I. Identifying physical events: Assuming all significant physical events trigger news results on a search engine, we separate those spiking queries which trigger a news result on Bing. These news triggering queries are then clustered based on their semantic similarity using Word2Vec[3]. Each of these clusters now represent a physical event and contain common variations of search queries depicting that event. To increase clustering recall, those spiking queries which did not fire news, but are semantically very similar, are merged with existing clusters. For further discussions, we denote an event cluster by E. To keep only significant events, we discarded those clusters which do not have minimum 5000 cumulative query impressions count[1]. In each cluster, top 5 queries by impression are taken as representative queries for that cluster, denoted as E_Q henceforth.

II. Preparing Candidate Set of Unusually-related queries: The queries which are not mapped to any event after the above task, are taken as potential search queries which could be unusually-related to some event(E). We represent the queries in this set as Q.

III. Mapping candidate queries to events: The mapping essentially represents the unusual-relatedness of query to the event, which has been calculated using following process. First, we evaluate correlation using:

$$Score_{correlation}(Q, E) = \frac{\#Times(Q, E)}{\#Times(E)}$$

where $\#Times(Q,E)$ is number of times the Q and E_Q have spiked together, and $\#Times(E)$ is number of times E_Q have spiked in the year. The $score_{correlation}$ signifies the temporal correlation of the query and the event. We keep only those mappings which get $score_{correlation}$ more than 0.6.

However, temporal correlation is necessary but not a sufficient condition to establish causation or unusual-relatedness. Hence, we further refine the mappings using following score to estimate the relation of query to event.

$$Score_{unusually-related}(Q, E) = \frac{Similarity(Q_T, E_T)}{Similarity(Q, E_Q)}$$

where $Similarity(Q_T, E_T)$ is the semantic similarity[2] of document titles obtained by searching E_Q and Q on Bing. Similarity(Q, E_Q) is the semantic similarity[2] of E_Q and Q. Note that score is directly proportional to similarity of titles, because it shows that the query could be related to the event. Moreover, score is inversely proportional to similarity of E_Q and Q, which captures the unusualness of relationship. We empirically chose a threshold of 0.8 to get final mappings.

4. EXPERIMENTS AND RESULTS

To measure unusually-relatedness defined in Section 1, we showed *event–query pairing* to 5 judges, and asked them to label it as one of – *'Unusually-Related', 'Directly Related'* or *'Not Related at all'*. We decided the label, which 3 or more judges agreed upon. In case of non-majority, we took the label as *'Can not decide'*.

For evaluation of our algorithm, we generated such unusually related pairs for four significant events of 2016, which are also stated in column 1 of Table 1. We took 100 sampled

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Event	Example Queries unusually related to the Event	Interpretation of result
Trump won U.S. presidential elections	living in canada; canada immigration office; canada jobs	Peaked interest in Canada as potential place to live due to Trump's stand on various public policies.
Hillary collapsed due to Pneumonia	symptoms of pneumonia in adults; is pneumonia contagious	Hillary collapsed due to pneumonia which developed curiosity about the disease.
Britain exit from EU	culture in switzerland; cost of living switzerland	Switzerland has special relationship with EU and speculation were that Britain might follow the same model.
Terrorist attack in Brussels	belgium people and culture; belgium gun laws	Attack in Brussels developed curiosity about culture and gun laws.

Table 1: Unusually-Related search queries for four significant events in 2016.

result pairs, and got the labels as described above. Result shows that 38% times pairs are 'Unusually-Related', 52% are 'Not Related at all', 4% are 'Directly Related' and 6% are 'Can not decide'. Table 1 also present examples of good results from our algorithm, along with an interpretation for query being unusually related to physical event.

For comparison, we also got judgment for 100 sampled pairs obtained by temporal correlation only i.e. mapping Es and Qs (on same day) without using our mapping algorithm. Results show that only 4% of them were 'Unusually-Related', 10% were 'Directly Related' and 70% were 'Not Related at all'. This indicates that on a given day multiple events and queries trend, which may not relate to each other. Thus, 9.5 times increase (4% to 38%) in accuracy of our algorithm is significant.

5. CONCLUSION AND FUTURE WORK

Our work presents a novel method to discover unusual search behavior related to physical events. While we realize the challenges which [4] associated with search logs, we show through various examples that deeper insights can be drawn from search logs, and hope to attract attention of research community on the same.

In future, we will be studying how re-occurrence of same events results in different behavior in search logs e.g. we will study how search trends have changed over time during release of multiple iPhone versions.

6. REFERENCES

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[1] An impression count is total number of times a query is issued on search engine.
[2] Using Word2Vec[3].