MemorZig: A Short-Term Memory-Based Algorithm for Efficient Odour Source Tracking

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1 Introduction

This study presents a short-term memory-based algorithm for odour localisation. The ability to localise odours is an innate ability for most creatures. Many professionals employ the assistance of trained animals to detect explosives or toxic chemicals in harsh spaces or inaccessible locations. However, in specific scenarios such as poisonous gas or fire detection, creatures' ability is often constrained, presenting significant challenges for both the animal and its trainer. Consequently, over the past three decades, researchers have devoted their efforts to developing various odour source localisation (OSL) approaches [1,2] for mobile robots that can replace animal labour. Despite the various artificial tracking algorithms proposed [4, 6], they are still unable to achieve the level of performance seen in natural tracking mechanisms [5].

Previous tracking algorithms [3, 7] have primarily focused on considering only the current state of odour concentration. To address this gap, we introduce MemorZig, which utilises short-term memory-based mechanisms to adjust a robot's movement dynamically. This algorithm considers not only the current state of odour concentration but also the previous measurements, leading to improved efficiency and flexibility. This study contributes to the ongoing efforts to enhance odour localisation mechanisms and develop more effective solutions for hazardous substance detection.

2 Algorithm Design and Evaluation

Zigzag is an algorithm which is commonly utilised for odour localisation. By giving a constant rotation angle α (Figure 1), a robot can move closer to the odour source while detecting the boundary of plumes. According to [8], the success rate of zigzag was about 50% to 60%. The new algorithm follows a movement similar to zigzagging initially by heading towards the direction of α. Nonetheless, when a boundary is encountered, the heading angle β, based on a pre-fixed distance d, will be altered by considering the past odour concentration readings. This algorithm is designed to be more efficient than a slow, aimless search. Specifically, the algorithm calculates the location with the highest odour concentration from the previous path. It directs a robot towards a position located d ahead of that spot. This approach allows a robot to search for the source of the odour in a more targeted and effective manner. As this approach of adapting a zigzag angle utilises short-term memory, we named it MemorZig.

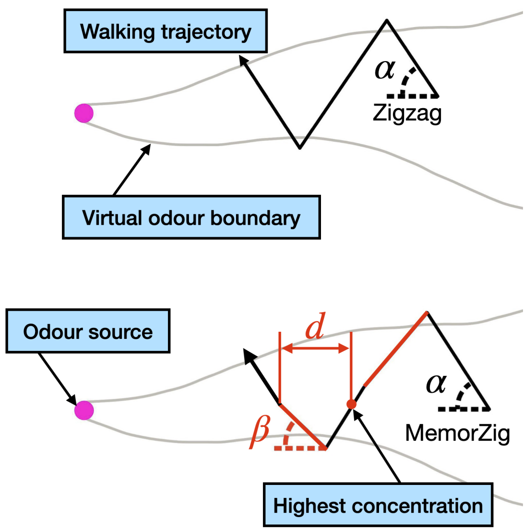

Figure 1: Conecpts of two tracking algorithms.

To evaluate the effectiveness of the new algorithm, we compared it to the conventional zigzag approach. Two algorithms were integrated into a mobile robot (AlphaBot2-pi, WaveShare, China) equipped with a gas sensor (MQ-3, Risym, China), as depicted in Figure 2. The robot was controlled independently by an onboard microcomputer (Raspberry Pi 4 Model B, Raspberry Pi Foundation, UK). The value of α was set at 75°, based on a previous study [7].

The experiment was conducted in a well-ventilated environment, with the robot placed 1.5 m away from the odour source (70% ethanol). A fan was set up behind the odour source to increase the diffusion rate, creating an airflow of 2 m/s. To compare the efficiency of the two algorithms, we recorded the time taken by the robot to move from the starting point to the target zone, an area with a radius of 8 cm from the source. This experimental setup evaluated the performance of the algorithm in detecting the odour source in a controlled environment. In addition, the well-ventilated environment allowed a more realistic evaluation of the algorithm's ability to detect gases.

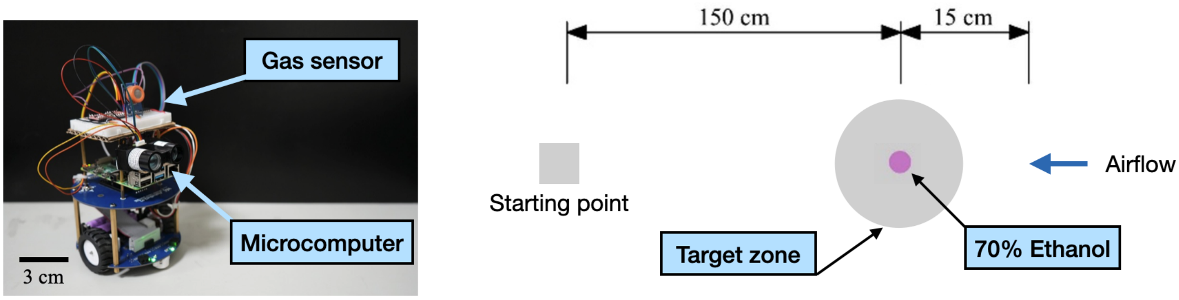

Figure 2: Experimental setup.

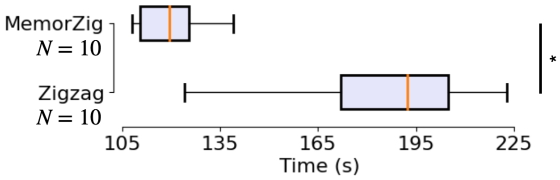

Figure 3: Time cost of two algorithms (*$P < 0.05$, independent samples t-test).

3 Results and Discussion

The time cost of two tracking algorithms is illustrated in Figure 3. The result displays that the average time cost for zigzag ($N = 10$) and MemorZig ($N = 10$) were 185.4 ± 28.74 s and 115.5 ± 17.87 s, respectively. Both algorithms gave 100% success rates. It is worth noting that the MemorZig algorithm displayed superior robustness and performance, achieving the desired outcome in considerably less time compared to the conventional approach. Specifically, the time cost of MemorZig was less than two-thirds that of the conventional method, underscoring the significant improvement ($P < 0.05$, independent samples t-test) in time efficiency brought about by the novel approach. Moreover, by examing the search process, we noticed that the turning angle of MemorZig ranged from 10° to 75°, with a mean value of around $60.13 \pm 18.72°$, which was smaller than the constant value of α.

The result indicates that the robot's short-term memory ability allowed it to gather information about the direction of potential odour sources. In contrast to the traditional approach, the dynamic turning angle strategy enabled a robot to locate a shortcut quickly by utilising previous odour-sensing findings, resulting in a shorter search process. Therefore, the experiment showed that this short-term memory played a crucial role in enhancing the efficiency of odour localisation.

4 Conclusion

In this study, we introduce a novel algorithm, MemorZig, that utilises short-term memory to enhance the efficiency of odour localisation. The experimental results have shown that the dynamic turning angle strategy employed by MemorZig surpasses the conventional zigzag approach. As a result, this innovative approach has contributed to the field of odour localisation by providing a new tool that overcomes the limitations of traditional zigzag algorithms.

The development of methods for locating the source of odour plumes has considerable potential for the future. With its powerful tracking ability, MemorZig may assist in advancing research on odour sensing and detection. By improving our understanding of how odour localisation works in nature, we may be able to develop related new techniques and applications.

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