Explainable AI : Shapley Values

A Unified Approach to Interpreting Model Predictions
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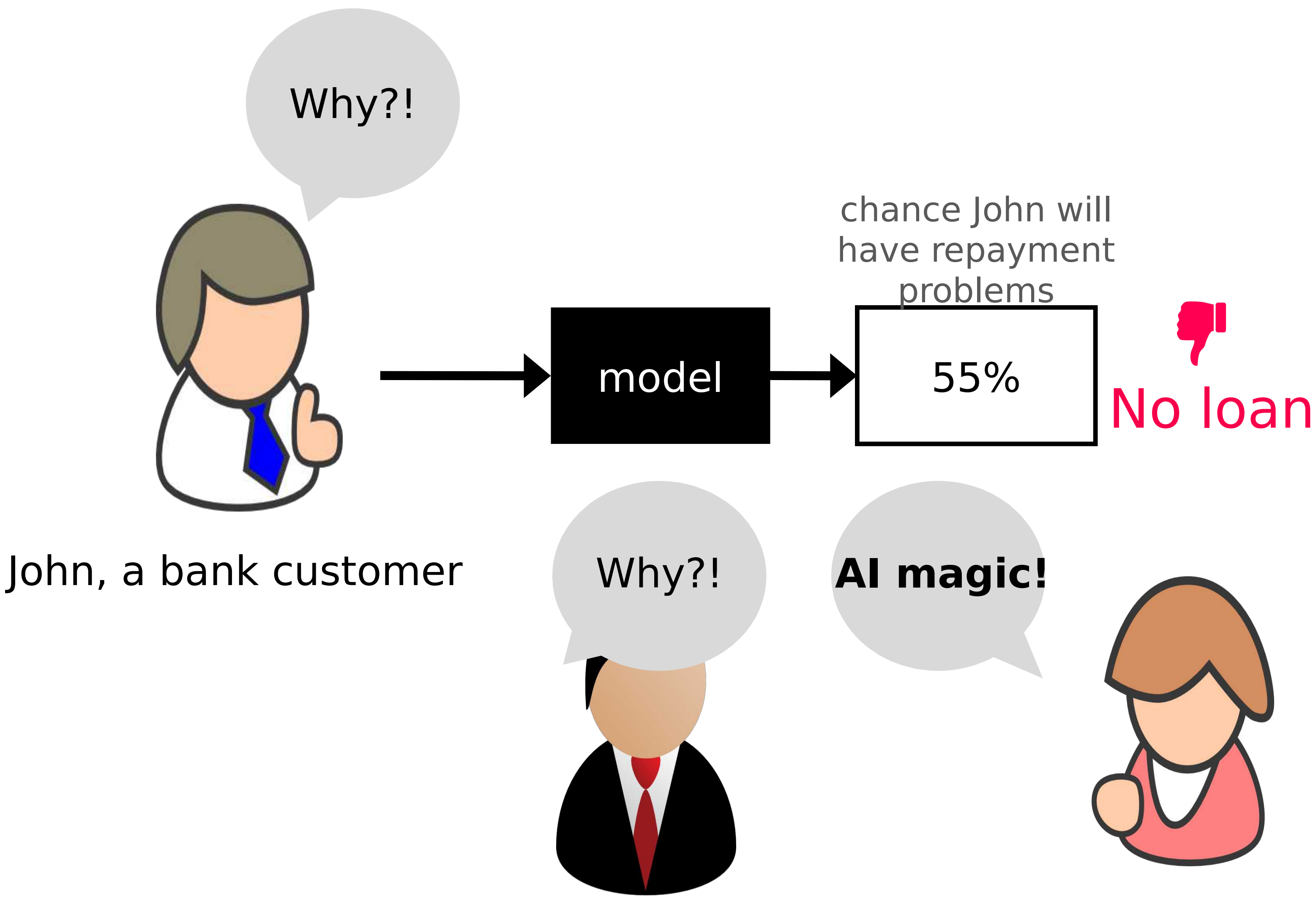
https://colab.research.google.com/github/leexa90/Explainable_AI_image_classification/blob/master/colabs_script.ipynb

Background on myself

- Graduated from NUS science 2015
- Working in A*STAR Bioinformatics Institute in areas of computational biology (2015-17) and crop analytics (2018 onwards)
- Attempted machine learning in areas of work and greatly helped by Deep Learning Developer's course
- Hobbies : Deep Learning, keeping fit, church

Need for Explainable AI



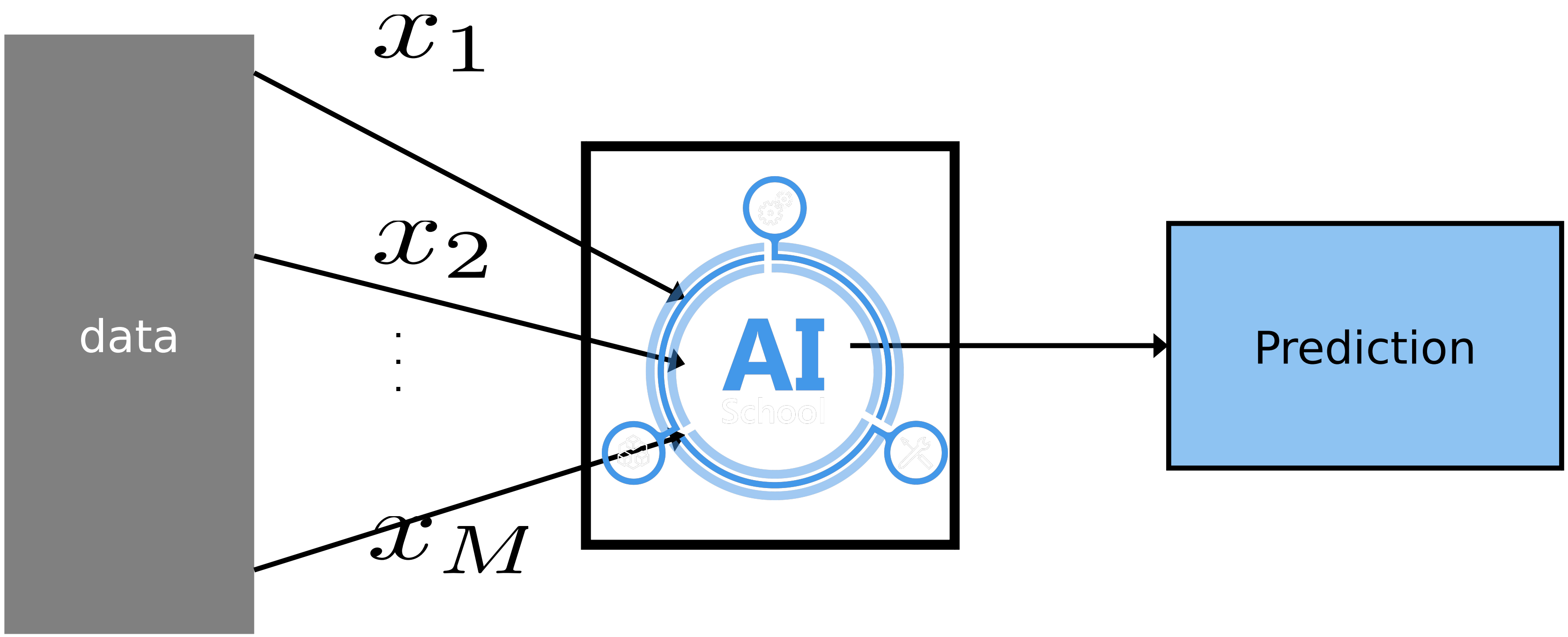
https://github.com/slundberg/shap/blob/master/docs/presentations/NIPS%202017%20Talk.pptx

Need for Explainable AI

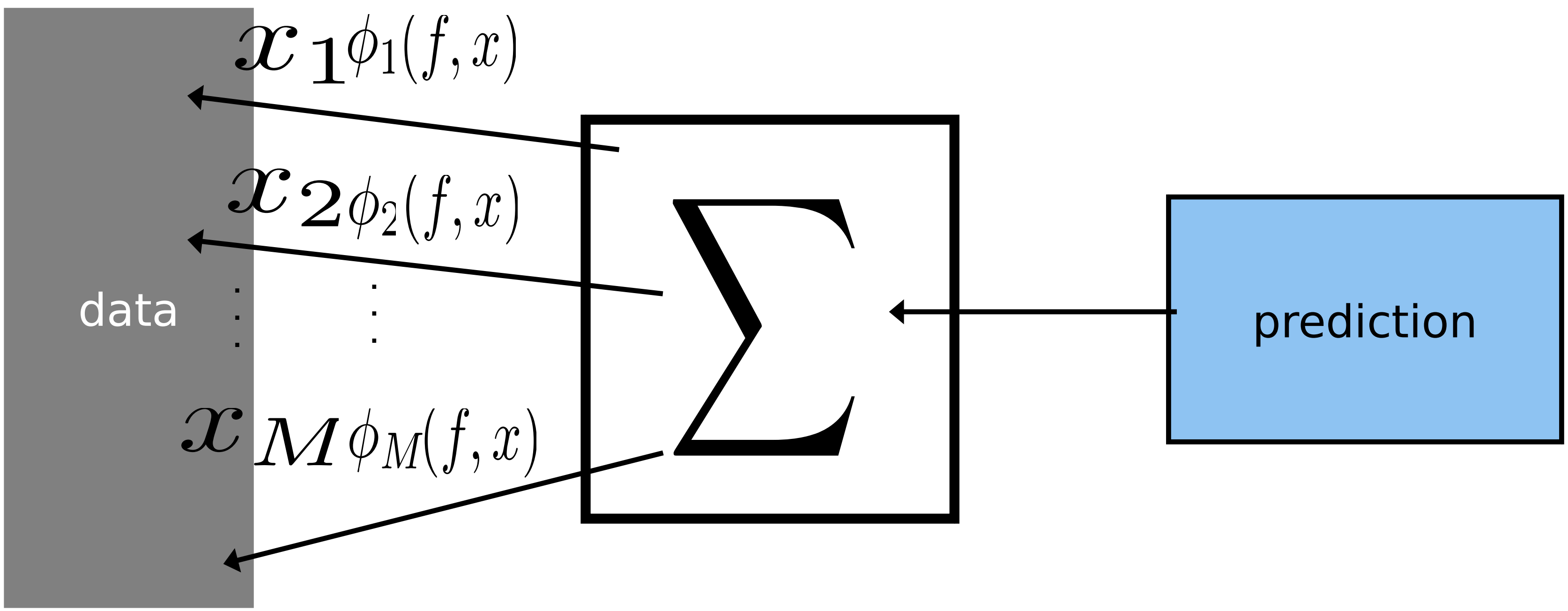
Some of the articles of GDPR can interpreted as requiring explanation of the decision made by a machine learning algorithm, when it is applied to a human subject.

UW Prof. Pedro Domingos, a leading AI researcher, started a firestorm with his tweet

Complicated AI Model



Explainable model: Additive feature attribution model



$$g(z') = \sum_{i=1}^{M} \phi_i z'_i,$$

where $z' \in \{0,1\}^M$, M *is the number of simplified input features, and* $\phi_i \in \mathbb{R}$.

Additive feature attribution methods

LIME

Ribeiro et al. 2016

DeepLIFT

Shrikumar et al. 2016

$$\Sigma$$

Shapley reg. values

Lipovetsky et al. 2001

Relevance prop.

Bach et al. 2015

QII

Datta et al. 2016

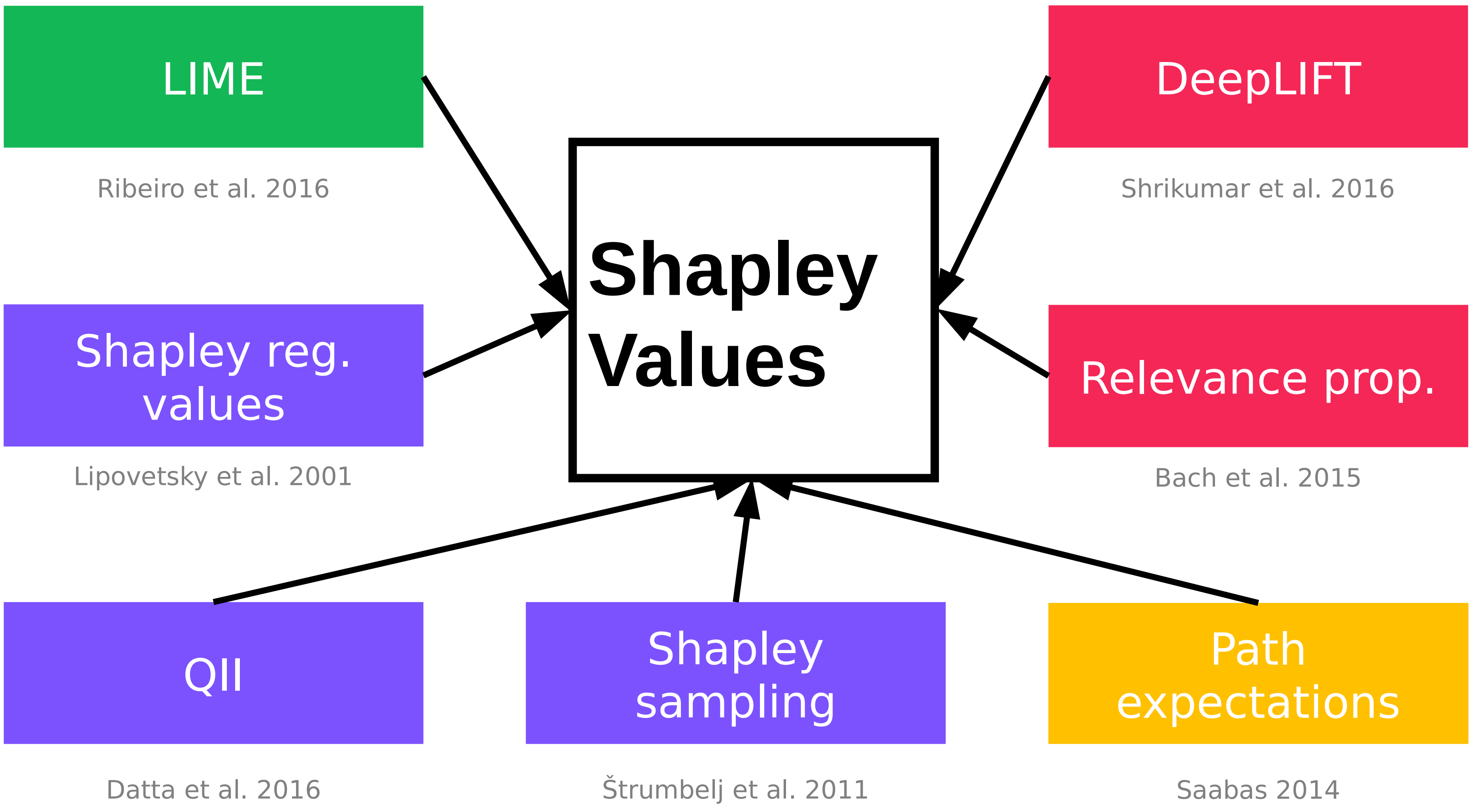
Shapley sampling

Štrumbelj et al. 2011

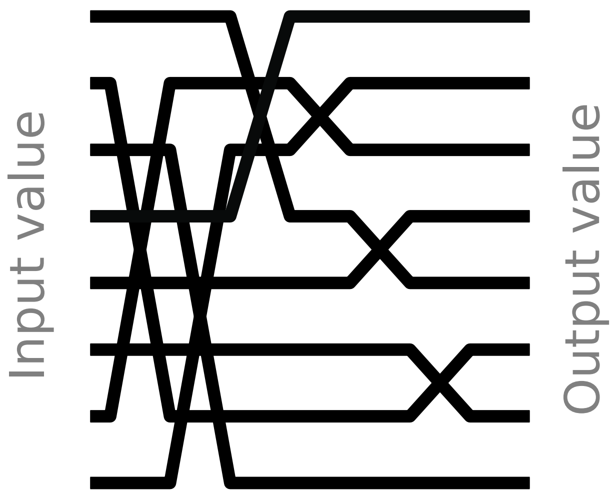
Path expectations

Saabas 2014

Additive feature attribution methods



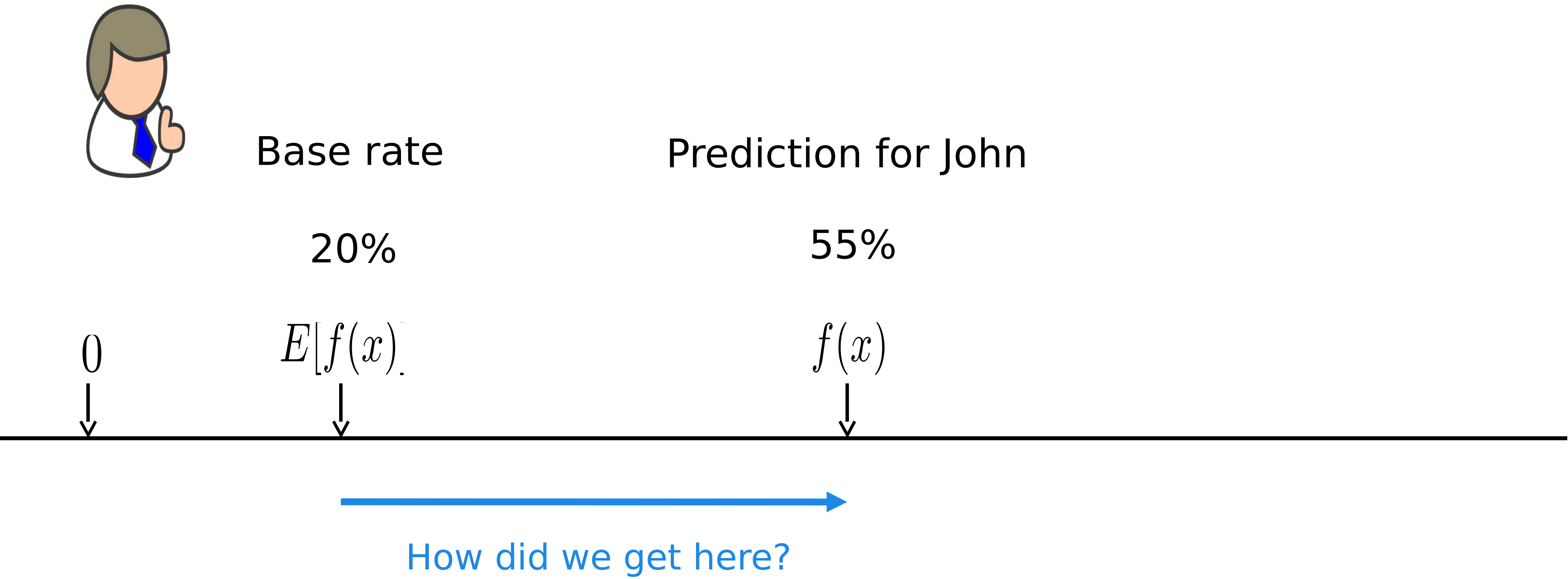
Why additive feature attribution methods may work



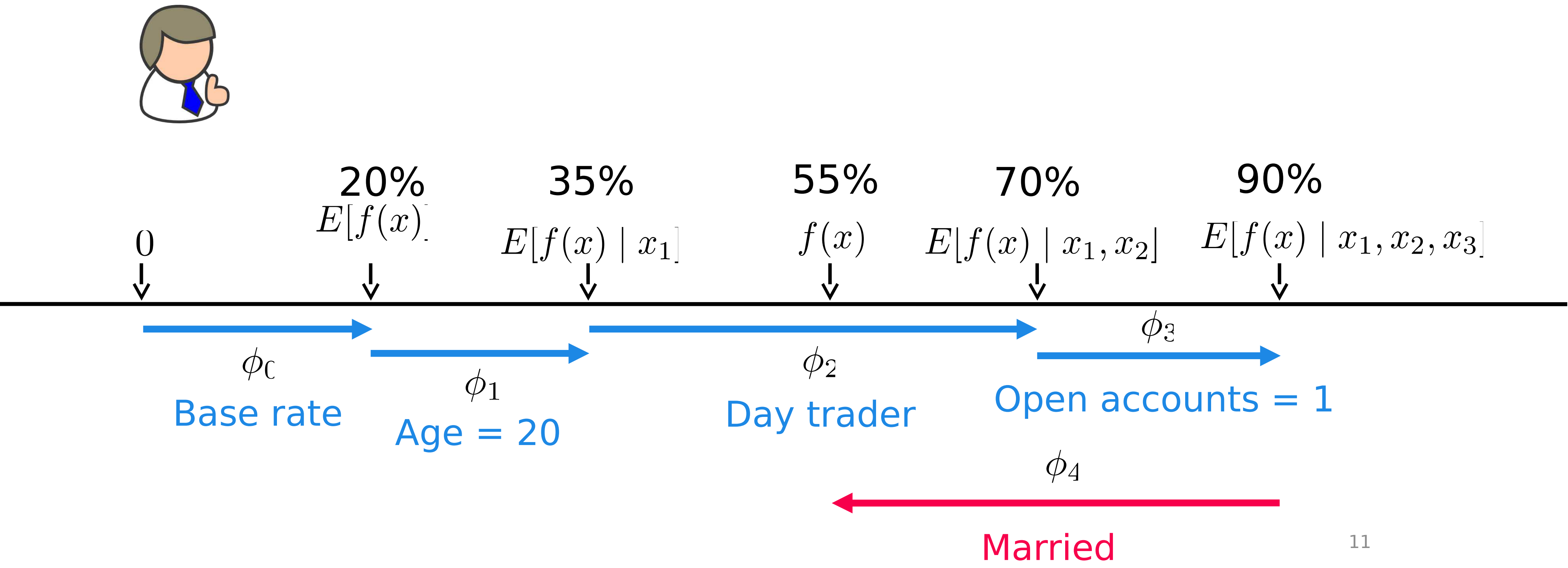
Complex models are inherently complex!

But a single prediction involves only a small piece of that complexity.

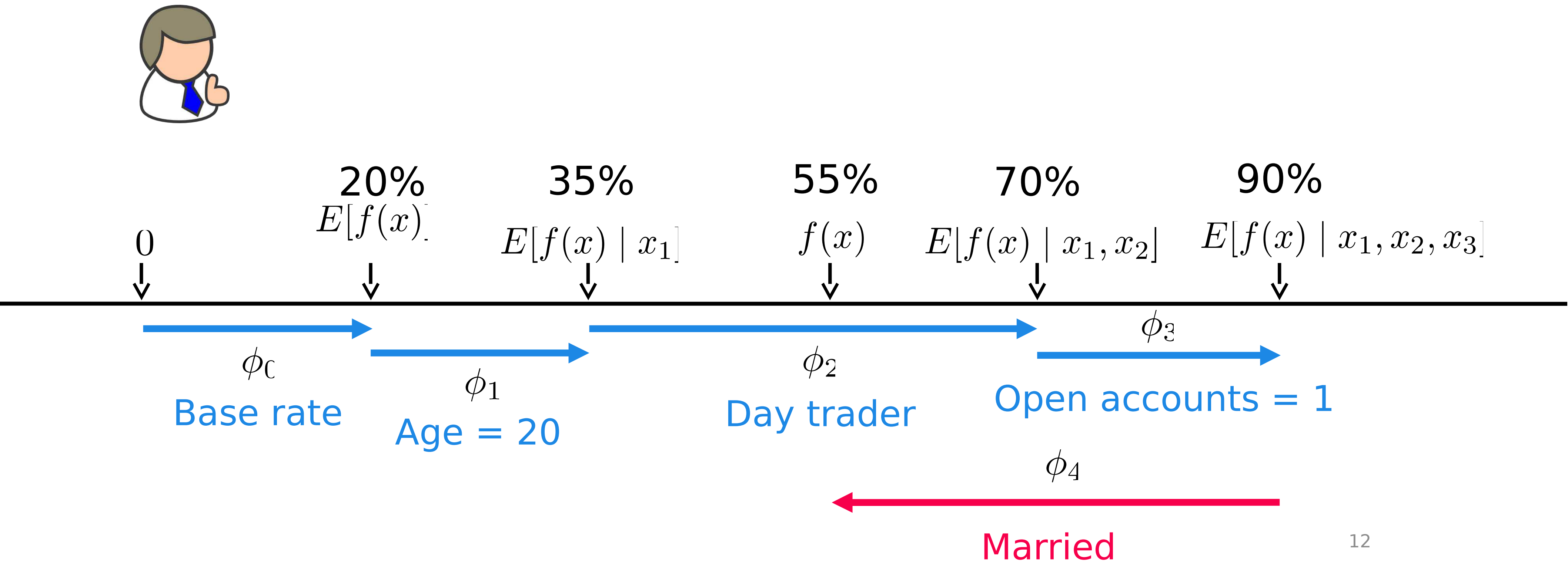
SHapley Additive exPlanation - (SHAP) values (1)



SHapley Additive exPlanation (SHAP) values (2)



SHapley Additive exPlanation (SHAP) values (2)



SHapley Additive exPlanation (SHAP) values (3) – phi values

$$Explain\,model = \sum_{i=1}^{m\,features} \varphi_i X_i$$

where X_i an input and φ_i is the effect of X_i on the model.

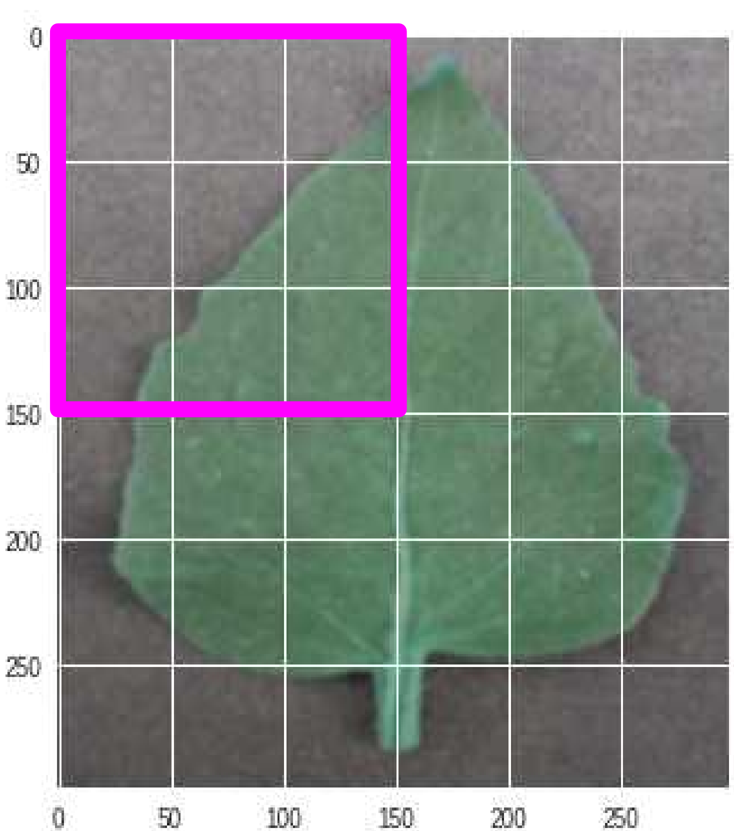
$$\varphi_{age} = \langle f\left(age \cup features_{some}\right) - f\left(features_{some}\right)\rangle_{shapley\,values}$$

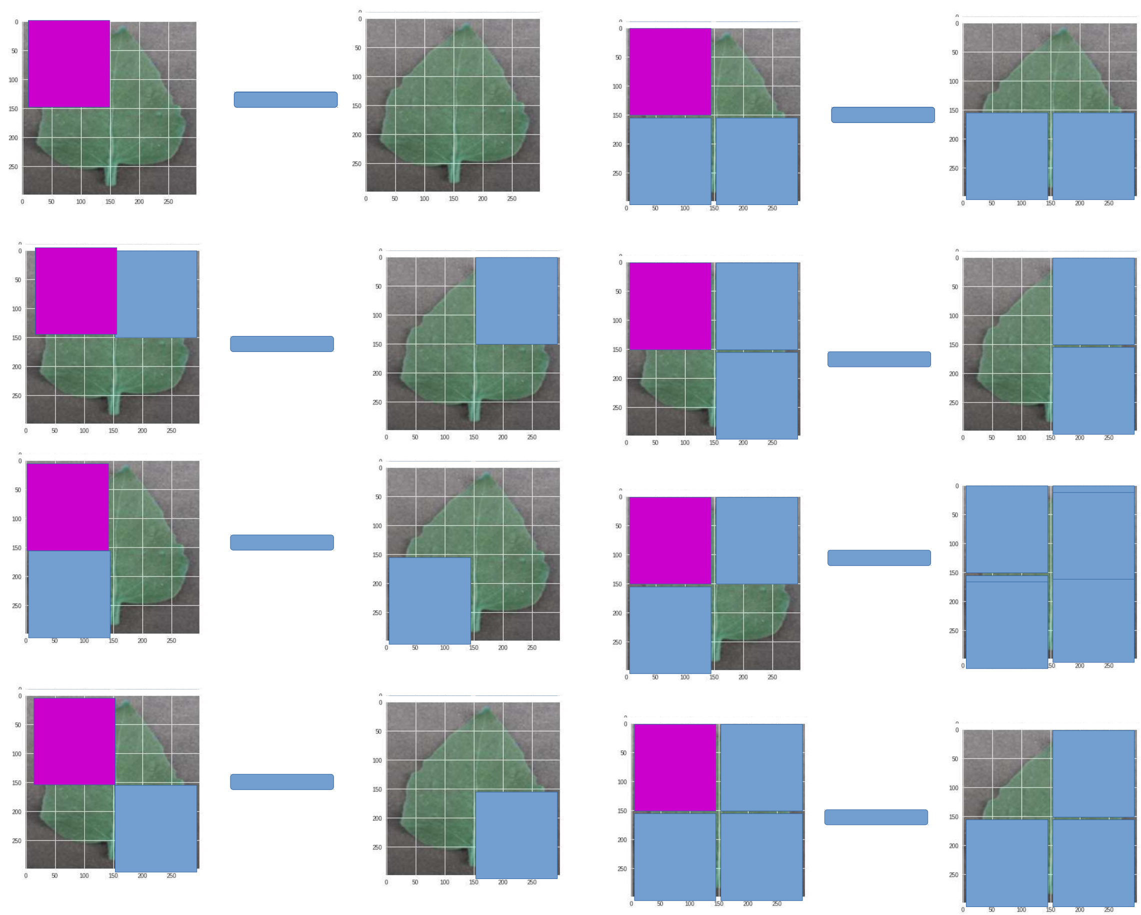
f is your model output, eg accuracy, squared error

$features_{some}$ is the set containing subset of features

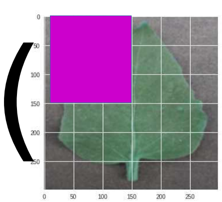
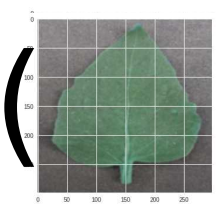
SHapley Additive exPlanation (SHAP) values (4) – phi values

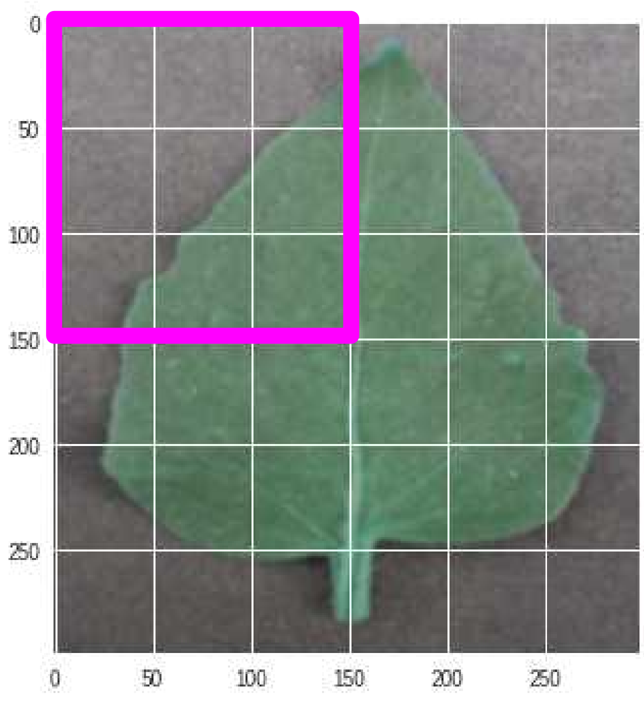
$$\varphi_{pink} = \langle f(pink \cup features_{some}) - f(features_{some}) \rangle_{shapley\ values}$$

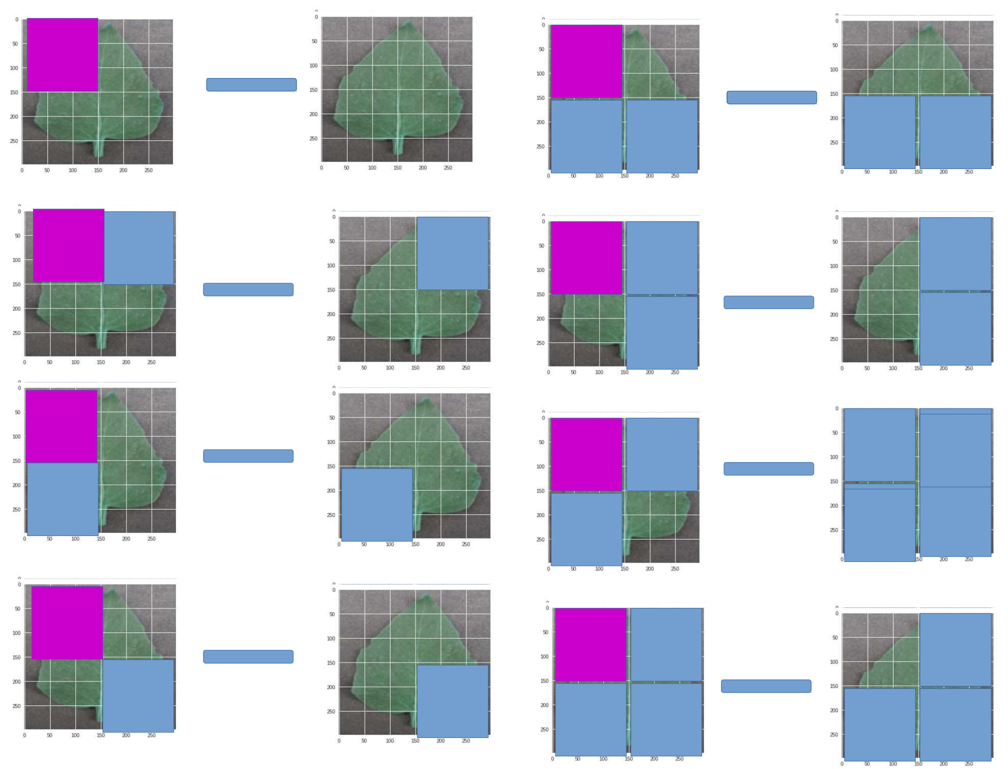




SHapley Additive exPlanation (SHAP) values (4) – phi values φ

φ_{pink}=weight_avg(f() − f())



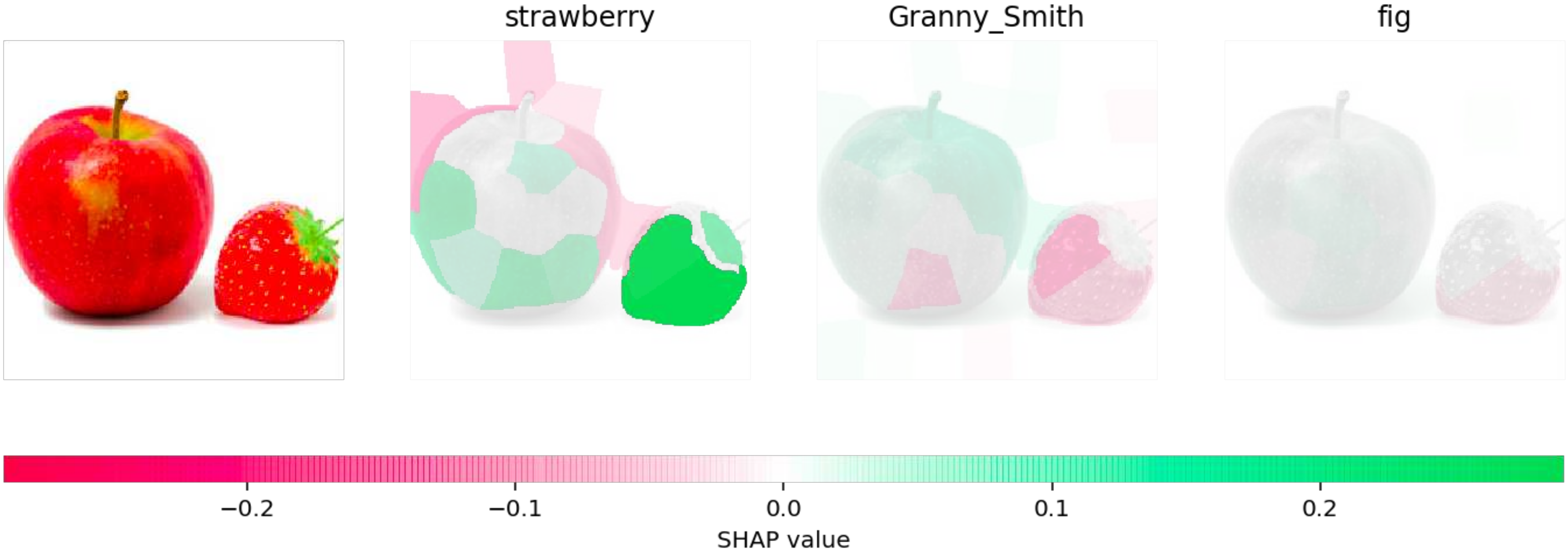


SHapley Additive exPlanation (SHAP) values (5) – solved using weighted linear regression

$$\phi = (X^T W X)^{-1} X^T W y$$

X is the feature binary vector of all combinations of X
W is weights for each example
y is model output for X

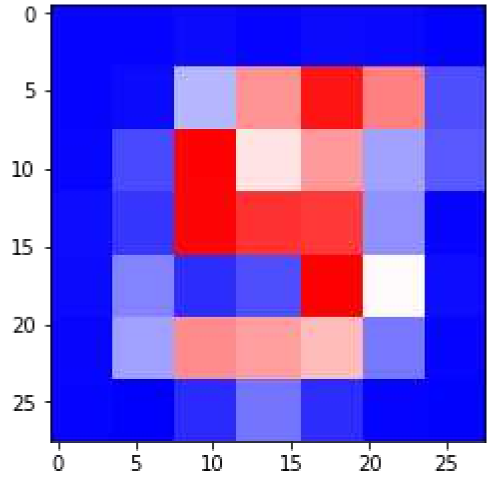
Another Example : VGG16



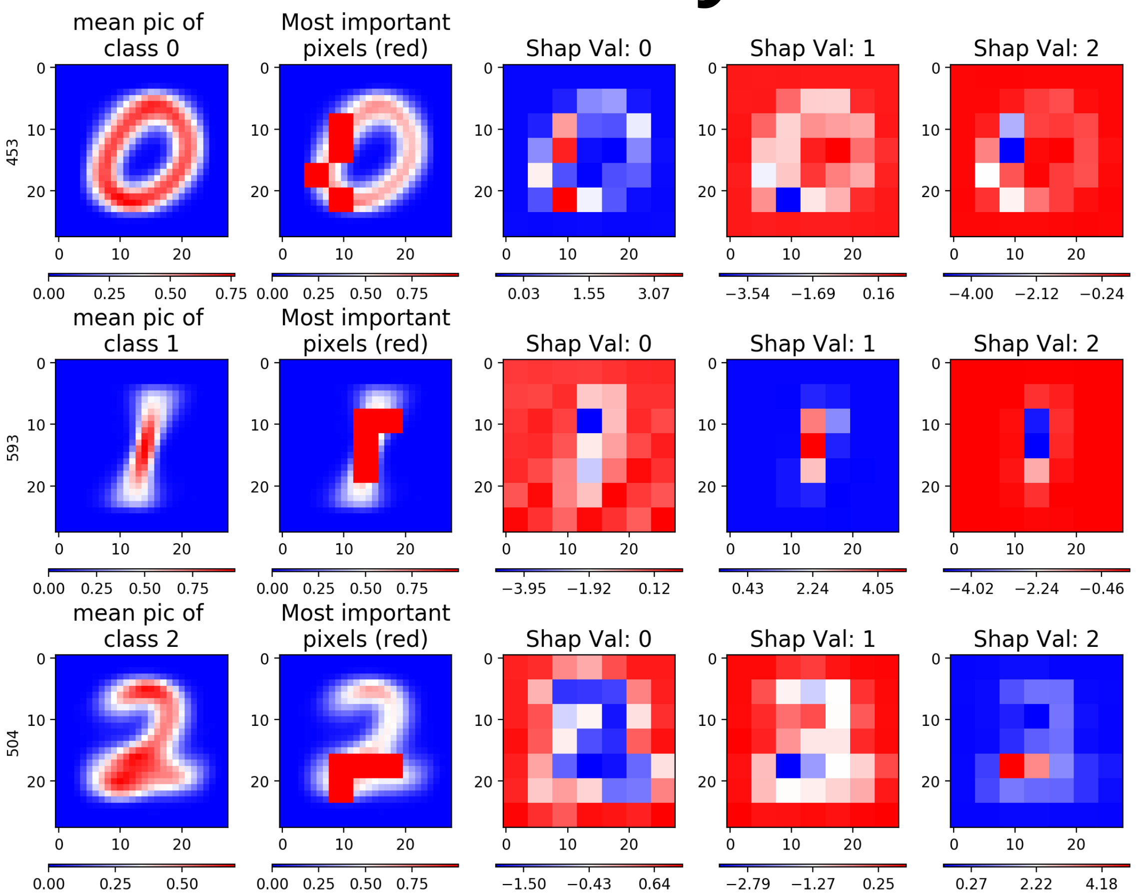
Applying to Mnist (1)

- Mnist model with 4 convolutional layers and 2 dense layers.
- Accuracy is 99.6%
- for each test image {
  - Split image to 7*7 = 49 pixels for shapley value computation
  - Sample 7367 combinations of pixels
    ~ all -1 pixel images, ${}^{49}C_1 = 49$
    ~ all -2 pixel images, ${}^{49}C_2 = 1176$
    ~ 33% of -3 pixel images, ${}^{49}C_3/3 = 6142$
  - Calculate shapley values for each pixel using weighted regression

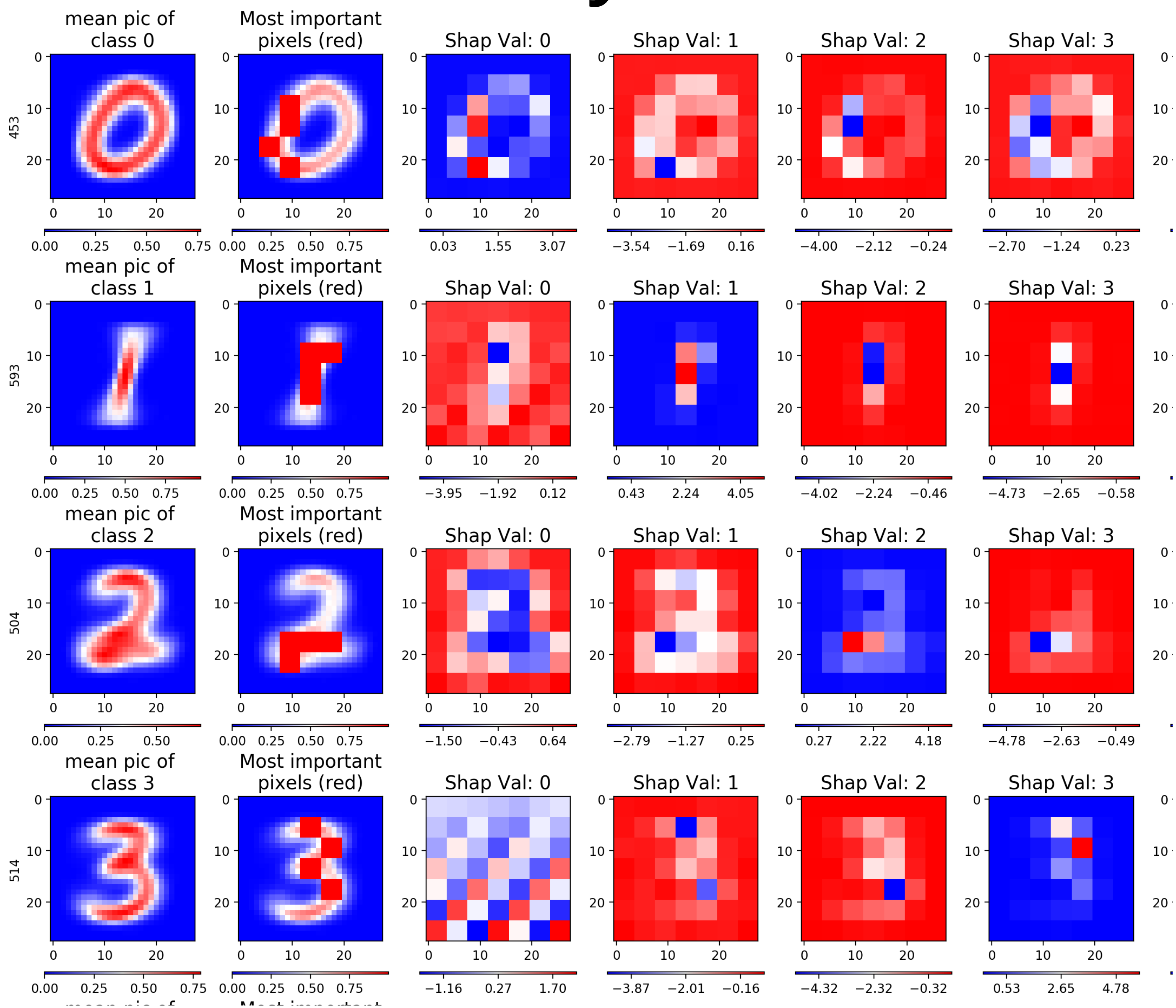
  }



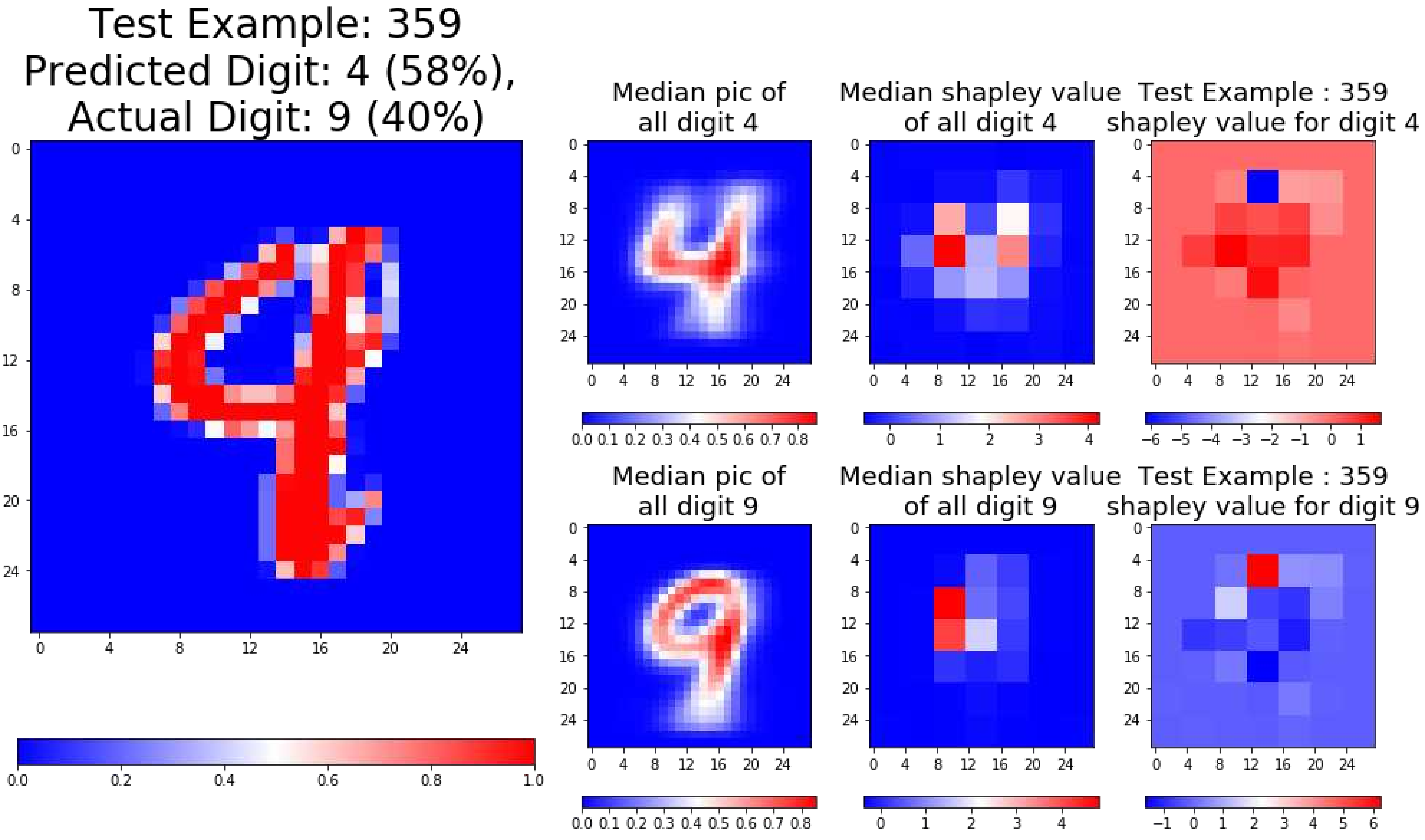
Applying to Mnist (2) – Global analysis



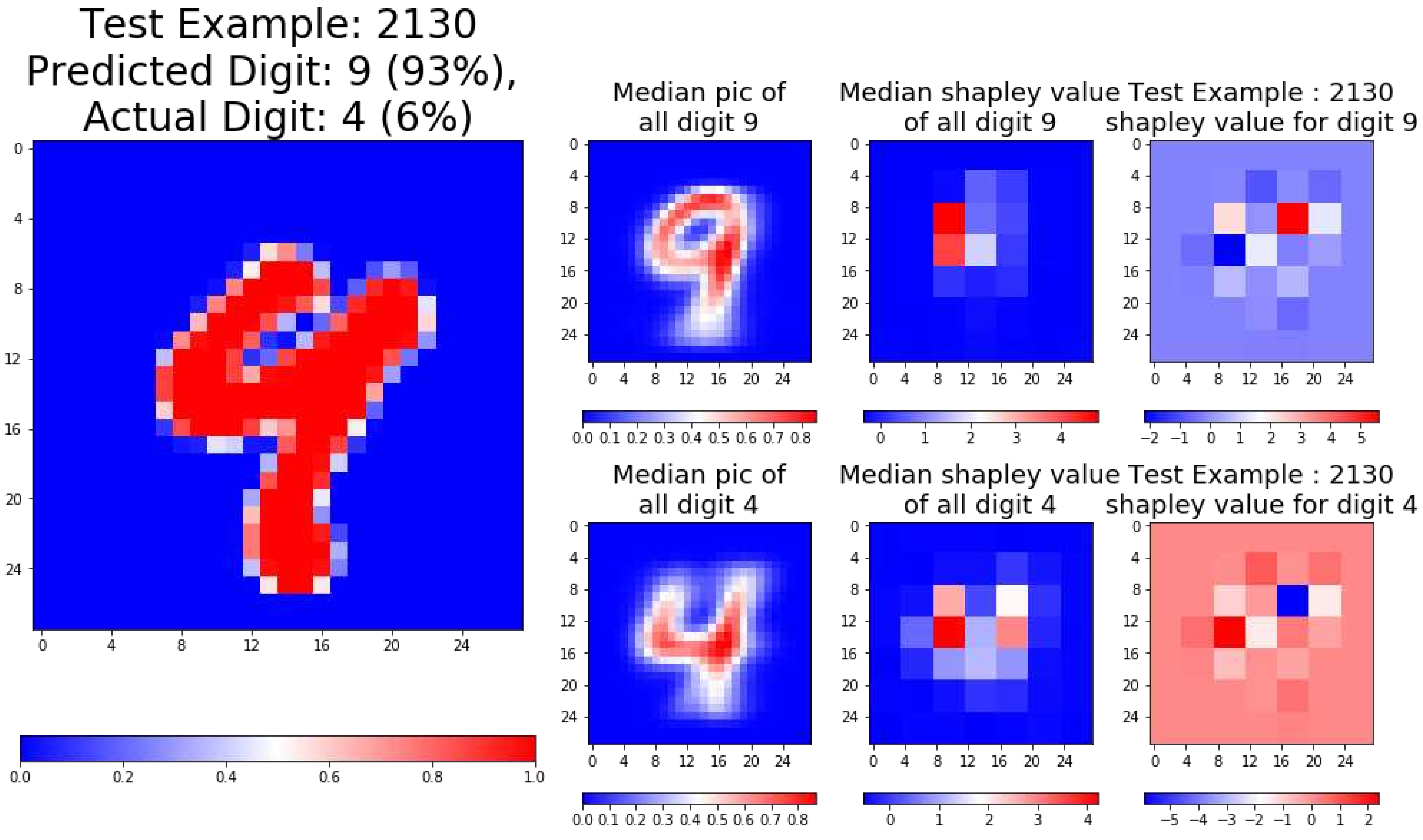
Applying to Mnist (2) – Global analysis



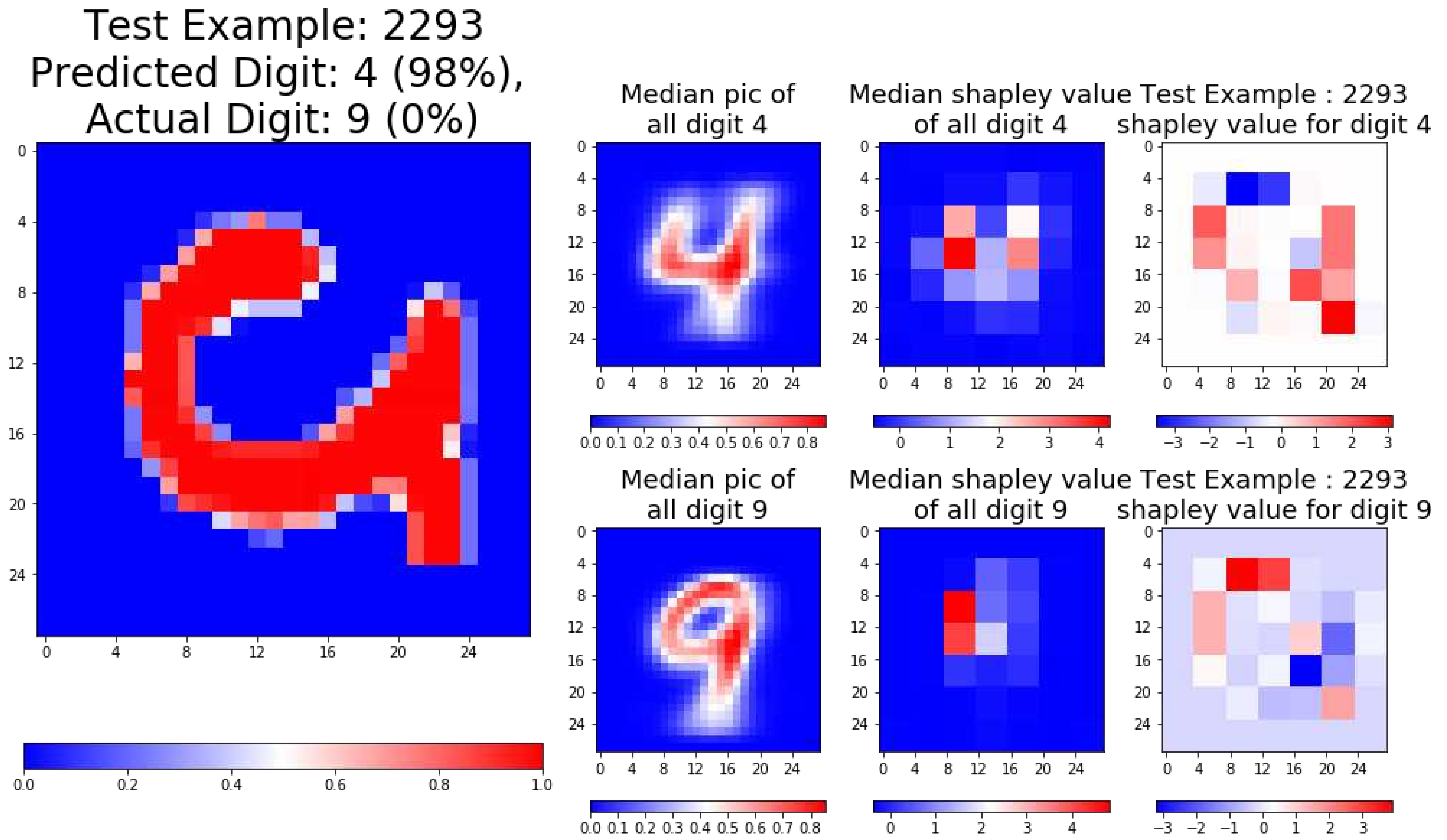
Applying to Mnist (3) – Individual analysis (a)



Applying to Mnist (3) – Individual analysis (b)



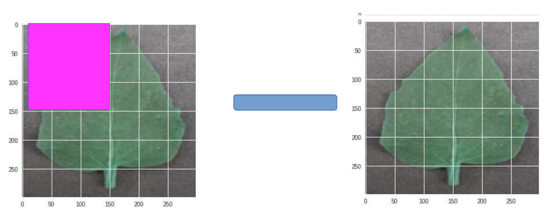
Applying to Mnist (3) – Individual analysis (c)



Drawbacks

$$\varphi_{pink} = \langle f(pink \cup features_{some}) - f(features_{some}) \rangle_{shapley\ values}$$

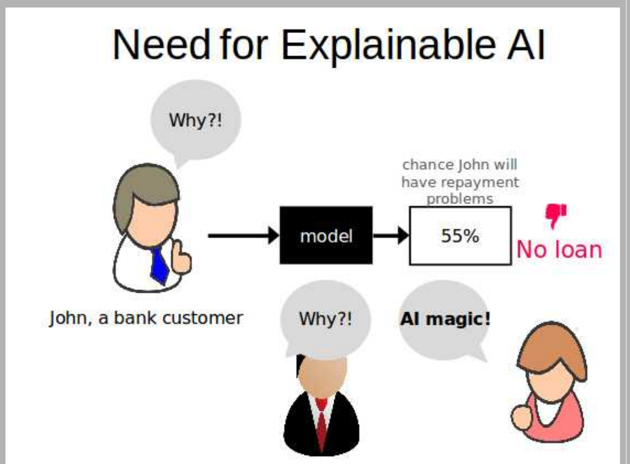
- Computationally intensive, requires to compute 2^m examples for m features followed by inverse of m*m matrix.
  ~ I only sampled 10^3 out of 10^{14} combinations
- How do you appropriately remove a feature ?



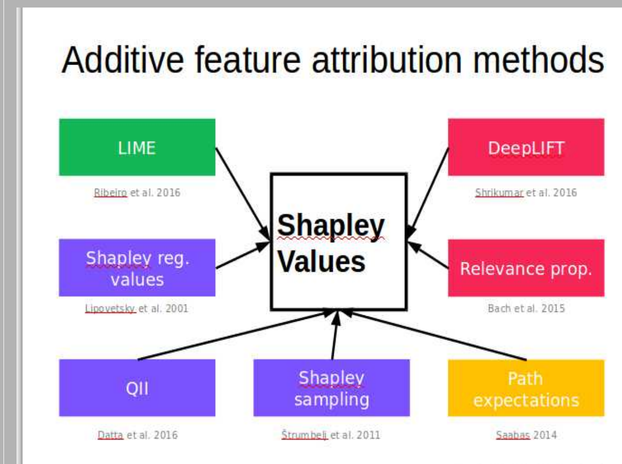
- Method does not explain inner workings, rather it is a model upon a model to explain the final output.

Summary

1.

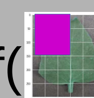
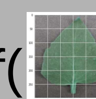


2.

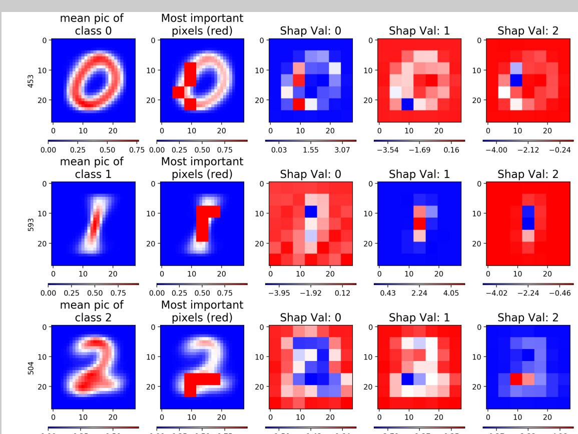


3. Intuition

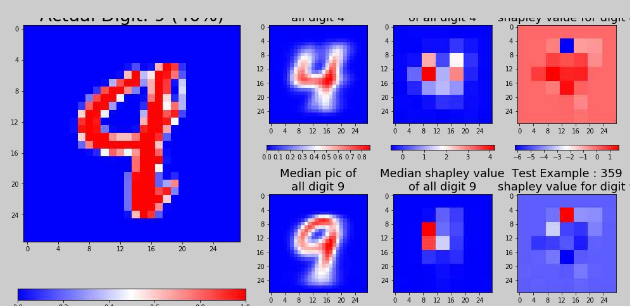
$$g(z') = \sum_{i=1}^{M} \phi_i z'_i,$$

φ_{pink} =
weight_avg(f() − f())

4. Analysis of global predictions

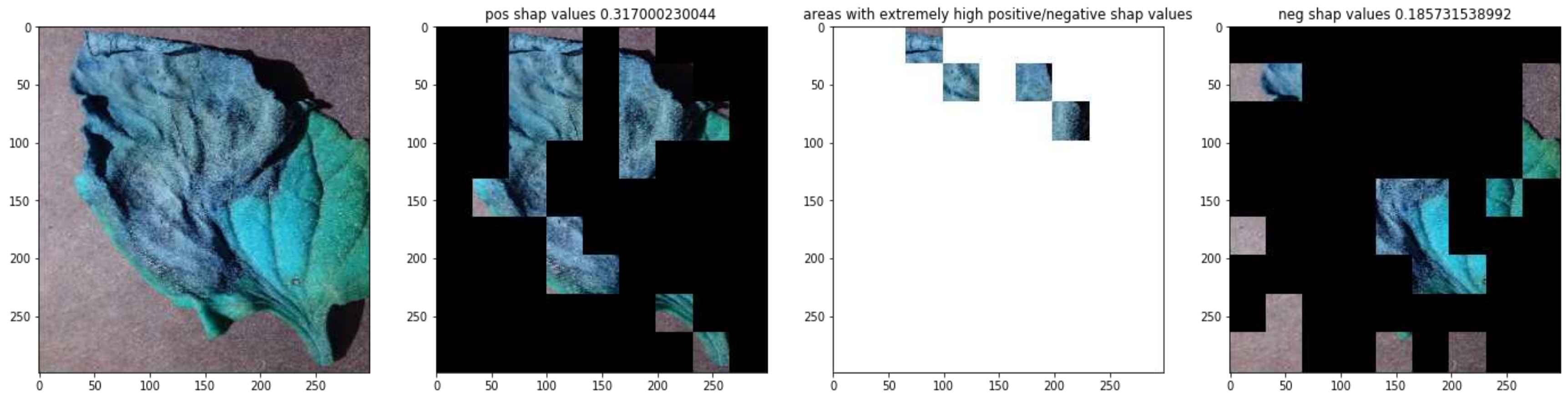


5. Analysis of each prediction



6. Drawbacks

Another application : Transfer-learned Inception3 model



References

- Scotts slides https://github.com/slundberg/shap/blob/master/docs/presentations/NIPS%202017%20Talk.pptx
- A Unified Approach to Interpreting Model Predictions(2017), Scott Lundberg, Su-In Lee
- Analysis of regression in game theory approach (2001),Stan Lipovetsky, Michael Conklin