Estimating Communication by Position Information in Office

Nobuyuki INAMIZU

Abstract: This study shows that it is possible to use position information to estimate the volume of communication in offices to some degree based on (1) office position information from sensing technology and (2) data from daily questionnaires from a survey of 308 employees in a corporate office. The relationship between the office environment and communication has come to the fore in recent years, and the findings of this study suggest how communication within an office can be estimated for a large sample at a low cost.

Keywords: sensing technology, diary study, personal space
Introduction

The office environment has become a popular topic in recent years. In particular, more research is being done on the relationship between employees’ activities and communication in nonterritorial offices and activity-based working/offices (Inamizu, 2013, 2014, 2015, 2016; Inamizu & Makishima, 2019).

Studies observing and recording workplace activities and communication have been around for a long time. For example, Mintzberg observes managers’ detailed activities to find out what they actually do and lists the characteristics of an excellent manager (Mintzberg, 1973, 2009). Additionally, Kotter discusses the usefulness of agenda setting and network building through observations of general managers (Kotter, 1982). Inamizu, Fukuzawa, Fujimoto, Shintaku, and Suzuki (2014) use videos of an auto assembly line to describe the real activities of an on-site leader and to identify effective management methods. However, these studies all use a limited survey sample. When observing and recording daily activities, researchers have had to limit the number of subjects to about 10 people at most. This is a problem when one is trying to ascertain employees’ activities and communication in an office.

In recent years, there have been attempts to deal with this problem by using sensing technology. For example, Yano (2014) and Waber (2013) introduce very interesting ideas for enabling the acquisition of data on activities and communication in the office by having people wear tags with acceleration sensors around their necks while they work. Although this is a fascinating technique, it is currently very expensive, and it would impose a considerable burden on employees. The greater the cost or burden, the more difficult it is to obtain data over a long period of time.

Therefore, this study proposes a low-cost method for obtaining data in detail from a large sample on their office activities and
communication. Recent developments in sensing technology have made it possible to obtain quite accurate position data in offices. Certainly, initial cost of the sensor apparatus is high, but employees may not have to bear much of an additional burden if it is used only for capturing position data. Further, knowing the position data enables us to ascertain the spatial distances between employees. In fact, studies on personal space have accumulated knowledge on spatial distance and the distance appropriate for communication (Sundstrom & Sundstrom, 1986). We believe that we can use studies of personal space to estimate communication from position information (spatial distances).

Below we show that it is possible to perform some estimates of office communication from position information based on (1) office positional information from sensing technology and (2) data from daily questionnaires through a survey of 308 employees in a corporate office.

**Method**

The sample in this study comprises 308 employees working in the head office of MITSUI Designtec Co., Ltd., a firm that designs offices and other spaces. The office is divided into four floors of the building it occupies: floors 1, 2, 3, and 7. Each floor is about 40 × 20 m². The first floor consists mainly of the reception area and conference rooms. The second, third, and seventh floors comprise office spaces, which include several open meeting areas (i.e., the walls do not go up to the ceiling). Additionally, it is a nonterritorial office, meaning that most employees are not assigned their personal desks.

We installed sensors in the office’s ceiling and put BLE (Bluetooth Low Energy) beacons on tags for the employees to wear (Figure 1).¹

¹ We were able to significantly reduce the burden on employees because the
Therefore, despite some errors, we were able to find out who was where and when. Moreover, the data were captured once per second.

Next, we conducted a daily questionnaire (a questionnaire survey that respondents completed every day) to ensure that we would be able to estimate communication from the positional information. The survey began, “These questions concern your communication with others in the office today. *Please include time spent in meetings and discussions.*” For the questions, “time spent in face-to-face communication with supervisors,” “time spent in face-to-face communication with colleagues,” and “time spent in face-to-face communication with subordinates,” respondents would choose from the following: up to 15 minutes, from 15 minutes up to 30 minutes, from 30 minutes up to 60 minutes, from 1 hour up to 2 hours, 2 hours or more, and not applicable.

The data analyzed in the study were taken from employees’ position tags were light, and because of the tags’ low power consumption, it was not necessary to charge them every day.
information and daily questionnaires over the nine business days from Tuesday, October 10 to Friday, October 20, 2017.2

**Analysis of Sensor Accuracy**

First, we tested the accuracy of the sensors by installing 11 tags in specific places in the office for one hour (3,600 seconds) between 3:00 a.m. and 4:00 a.m. on October 10 to estimate how much movement there would be when the office was unoccupied. This was done to test whether the data collected by the sensors would make it seem that movement was taking place when there should have been no movement.

In the test, we calculated the average position of each tag during the one-hour period (average value of the X-coordinate and the Y-coordinate) and assumed that this was the tag’s real position. We then computed the distance from the average position each second, and calculated the mean of each tag’s “distance from the average position.” We found that the means of the tags’ “distance from the average position” were 0.76 m (0.499), 0.73 m (0.443), 0.71 m (0.454), 0.71 m (0.411), 0.67 m (0.403), 0.50 m (0.365), 0.62 m (0.336), 0.45 m (0.293), 1.22 m (0.619), 0.97 m (0.615), and 0.88 m (0.460) (the figures in parentheses are standard deviations). From these findings, we can say that the error was about 0.75 m.

Next, let us think about how we can estimate communication at an office using spatial position information and with what criteria. According to studies of personal space, conversations on personal topics are conducted in medium-level voices at distances of between 0.45 m and 1.2 m. Conversations on formal topics in ordinary voices (voices that can be heard from up to 6 m away) take place at distances of 1.2–3.6 m (Sundstrom & Sundstrom, 1986). In

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2 The study was performed using data provided by MITSUI Designtec Co., Ltd., from tests run in October 2017.
Inamizu

terms of an office environment, the former can be called communication in an office space, while the latter corresponds to communication in a conference room.

First, with respect to the latter, we assumed that “when we obtained position information from sensors installed in conference rooms and meeting spaces, the communication took place with people (thought to be) in the same conference room or meeting space, regardless of the distance.”

At the same time, with respect to the former, we assumed that the communication occurred when position information was within an interpersonal distance of 1.2 m. However, there may have also been times when people were merely passing each other as they walked through the office. Therefore, we added the criterion that the distance needed to be within 1.2 m for at least 30 seconds. Additionally, to minimize errors in position information, we assumed that “communication took place if the distance was 1.2 m or less for 12 seconds within the past 30 seconds (or 40% of the period).”

How accurate are these estimation criteria for communication within an office space? Even if the true distance between two people is 1.2 m, their positions will vary data-wise, sometimes being 1.5 m and other times being 0.7 m. Therefore, we conducted our test using the following procedure based on the position data of the previously mentioned 11 tags placed for one hour in a specific location.

1) For each pair of tags, we added 1.2 m to the X-coordinate of the data from one of the tags. MITSUI Designtec Co., Ltd. provided data of the 11 tags placed in only one location. However, it seemed that processing this data would enable us to elicit pseudo-data for distances of 1.2 m.

2) We divided the hour (3,600 seconds) into 120 intervals of 30 seconds each.

3) For each interval, we calculated the probability of being within 1.2 m for each tag pair (for instance, if it was not within 1.2 m for 10
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4) We plotted the frequency distribution of the data. We found that in about 56% of all cases (cases that deemed communication to have taken place), the probability of not being within 1.2 m was 0.60 or lower (Figure 2). In other words, if two people were communicating at a distance of 1.2 m, there was about a 56% chance that communication could be captured based on the above criteria.

Next, let us look at the case when the true distance is less than 1.2 m. As in the previous case, we placed 11 tag pairs in a specific

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**Figure 2.** The case when the true distance is 1.2 m

*Note:* The smiley mark is the real place. The dots around the smiley mark indicate variations in data.
location for one hour and ran the test using data that added 1.0 m to the X-coordinate for the data from one of the tags. We found that in about 75% of all cases (cases in which communication was deemed to be taking place), the probability of not being within 1.2 m was 0.60 or lower (Figure 3). In other words, if two people were communicating at a distance of 1.0 m, there was about a 75% chance that communication could be captured based on the above criteria.

Now, let us test a case in which the true distance is more than 1.2 m. We postulate that communication does not occur (or is difficult) when people are separated by a distance of more than 1.2 m. However, because the data for the two people’s locations vary, even if they are actually 1.5 m apart, for example, the data will
sometimes put the distance at 2.0 m and at other times put it at 1.0 m. Therefore, as in the previous cases, we ran our tests with data that added 1.5 m to the X-coordinate among the data for one of the tags in each of the 11 tag pairs placed in a specific location for one hour. We found that in about 25% of the cases (cases in which communication was deemed to be taking place), the probability of not being within 1.2 m was 0.60 or lower (Figure 4). In other words, if two people located 1.5 m apart were not communicating, there was about a 25% chance that communication could have mistakenly been deemed to have taken place based on the above criteria.

**Figure 4.** The case when the true distance is 1.5 m
When we used the same method to look at the case where the true distance was 2.0 m, the probability of not being within 1.2 m was 0.60 or lower in about 3% (of the cases in which communication was deemed to be taking place) (Figure 5). In other words, even when two people located 2.0 m apart were not communicating, communication was mistakenly deemed to have taken place about 3% of the time based on the above criteria.

To summarize the foregoing, the above-mentioned criteria are valid to some extent. For the data in this study, where the results were about 56% when the distance was 1.2 m and 75% when the distance was 1.0 m, it seems that communication was correctly deemed to be happening about 60–70% of the time when the true distance was 1.2 m or less. However, even when the true distance was 1.5 m, communication could mistakenly be deemed to be happening about one-quarter of the time. However, when the true distance is 2.0 m or more, there are almost no instances of mistakenly deeming communication to be happening.
Validity of Communication Estimated by Position Information

This section tests the validity of communication volume estimated from sensors’ position information based on the foregoing criteria by comparing the data from the sensors with data from the daily questionnaire.

This section’s analysis focuses on communication with supervisors. This is because while the daily questionnaire includes one question each about supervisors, colleagues, and subordinates, in most cases, there are multiple colleagues and subordinates, but the supervisor can be identified as almost one person.

First, we calculated the daily communication volume between each pair of employees from the sensors’ position information, then extracted only the supervisor-subordinate pairs. Next, we extracted the responses on communication with supervisors from the daily questionnaire. We then combined the data into an integrated data set.

Table 1 and Figure 6 give the test results derived from the integrated data set. Table 1 gives the mean, median, and standard deviation of the communication volume estimated from positional information for the daily questionnaire’s five possible responses regarding communication with supervisors: 1 (up to 15 minutes); 2 (from 15 minutes up to 30 minutes); 3 (from 30 minutes up to 60 minutes); 4 (from 1 hour up to 2 hours), and 5 (2 hours or more). Figure 6 plots the mean values, with the daily questionnaire responses on the X-axis and the communication volume (in seconds) on the Y-axis. As can be seen, a positive correlation was observed between the communication volume from the position information and the results of the daily questionnaire.

However, the answer of “four” or “five” in the daily questionnaire should mean that there was an hour or more of communication with the supervisor, but the communication volume estimated from the
position information added up to less than one hour (3,600 seconds). This could be attributed to an error in positional information. Communication that can be captured from position information was about 56% at a distance of 1.2 m and about 75% at a distance of 1.0 m. Also, even if the distance is more than 1.2 m, we could also assume some instances of mistakenly deeming communication to be happening. At the same time, the answers in

| Daily Questionnaire results | Mean      | Median    | S.D.       | \( N \) |
|----------------------------|-----------|-----------|------------|--------|
| 1                          | 572.94    | 32.00     | 1241.953   | 575    |
| 2                          | 1169.05   | 171.50    | 2382.403   | 328    |
| 3                          | 1930.90   | 603.00    | 2820.622   | 317    |
| 4                          | 2599.08   | 1591.00   | 2832.552   | 217    |
| 5                          | 3075.57   | 2439.00   | 3339.120   | 113    |

**Figure 6.** The relation between daily questionnaire results and estimated communication volume
the daily questionnaire are only subjective, so there may be problems with the accuracy of the responses.

In summary, although there is some room for further consideration, because a positive correlation was seen, we proved that communication volume estimated from positional information has some degree of validity.

Conclusion

This study showed that communication estimated from position information from sensors in an office on the basis of certain criteria (jointly in a conference room or other area, or a total of 12 out of 30 seconds (40% of the time) within a 1.2 m distance) can be valid. If communication gathered from position information can be estimated to some degree, it will be possible to get an idea about office communication for a large sample at a low cost. Being able to do this would definitely be useful in research on organizational communication and research on social networks.

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