

Shakespearian information: Transfer entropy of associated character interactions within Much Ado About Nothing.

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The classical Shakespearian comedy Much Ado About Nothing is analyzed for the amount of information present in the character patterns between its scenes. This measure, known as transfer entropy, displays a sizable deviation from random. These deviations imply that characters within this play carry more information in their pasts about their own futures, than do other characters about their futures. Additionally, projected target-source character pairs display higher than average transfer entropies, given the later's compulsory occupations at the receiving end of ploys by the former.

I. INTRODUCTION

Shakespeare's prowess as a playwright requires no introduction [1–3]. As such, Much Ado About Nothing (MAAN), one of Shakespeare's most renowned comedies was deemed an appropriate test case for the application of transfer entropy (TE) measures on the structure of character interactions within performance art [1]. Equity of clausal efficacy does not exist for characters within performance art. Major characters drive the plot and the behavior of others more significantly than do their minor counterparts. It is possible that this heterogeneity may be captured by the TE conveyed between various character pairs.

TE is an information measure used to assess the amount of information gained about the future state of a target object by knowing the history of a separate source object [4]. In context of performance art, this may be understood as the future presence of characters based on the current presence of others.

MAAN is hypothesized to have a potential for high transfer entropy values for specific character pairs given the structure of its interwoven plots. The play revolves chiefly about two separate ploys. Each ploy is designed to trick specific characters into actions of which they themselves would may never willingly engage. The first is designed to spur love where it is not, the second, to divide it where it naturally arises. Hereafter these plots will be referred to as the love-plot and the hate-plot, respectively. Though the play begins with each ploy sharing the spotlight, the hate-plot dominates the penultimate moments near the conclusion. If all pairwise character interactions are considered for TE, it may be predicted that the masterminds of these plots may impart an increased knowledge about the future states of their targets, relative to their targets own histories.

Of the myriad other interactions taking place within the play, it may be expected that Don Pedro, Claudio, and Leonato, share a high transfer entropy with the targets of their love-plot, Beatrice and Benedick. Meanwhile Don John, Conrad, and Borachio, might share high transfer entropy as well via the hate-plot upon Claudio and

Hero.

II. MODEL DESCRIPTION

In order to apply TE to Shakespeare's work, the original written form of MAAN was divided first into its 17 natural scene, and then into sub-scenes (66 in all). The sub-scene division was necessary in order to reflect character entrances and departures from the stage, signifying natural divisions in the dialog. In this formulations characters are represented as nodes, while interactions between characters are represented as edges. All characters present in a given sub-scene were given credit for their participation with each other in the form of unit-weight edges. The pairwise interactions between all participants within all sub-scenes of a scene were then summed, providing the weight of the edge between them (such as that displayed in FIG. 1 for the total play) before being converted to boolean values of either present or absent for use in TE measurements (FIG. 3). TE was calculated via

$$T_{Y \rightarrow X} = \sum_{(x_n^k, x_{n+1}, y_n)} p(x_n^k, x_{n+1}, y_n) \log_2 \left(\frac{p(x_{n+1} | x_n^k, y_n)}{p(x_{n+1} | x_n^k)} \right)$$

where Y refers to the the source node and X the target. n is an index used to signify the reference time step (scene), and k refers to the history length of the target being compared to be influence of the source [4]. The summation states that all possible combinations of states will be considered for all possible time steps of length k+1. In short, the above equation compares the amount of information contained within the self-history of character X as to its own future state, with the increased amount of information which would be gleaned if the current status of character Y is known. Therefore TE references the affect of character Y on character X.

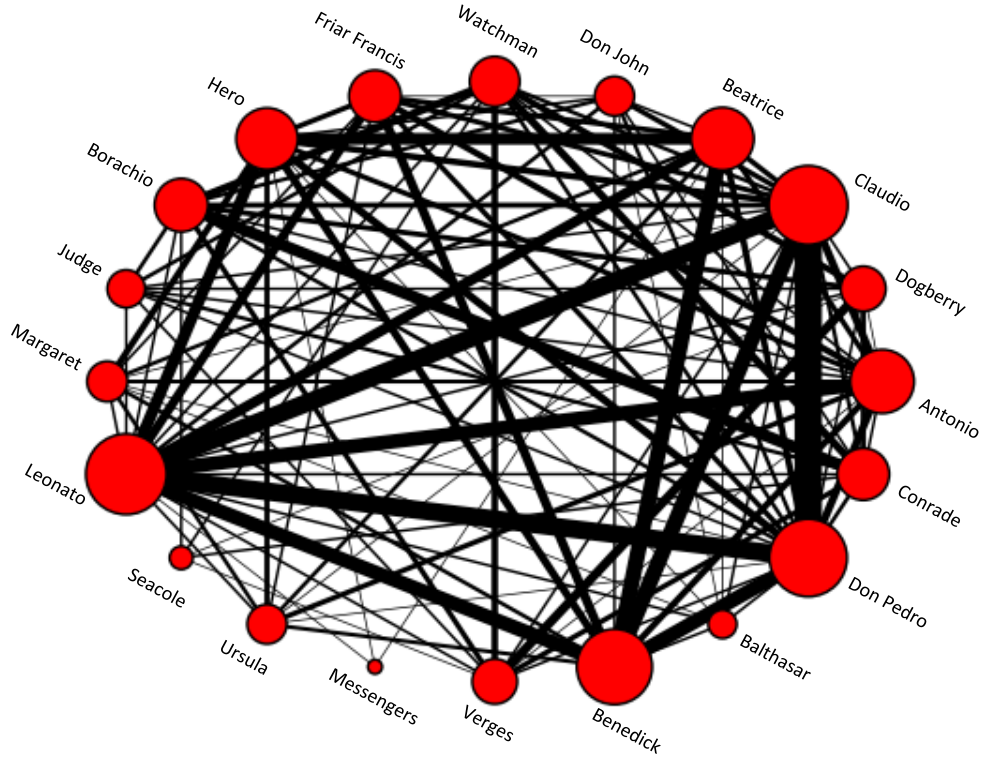


FIG. 1. The summation of all character interactions for the entire play. edge weights reflect total communication, where as the size of the nodes reflect the summation of all incoming communications from any other node.

III. RESULTS

An overview of all character interactions is displayed in the circular network diagram of FIG. 1. Here, the weights of the connecting edges reflect the total interactions between any two characters throughout all scenes of the play, with the size of the individual character nodes reflecting their total incoming weights. The transfer entropy statistics displayed in FIG. 2 evidence a system where the majority of node pairs (77%) contain a non-zero transfer entropy. Slightly more than half of which, do not share an edge with one another (42% vs. 35%). FIG 3 displays the transfer entropy of all character pairs in rank order (blue lines) against a randomly generated network of character interactions with the same average of total character appearances (gray line with ± 1 SD gray region). It is of note that the entire TE character line is below that of the randomized network, and accept for one location, is also below one standard deviation.

IV. DISCUSSION

When the transfer entropy is viewed in rank order against randomized networks (blue line in FIG 3 against the gray region), it becomes apparent that the sequence of source character appearances imparts less information

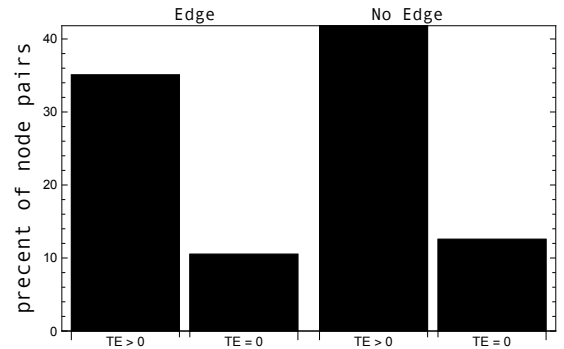


FIG. 2. Percentage of all node pairs categorized by the presence of a connecting edge, and the presence of a non-zero transfer entropy for the couple

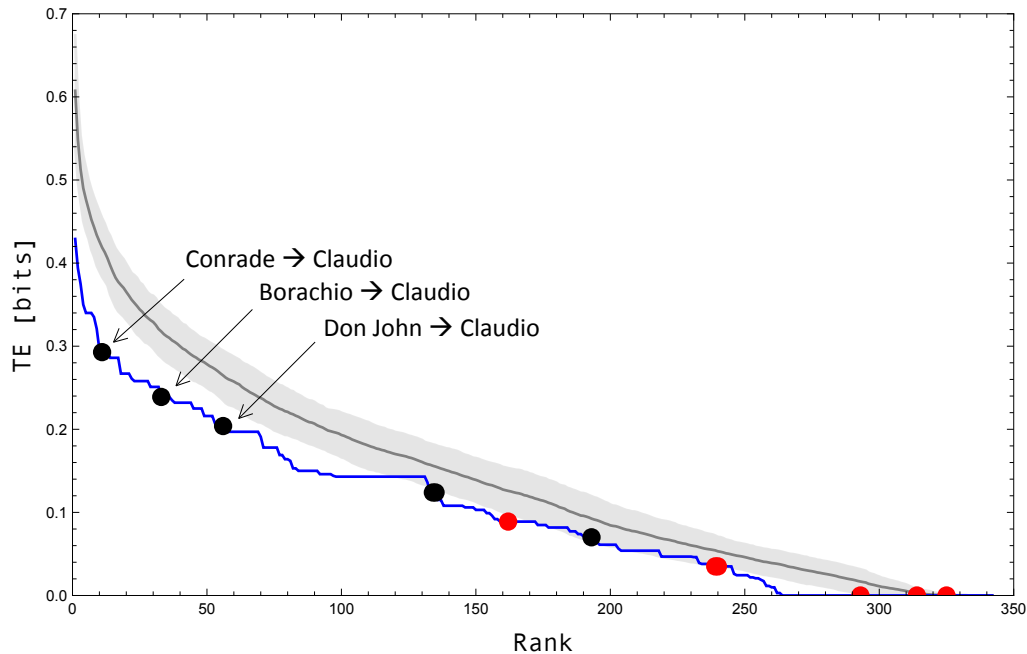


FIG. 3. TE of all node pairs in rank order. The blue line reflects the characters in the play, where as the gray line and associated soft gray region reflect randomized interactions and single the standard deviation region. Black dots signify the affects of evil-plot perpetrators (Don John, Conrad and Borachio) on Claudio and Hero, with Red dots signifying the effects of the love-plot perpetrators (Don Pedro, Leonato, and Claudio) on Benedick and Beatrice.

on the targets than if the characters were brought in at random. Thus, the characters appear to contain more information about their future in their own pasts than if their pasts were randomized, and this has the effect of decreasing the influence of other characters relative to the random associations. Still, we consider which characters have the greatest predictive capacity on the future of others (high TE values skew to the right of FIG. 3. The seven highest values for transfer entropy (not explicitly labeled) imply that only three characters, Conrad, Borachio, and Don John impart the most information about the future states of other characters, most specifically Benedick and Claudio.

This result is entirely fitting given the roles of these three in perpetrating the penultimate hate-plot on Claudio. The specific effects of all three perpetrators on Claudio are directly identified in FIG. 3. The relative place-

ment of the love-plot (red dots) vs. the hate-plot (black dots) also appears to fall in line with their changing relative importance as the play matures.

This first pass at applying TE measures to performance art suggests trends which may be uncovered through comparison to other works. Do all artistic performance pieces display negative deviations from random in their TE measures? And, can distance from random be correlated with qualitative measures of the same works given artistic focusses on suspense? Thus, this approach may potentially unveil quantitatively accessible trends which may be pitted against qualitative assessments of the worth of such art. Follow-on work will therefore focus on the differences between the various genres for which Shakespeare was renowned - tragedies, comedies, etc. - laid against a backdrop of his contemporaries.

[1] Shakespeare W. Much Ado about Nothing: By Shakespeare. R. Walker, Change-Alley, Cornhill; 1735.

[2] Shakespeare W, Budd FE. Much ado about nothing. Cambridge University Press; 1936.

- [3] Ornstein R. Shakespeare's comedies: from Roman farce to romantic mystery. Newark [Del.]: University of Delaware Press; London; Cranbury, NJ: Associated University Presses; 1986.
- [4] Kim H, Davies P, Walker SI. New scaling relation for information transfer in biological networks. *Journal of The Royal Society Interface*. 2015;12(113):20150944.