Datacubed Health

GEOFENCING FOR AUTOMATED EVENT DETECTION AND CASE MANAGEMENT

Use of Geofencing on the Linkt platform constitutes an innovative solution for detecting adverse events and outcomes for large-scale, long-duration clinical trials and research. Geofencing uses location information securely held within a participant's own device (e.g., mobile phone) to allow the device to detect whether a participant has crossed a virtual perimeter around a geographic landmark (e.g., hospital, clinic). Standard approaches to capturing adverse events, like phone banks and electronic medical record (EMR) searches, suffer from poor scalability, susceptibility to missed data, and delayed reporting; issues addressed by automated systems such as geofencing.[1-4] We examined geofencing data for two independent sub-studies using the Linkt geofencing feature – an observational community-based study of COVID-19 (N=360) and a vaccine clinical trial by a major pharmaceutical company (N=40). This preliminary report summarizes the real-world performance of geofencing for automatic detection of geofence crossings.

The process of detecting potential hospital visits through the Linkt platform involves automatic capture of geofence events, which in turn trigger chatbots to confirm hospitalization and record symptoms. If geofence crossings are not detected, participants can report symptoms using a self-report chatbot. Geofencing together with the chatbot and the case alert system creates a powerful tool for automatic detection of hospitalizations and potential adverse events.

GEOFENCE CROSSINGS

Datacubed Health examined geofence data for participants that logged into the Linkt mobile app as part of two sub-studies using the Linkt geofencing feature. The observational community-based study of COVID-19 (N=360) comprised 67 geofenced medical centers. The vaccine clinical trial by a major pharmaceutical company (N=40) comprised 2 geofenced medical centers.

The total number of distinct geofence crossings were estimated by combining *Enter* and *Exit* events, which are distinguished by the iOS and Android operating systems. Every *Enter* event was considered a distinct crossing. However, *Exit* events were only considered a distinct crossing if they were immediately preceded by a different *Exit* event (i.e., indicating that the *Enter* event was not captured by the device.) Assuming statistical independence of detection failures, the information about distinct events was used to estimate the number of missed *Enter* events, missed *Exit* events, and the overall miss rate for distinct geofence crossings.

Linkt recorded an estimated 10,700 distinct geofence crossings. Geofence crossings were not uniformly distributed across participants, instead following an exponential or Poisson distribution (Fig. 1). No geofence crossings were recorded for the majority of participants (62%). Among the participants with one or more geofence crossings, a single participant accounted for 27.6% of all

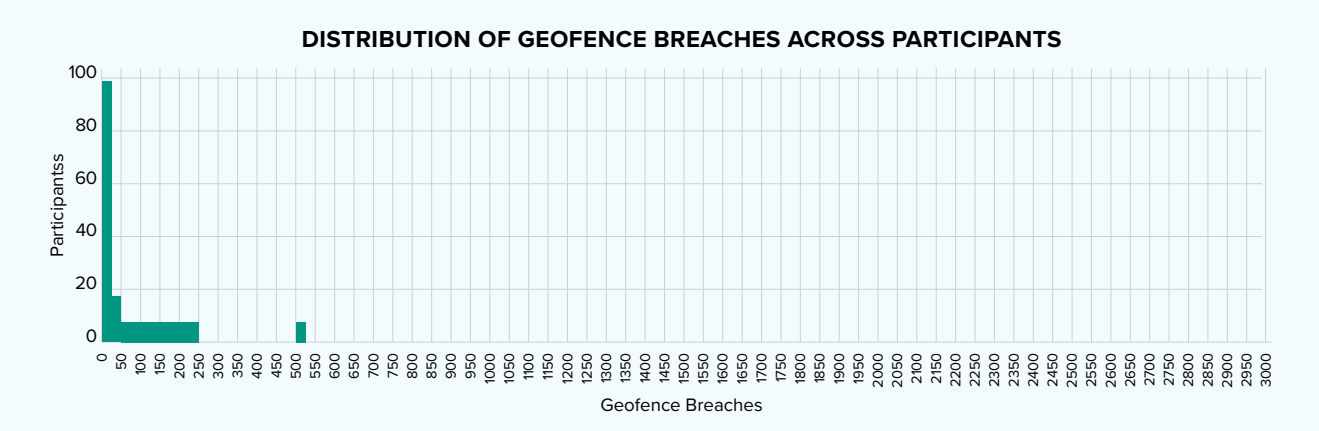

Figure 1. Distribution of the number of geofence crossings across study participants with at least 1 event.

detected geofence crossings and the top ten participants accounted for 57% of all detected geofence crossings.

LOW MISS RATE FOR GEOFENCE EVENTS

With geofencing technology, it's expected that some geofence crossings may not be detected by the device and, in turn, recorded by the Linkt app because successful detection of geofence crossings depends on many factors, including:

- device hardware (e.g., GPS chip)
- cellular network provider (e.g., distance from closest cell tower)
- proximity between geofences
- participant behavior (e.g., Linkt app installed on device and logged in, device charged and turned on, device data turned on, location services enabled, possession of mobile device at the time of the event, etc.)

Due to these factors, some geofence events may be missed by the device. For example, a study using geofencing to detect hospitalizations previously reported a sensitivity of 77%, with missed hospitalizations attributed to not having device / device off (30%), location services off (20%), or unknown causes (50%).1 No hospitalizations (as opposed to hospital visits) have been studied with the Linkt platform at this point, precluding examination of positive predictive value and sensitivity/specificity of geofencing for hospitalizations. However, discrepancies between recorded Enter and Exit events can be examined to estimate the overall miss rate for distinct geofence crossings (i.e., rate of missing both Enter and Exit events for a geofence crossing) to measure the performance of Linkt geofencing at detecting hospital visits.

ESTIMATED GEOFENCING MISS RATE

To estimate the overall miss rate for detecting a geofence crossing using the Linkt platform, the miss rate for *Enter* events and *Exit* events were examined separately. For the 10,700 distinct geofence crossings in our database, Linkt captured 8,658 *Enter* events and 8,861 *Exit* events, amounting to a miss rate of 19.1% for *Enter* events and 17.2% for *Exit* events. Linkt uses either *Enter* or *Exit* events (when the *Exit* event is not linked to an *Enter* event) to trigger case alerts which leads to an overall miss rate of 3.3%. This indicates that Linkt captured 96.7% of distinct hospital visits by capturing an *Enter* event, *Exit* event, or both events. Linkt captured both *Enter* and Exit events for 67% of geofence crossings, which permits estimation of the dwell time within the geofenced region. However, interpretation of missed events and event duration appears to be complicated by the observation that many "missed" geofence events occurred when the system captured a burst of events within a short period of time.

This may be explained by the system having trouble distinguishing between *Enter* events and *Exit* events when continuous movement occurs near the virtual boundary of a geofenced region.

GEOFENCE DWELL TIME AND HOSPITAL VISITS

Both enter and exit events were captured for approximately 67% of geofence crossings, allowing us to compute dwell time as the amount of time spent within a geofenced region (*Exit event – Enter event*). We found that dwell time was highly skewed towards events with shorter durations. The median dwell time was 1-m 36-s; however the captured dwell time ranged from milliseconds to days in duration. The dwell time for 42.8% of events was less than 60 seconds and the dwell time for 83.5% of events was less than 15 minutes, consistent with most events capturing brief passage through a geofenced region (e.g., commuting past the entry to a medical center). Datacubed Health found that 415 geofence crossings (6.1% of all geofence crossings) exceeded the 6-hour threshold recommended for identifying potential hospitalizations; however, 352 of these events were from a subset of 7 participants who have 25 or more geofence crossings. While this may indicate hospitalization, it is also possible that these participants live or work near a geofenced location – an uncertainty best deduced by a direct participant contact.

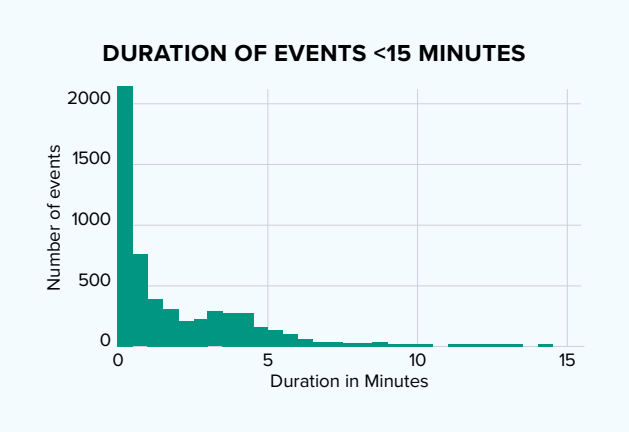

Figure 2. Distribution of the duration (i.e., dwell time) of geofence crossings, restricted to crossings with a duration < 15-m. Geofence crossings with a duration < 15-m account for 83.5% of all geofence crossings.

While dwell time can improve the specificity of geofencing for automatic detection of hospitalizations, the Datacubed Health system does not rely on dwell time alone as some missed *Enter* and *Exit* events are expected. In addition to a self-report chatbot that is always available to participants to report any symptoms, geofence events trigger a chatbot and the case alert system to rapidly query the participant and case managers to confirm participant symptoms.

CONCLUSION

Geofencing on the Linkt platform is a highly effective system for detecting geofence crossings, capturing 96.7% percent of distinct hospital boundary crossings (i.e., an overall miss rate of 3.3%). Coupled with the chatbot and case alert system, this technology can be leveraged to automate detection of potential hospitalizations for adverse events by enabling rapid querying of participants to confirm hospitalization and symptoms.

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