Similar Compounds Show Similar Activities- Is This True for Compound Combinations?

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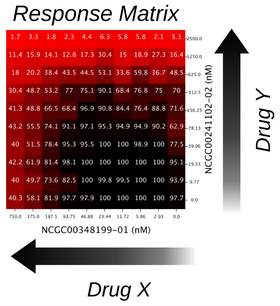
Introduction

Drug Combination and Synergy

- Drug combinations are used to treat many medical conditions such as: HIV, malaria, and cancer
- Sometimes the combined effect of drugs is different than their individual effects
  - Better effect: synergism
  - Same effect: additive
  - Worse effect: antagonism

Response Matrix



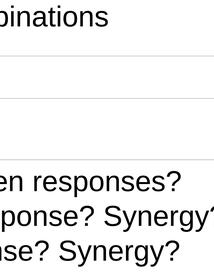
Combination Screening

- Traditionally, screening for drug combinations is slow process
- Since NCATS has high throughput screening, data for thousands of drug combinations can be generated quickly
- Presents opportunity to do large-scale analysis

Metrics to Measure Synergy

- Synergy is quantified with respect to a model of additivity [1]
- Three Models:
  1. Highest Single Agent (HSA)
  2. Bliss Independence Model
  3. Loewe Additivity Model
- Used Bliss Independence Model- convenient and more robust in a high throughput screening setting
- Synergistic- more blue; Antagonistic - more red

Synergy Matrix- Δ Bliss



Similarity Property Principle (SPP)

- "Similar compounds have similar properties" [2,3]
- Want to know if this is true for drug combinations

Questions

1. What are metrics for dissimilarity between responses?
2. Does chemical structure correlate to response? Synergy?
3. Does dose response correlate to response? Synergy?

Q1: Metrics to Compute Matrix Dissimilarity

Methods Insensitive to Spatial Distribution

1. Root Mean Standard Error

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(a_i - b_i)^2}$$

2. Euclidean Distance

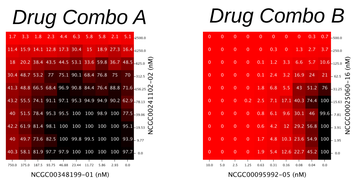
$$ED = \sqrt{\sum_{i=1}^{n}(a_i - b_i)^2}$$

3. Two- Sample Kolmogorov-Smirnov Test

Methods Sensitive to Spatial Distribution

4. Syrjala Test [4]

Drug Combo A *Drug Combo B*

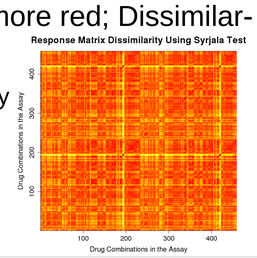


Using these metrics, dissimilarity was computed for comparing all pairs of drug combinations

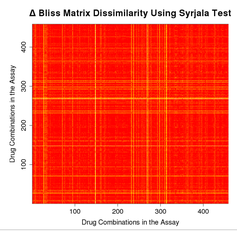
Q1: Visualizing Dissimilarity in an Assay

Malaria Assay ID 1764: screening 480 drug combinations
Similar- more red; Dissimilar- more yellow

Visualizing Dissimilarity of Response Matrices in an Assay

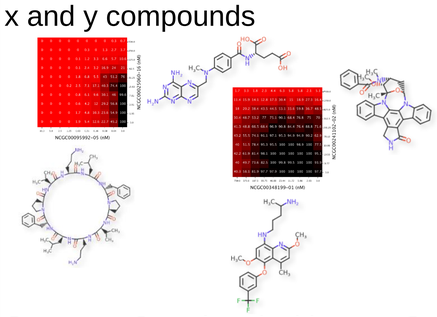


Visualizing Dissimilarity of Δ Bliss Matrices in an Assay

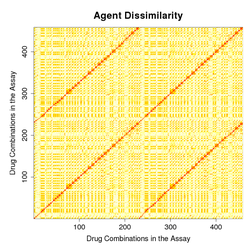


Q2: Chemical Structure Correlated with Combination Response and Synergy

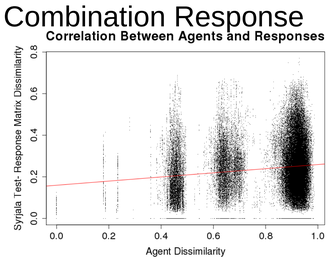
Method: compare corresponding x and y compounds



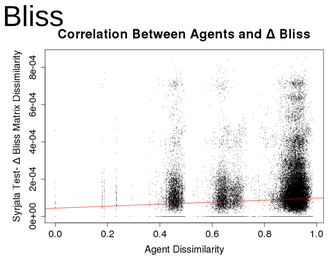
Visualizing Dissimilarity of Structures in an Assay



Structure Correlated with Combination Response

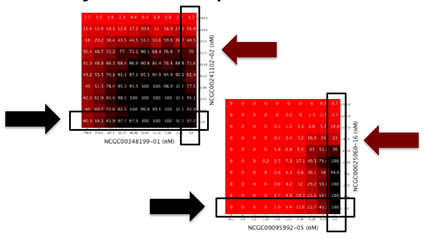


Structure Correlated with Δ Bliss

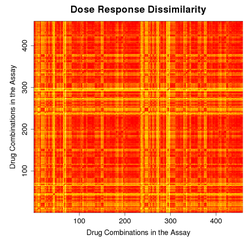


Q3: Dose Response Correlated with Combination Response and Synergy

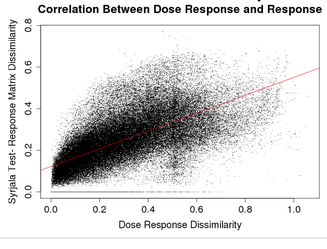
Method: compare corresponding x and y dose responses [5]



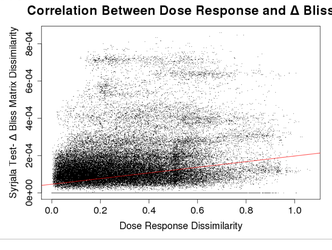
Visualizing Dissimilarity of Dose Responses in an Assay



Dose Response Correlated with Combination Response

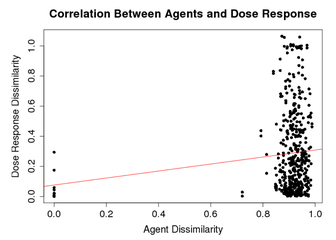


Dose Response Correlated with Δ Bliss



Conclusion

Individual Compounds:



- Structural similarity suppose to correlate to dose response similarity
- Correlation not shown (R^2 = 0.014; no correlation)
- Suggests that using dose response as the compound property does not illustrate the SPP well

Drug Combinations:

	Structural Dissimilarity	Dose Response Dissimilarity
Combination Response Dissimilarity	R^2 = 0.020 no correlation	R^2 = 0.437 correlation
Δ Bliss Dissimilarity	R^2 = 0.006 no correlation	R^2 = 0.052 no correlation

- For SPP to hold, both have to correlate- this is not the case
- Correlations with Δ Bliss even weaker than response
- Means SPP does not seem to hold
- Suggests that understanding drug combinations is more complex than understanding individual compounds

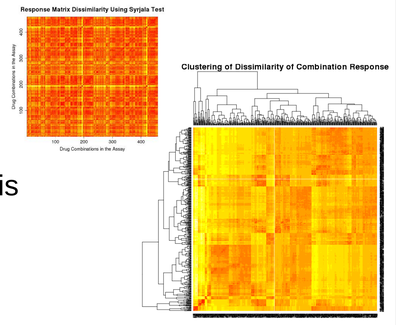
Discussion

Limitations

- Dose response was not a compound property that illustrated the SPP well
- Will be able to draw better conclusions about if the SPP for drug combinations using a different compound property

Future Work

- Clustering of response matrices- group together the drug combinations based on which show similar response matrices
- Work on SPP within specific clusters
- Perform more analysis:
  - Data for other medical conditions in addition to this work on Malaria,
  - Larger overall volume of data



References

[1] Nikolaus J. Sucher (2014). Searching for synergy in silico, in vitro and in vivo. *Synergy*, 1(1), 30-43.

[2] Yvonne C. Martin, James L. Kofron, Linda M. Traphagen (2002). Do Structurally Similar Molecules Have Similar Biological Activity? *Journal of Medicinal Chemistry*, *45* (19), 4350-4358.

[3] Rajarshi Guha, John H. Van Drie (2008). Structure-Activity Landscape Index: Identifying and Quantifying Activity Cliffs. *Journal of Chemical Informatics and Modeling*, 48(3), 646-658.

[4] Stephen E. Syrjala, (1996). A Statistical Test for a Difference between the Spatial Distributions of Two Populations. *Ecology, 77*(1), 75-80.

[5] Lawrence I-Kuei Lin. (1989). A Concordance Correlation Coefficient to Evaluate Reproducibility. *Biometrics, 45*(1), 255-268.