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Fang Li

An experiment on quantifying noise emission dimensions of delivery bots

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Dr. Fang Li
Hochschule für angewandte Wissenschaften Neu-Ulm
University of Applied Sciences
Wileystraße 1, D-89231 Neu-Ulm

Hochschule Neu-Ulm
University of Applied Sciences

Zusammenfassung

Die Lärmemissionen von Bodendrohnen (bzw. fahrerlosen Transportfahrzeugen, delivery bots, transport droids, …) werden im Gegensatz zu Luftdrohnen in Wissenschaft und Praxis wenig diskutiert. Um in Bezug auf Lärmemissionen einen ersten Vergleich zwischen Bodendrohnen und Luftdrohnen zu ermöglichen, müssen die Lärmemissionen von Bodendrohnen zumindest grob quantifiziert werden. In diesem Beitrag wird über ein Experiment zur Quantifizierung der Lärmemissionsdimensionen einer Bodendrohne berichtet, welches eine erste Grundlage für einen strukturierten Vergleich der Lärmemissionen zwischen Bodendrohnen und Luftdrohnen schafft. Als Ergebnis dieses Experiments haben wir Lärmemission von Bodendrohnen in der Dimension von 19 dBA in 1 Meter Entfernung und 4 dBA in 10 Metern Entfernung bei einer Fahrtgeschwindigkeit von 7,2 km/h ermittelt.

Freie Schlagwörter: Bodendrohne, delivery bot, FTS, Lärmemission

Abstract

The noise emissions of delivery bots (also known as autonomous ground vehicles, ground drones, transport droids, …), contrary to that of air drones, are not widely discussed in academic and practical fields. To enable a comprehensive comparison between delivery bots and air drones, noise emissions of delivery bots need to be quantified. This paper presents an experiment on quantifying the noise emission dimensions of one delivery bot as to build a first basis for a structured noise emissions comparison between delivery bots and air drones. As a result, it presents a noise emission dimension of 19dBA at a 1 meter distance and 4dBA at a 10 meters distance for a fast moving (7.2km/h) delivery bot.

Keywords: AGV, delivery bot, transport droid, ground drone, noise emission dimensions

JEL-Klassifikation: O3

1. Introduction

Autonomous delivery arises nowadays as an innovative and effective measure to reduce labor shortage and carbon emissions of last-mile delivery. Air drones and delivery bots both have the potential to be used in last mile delivery settings. Up to date the use of both technologies can be seen as still in test phases, and both have to overcome some challenges (security, safety, energy efficiency, battery reach, noise emissions, …) prior to a broad commercial use. While noise emissions of air drones are usually significant (and thus declared in the relevant technical documents of the air drone providers), delivery bots are known to be significantly less noisy. However, quantitative data on noise emissions of delivery bots are difficult to obtain, as they often remain unreported in technical data sheets of delivery bot providers. In order to build a first basis for a noise emissions comparison, the noise dimension of delivery bots needs to be quantified.

2. Research Questions

The presented experiment is designed to answer the following research questions: Which different type of noises are emitted from delivery bots? Which measure could be used to compare noise emission dimensions of delivery bots to noise emission dimensions of air drones? And how loud are different noise types at given distances?

3. Experimental Design

The experimental design is introduced in this section.

3.1 Experimental settings

The object of research in this experiment is a delivery bot model as shown in Figure 1. As observed in the experiment, the delivery bot emits noises when it moves, turns, and brakes. In addition, it makes vocal alarms as a safe warning when it is close to obstacles. Therefore, the noise type of the delivery bot is categorized into three groups: noise of movement, noise of operations (i.e., turn and brake), and noise of alert.

Name: TH17, Twinswheel
Available Mode: Follow-me, remote control through joystick
Max. Load: 50kg
Speed: 3.6km/h, or 7.2km/h
Battery type: in-built battery
Size: Length 85cm, Width 55cm, Height 50cm

[1]Figure 1 Delivery bot in experiment

In addition, the delivery bot has two optional operation speeds: 3.6km/h and 7.2km/h. In this experiment, noise emissions were measured for both two operation speeds of the delivery bot.
The delivery bot is designed for a maximal payload of 50kg while air drones have limited payload capacity. In order to enable the comparability of emission noises of delivery bots to that of air drones, the delivery bot was loaded with a payload of 2.5kg in the experiment.
The delivery bot in the experiment was operated by a human controller via a joystick.
The noise emissions of the delivery bot is measured with a calibrated sound level meter device as shown in Figure 2. It is a class 2 device due to the limited measure range, solution, and accuracy. However, it is still qualified to provide a noise dimension of delivery bots in comparison to air drones. Noise emissions are quantified by sound pressure levels in the unit of decibels (dBA).

[1] Source: *http://www.twinswheel.fr/*

Name: PCE 322A, ISO-calibrated
Class: Class 2 (DIN EN 61672-1)
Measure range: 30 dB ~ 130 dB
Measure solution: 0,1 dB
Measure accuracy: +- 1,4 dB

[2]Figure 2 Sound level meter device in experiment

In order to provide comparative results to air drones, this experiment measures sound pressure levels of delivery bots at a 10 meter distance, as this figure is usually reported in technical data sheets of air drones. In addition, since delivery bots are designed to operate on sidewalks, this experiment also measures sound pressure levels of delivery bots at a 1 meter distance so as to interpret how loud the noises are perceived by closeby pedestrians.

The whole experiment was performed indoors in one selected area of a regular meeting room without any interruptions. Two persons were involved in the experiment, one for operating the delivery bot and the other one responsible for adjusting and reading the sound level meter device. Figure 3 depicts the overall geographical layout of the experimental setting. Assuming that the sound pressure levels of different points in the room would be different, the sound pressure levels of the delivery bot were measured at four positions (1, 2, 3, and 4) around it in turn, each with a 1 meter distance to the test area in the center. The test area in the center is 85cm long and 55cm wide, which is identical to the footprint of the delivery bot. For the sound pressure level at a 10 meters distance, only two positions were considered (position 5 and 6) due to the space limit of our experiment room. During measurement at position 1 and 3, the delivery bot moves linearly between point A and point B. It moves between point C and point D for the measurement at position 2, 4, 5, and 6. To make sure the delivery bot moves steady through the test area, all the points A, B, C, and D are set 3 meters away from the test area.

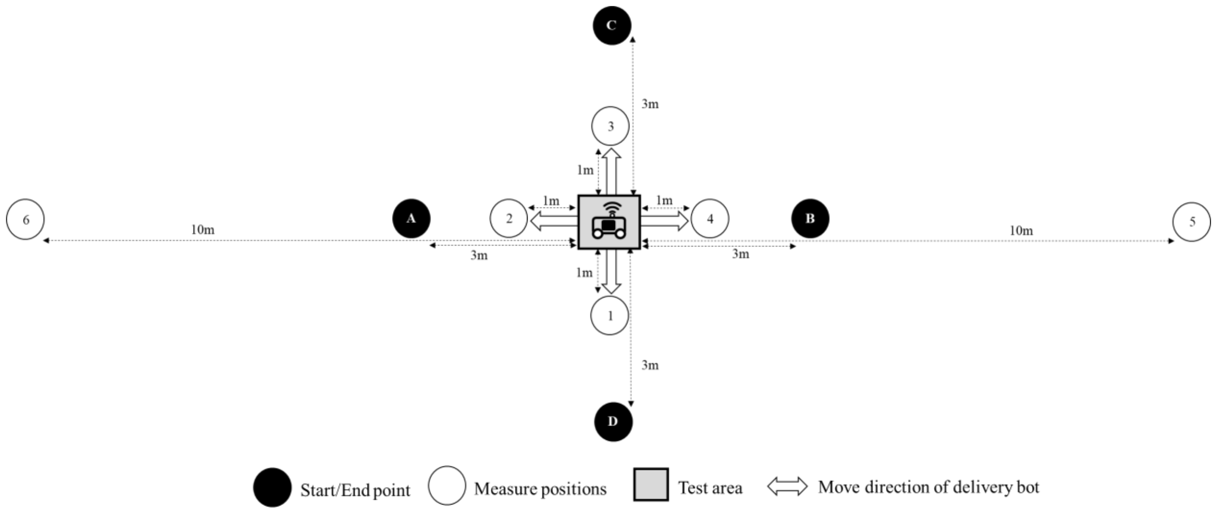


Figure 3 Experimental settings

In the experiment, we measured different types of noise emissions of the delivery bot at all positions 1, 2, 3, 4, 5, and 6. For each position, six individual dBA data readings were collected for the low and high speed operation, each.

3.2 Noise of Movement

The detailed experimental process for measuring the noise emissions of the delivery bot for slow movement at a given position (e.g. position 1), are depicted in Figure 4 and introduced as follows:

[2] Source: *https://www.pce-instruments.com/*

1) Fix the sound level meter device at position
2) Read sound level meter device as the base environment noise (dBA) at position
3) Start the delivery bot from point A (or point B)
4) Run the delivery bot along the line AB at low speed
5) Read sound level meter device (dBA) when the entire delivery bot is just above the test area
6) Run the delivery bot further to point B (or point A)
7) Repeat step 3-6 for several times until six individual dBA data readings were collected for the position for slow movement

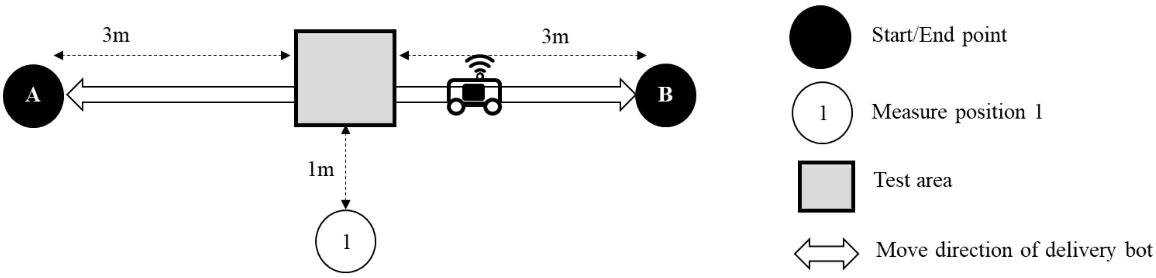


Figure 4 Experiment processes at position 1

The same process was performed afterwards again for measuring the noise of the delivery bot for fast movement. Noise emissions of both slow and fast movement were measured as well at all other positions 1-6.

3.3 Noise of Operations

3.3.1 Noise of Brake Operations

The delivery bot brakes at once when it encounters an identified obstacle or when it is stopped by the controller. The experiment recorded the noise of braking in the center area at all six positions for both low and high speed. The detailed measure processes at a given position (e.g. 1) are introduced below:

1) Fix the sound level meter device at position 1
2) Read sound level meter device as the base environment noise (dBA) at a given position
3) Start the delivery bot from point A (or point B)
4) Run the delivery bot along the line AB at the low speed
5) Brake it when the entire delivery bot is just above the test area and read sound level meter device (dBA) at the same time
6) Run the delivery bot further to point B (or point A)
7) Repeat step 3-6 for several times until six reliable dBA data of brake are collected at the given position for slow movement

The same process was performed afterwards again for measuring the noise of brake operations of the delivery bot at fast speed for all other positions. Noise of brake under both slow and fast movement was measured individually.

3.3.2 Noise of Turn

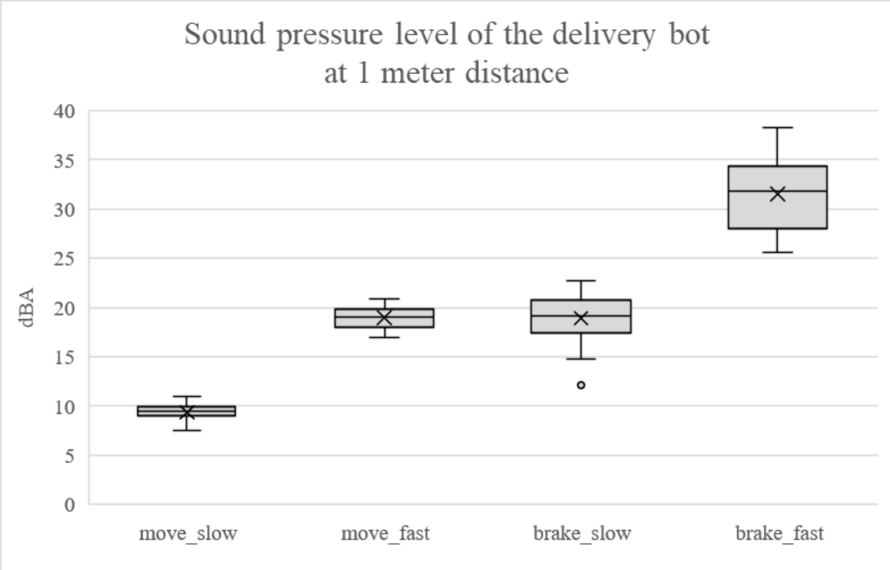
The noise of turn (i.e. the noise induced by changing the direction of the path) depends on the angle of the direction change and on the timespan used to perform this direction change. As both factors strongly depend on the manual control operators, it is neglected in this experiment.

3.3.3 Noise of Alert

Since the sound-level of alarms could be adjusted manually, it is neglected in this experiment.

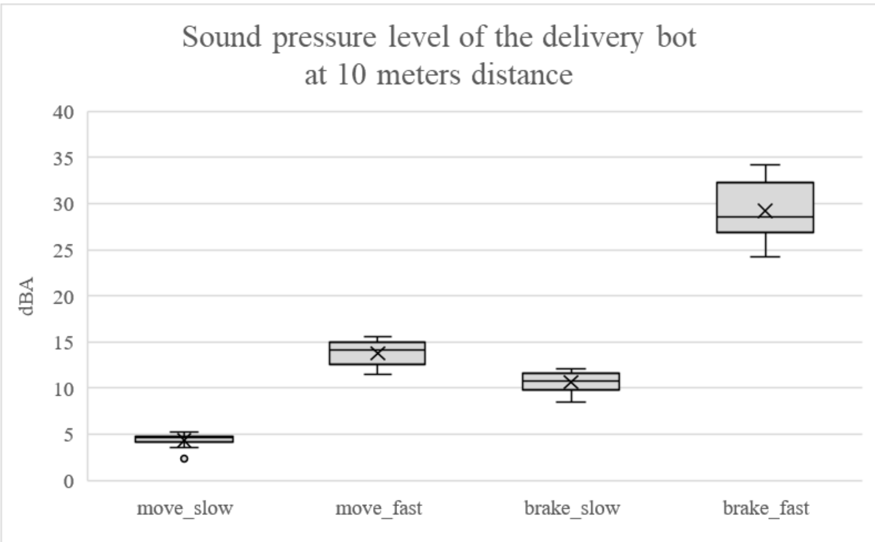
4. Results

The experiment has collected a total of 144 data for all measurement categories. That is 48 data for noise of movement at 1 meter dance (24 data for low speed and 24 data for high speed), 48 data for noise of brake at 1 meter distance (24 data for low speed and 24 data for high speed), 24 data for noise of movement at 10 meter distance (12 data for low speed and 12 data for high speed), and 24 data for noise of brake at 10 meters distance (12 data for low speed and 12 data for high speed).
Results are presented in two groups according to the measuring distances, respectively in Figure 5 and 3Figure 6.



[3]Figure 5 Boxplot – sound pressure level of the delivery bot at 1 meter distance

Generally, Figure 5 tells that at 1 meter distance from the delivery bot, the sound pressure level is around 9dBA when the delivery bot moves slowly at 3.6km/h and the sound pressure level is about 19dBA when it moves at the speed of 7.2km/h. The delivery bot emits around 19dBA noise when it brakes at the slow speed to 1 meter distance. When it brakes suddenly at the high speed, it emits around 32dBA noise to 1 meter distance.



[3]Figure 6 Boxplot – sound pressure level of the delivery bot at 10 meters distance

[3] Note: The concrete dBA level is related to the entire experimental settings.

As depicted in 3Figure 6, at 10 meters distance from the delivery bot, the sound pressure level is around 4dBA when it moves at slow speed and it is about 14dBA when the delivery bot moves at the fast speed. While braking, the delivery bot emits a sound pressure level of 11dBA at slow speed and 29dBA at fast speed measured at a 10 meters distance.
Based on the above data relating to the specific environmental settings, we estimate that 19dBA at 1 meter distance and 14dBA at 10 meters distance for fast movement seems sufficient to be used as a noise dimension indicator for regular operations of delivery bots (as fast break occurs in exceptional cases, only). These noise dimensions could be employed with reference to the experimental background as comparative data to the noise of air drones.

5. Critical Discussion

A critical discussion of used methods as well as results follows in this section.

5.1 Discussion of Methods

"Space limitation": Although the experiment was performed without any external interventions, the experiment room is not 100% isolated since it is a regular conference room. In addition, due to the limited room space, the noise at 10 meters distance were only measured at two positions.
"Operation limitation": It requires an excellent controlling skill to operate the delivery bot through a joystick, especially when it moves at the high speed. The delivery bot did not always move completely straight on the predefined line through the test area. Reading the sound level meter device manually may also result in certain inaccuracy since the data on the device screen changes every second. Therefore, noises at each position were measured several times in this experiment and only the reliable data went into final analysis.
"Device limitation": The sound level meter used in the experiment has limited precision (s. Figure 2). In addition, it is designed to measure noises between 30dBA and 130dBA with this device for best results. However, this paper aims not to measure data of one vehicle precisely, but to come up with a noise dimension indicator. Therefore, the used device may be considered to be sufficiently qualified for this application.

5.2 Discussion of Results

The noise dimension is based on the data measured during the experiment; therefore, it is influenced by the whole experimental settings. Hence, any interpretation of the results without referring to the experimental background is to be seen critically. In addition, the experiment measured only the sound pressure level in dBA. The measurement of noise's frequencies (which indicated whether the noise is a low or high-pitched sound, and how "unpleasantly" the noise is perceived by humans was not part of our experimental design.

6. Need for Further Research

This paper presents an experiment on how to quantify the noise dimension of a delivery bot based on the data measured at a 1 meter and at a 10 meters distance in both operation modes - slow and fast moving. To provide more precise results, a larger number of delivery bot models as well as improved sound recording equipment should be employed for future research. In addition, the analysis of noise frequencies requires further research.