0hW4ykvsxi_AGUT11konc/edit?usp=sharing

Demo Video

https://www.youtube.com/watch?v=27eBo_ge7hU

Source Code

GitHub Repo: https://github.com/VarunyaY/CS-529-NN_Loss_Function_Visualization
Executable: https://rakula3.people.uic.edu/Final%20Project/

Changes made from Beta to Public Release

1. The scatter plot dots were too small for higher values of loss. So the size of the dots were increased so that even lesser number of dots could be perceived on screen.
2. The color combination of dots in Beta were not differentiable at all values of loss. We tried with contrast higher intensity colors but these weren't differentiable when more dots appeared on screen. So, we went with a balance of contrast light and dark colors which is better than previous combinations.
3. As suggested by the client, to introduce interactivity of the scatterplot to the landscape, a plane was placed cutting through the landscape. Since various transparencies of the plane didn't prevent occlusion, a wireframe plane used was used for this purpose.
4. As users might have difficulty and as suggested by the professor, legend with respect to axes was placed below it.

Other attempts

1. Brushing of the landscape wasn't successful due to the geometric technique we employed to structure the landscape. With an alternative, we were successful at achieving this but for each loss value change, the models took a lot of time loading the landscapes.
2. We tried implementing different colors for each model, so that it would be easy for the user to co-relate all the encodings of the same model. Since we were trying this with a time constraint, we couldn't make clear choices on how cleverly legends could be implemented in a dynamic manner while leveraging the left over space.

Client Feedback

Appreciation:
He liked the way the project was pulled of for comparing different models through the landscape by implementing the geometric technique and interactivity through scatterplot and the landscape.

Improvements:

1. The client has suggested to make a standalone application so that it could be scaled to other models and higher volumes of data for research purposes.
2. To show the heatmap in a way to compare the models selected. The size of the model's heatmap is to be compromised here, but the overall view with other models was the one he has suggested for.
3. Highlighting the threshold values in the landscape as per a selected loss value.