Review on: Odor Localization Robot Aspect and Obstacles

[1]Ata Jahangir Moshayedi, [2]D.C. Gharpure

Department of Electronic Science, University of Pune, Pune: 411007, India
Email: [1]MOSHAYEDI@electronics.unipune.ernet.in, [2]dcg@electronics.unipune.ernet.in

Abstract— Since 1982, creature Olfaction system has attracted researchers to do the similar system. Although the olfaction system is still a mystery for humans but the initial step built successfully with the term of E_Nose. Extended application of E_Nose opens a new gate for researchers. This topic which is called odor localization, caused lots of affording for scientists to hire the robot and explorer the source by the movable source detector. The new challenge of current decade has started on 1990 companionship to equip robot with the help of sensors to do the exploring. The current survey is based on previously reported on Plume and odor tracking activities aimed to compare the reported researcher work and summarizes them with the stress on the practical work.

Mainly discussed at the work which tried to implement and interface the real indoor or outdoor environments by the single robot. Initially a review to study various aspects related to this field and the challenges involved was carried out. This review presents a survey of the odor localization research activities and experiments carried out tried to give the researcher new aspects

Index Terms— Odor localizer , plume tracker, Chemo taxis, Anemotaxis, Infotaxis, gas sensors, biological algorithm, robot.

I. INTRODUCTION

New gate for researchers. Odor tracking activities are designed to find and localize hazardous material spills or leaks (like gas leaks), bomb detection, mine detection and for identifying dangerous areas for humans. Formerly birds were used in mines to find gas leaks like CO2, CO [1]. Even today dogs are used for activities like bomb/drugs detection or rescuing people buried by avalanches. But the major issues involved are, long time required to train such animals [2], failures due to fatigue and inability to work in dangerous/hazardous areas.

These have driven the researchers, to devise electronic systems that can perform such odor tracking activities automatically, constantly and accurately by utilization of sensors mounted on a mobile robot to implement movement [3]. The overview of odor localization and plume tracking activities are mentioned in Fig 1.

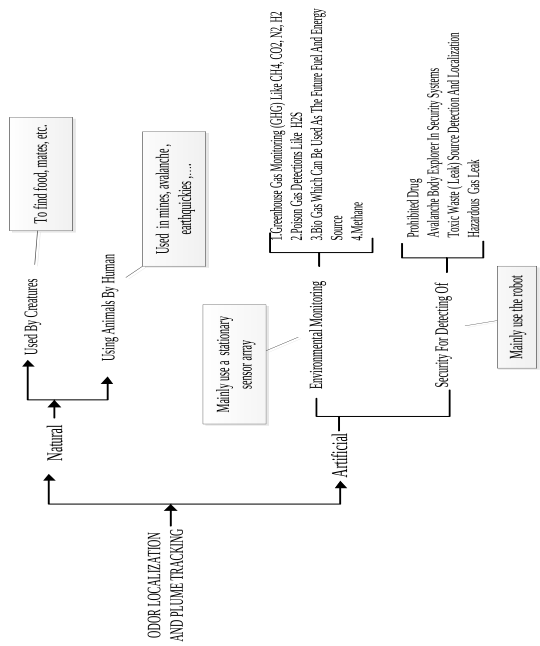

Figure 1: Odor localizing and plume tracking activities overview

In nature, plume tracking and olfaction is used for exploring, hunting, recognition, mating and inspection [5-11].Animal odor tracking is based on odor concentration detection, which varies spatially as well as temporally. Chemical information acquired, is used for [12] maintaining upstream movement towards odor. Insects like moth, take advantage of multiple types of sensory information, for detection of wind direction and speed of their movement [13-17] namely straight Upwind, till in the plume and casting, Zig Zag movement or spiraling to reacquire/detect the plume. E coil; use the random walk which is suddenly changed to find the source [6]. Blue crab, crayfish, lobsters [7,10-11] use sensors on the antenna to detect odor flow for food localization. In general three movement mechanisms can be seen [7]:

1. Chemo taxis: wherein movement is determined by the concentrating gradient of odor

2. Anemotaxis: the movement is based on air flow measurement and observation.

3. Infotaxis (the new terms are entered recently) the movement mechanism based on probability and information theory for searching as a strategy. [18]

Mainly the Chemo taxis and anemo taxis algorithms have been implemented in robots.

II. CURRENT ODOR LOCALIZATION SYSTEMS

The main problem in current plume/ odor localizing activity is the slow response of the sensor used as compared to biological olfactory systems. Also predicting the gas distribution is difficult due to chaotic dispersal of gas with dynamic and variable environmental conditions.

Work in this filed can be traced back to Ishida, H, et al 1996 [19], with an attempt to model the behavior of male silkworm while tracking the sexual pheromone and using that in the odor localization. Initially, behavior of the real silkworm was studied for five days, in an area of 0.4m × 0.7 m and a video camera recorded the movement and $TiCl_4$ smoke was used to visualize the plume.

The study showed that, moth's speed of 1 cm/s, helped localization and chances of success in tracking, was observed when the moths were located inside the plume. Their system (See **Error! Reference source not found.**) included the semiconductor gas sensor (TGS 822) and a small fan to realize the moths antenna and wings. The setup consists of mobile personal computer and a directional probe as shown in Fig and thermistor anemometer. Ethanol odor was used, with speed 1 cm/s and odor was sampled, with the fan in on/off mode.

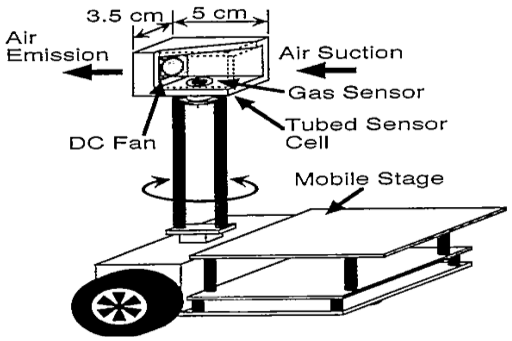

Figure 2: Probe robot platform

Their study highlighted the need of three dimensional data acquisition. Their result shows, the fan, which sucked the ethanol odor, increased the sensor's response.

T.Nakamoto, et al, 1996[20] described active odor sensing for odor-source localization system. The experiments are conducted in a clean room (5.8 m to 7.3 m) with two air supply openings at the ceiling and two exhausts opening near the ground and the average wind velocity of 30 cm/s.

Four gas sensors (TGS800, TGS813, Figaro Inc) are used for obtaining the gradient of concentration and four anemometric sensors around a pillar are used to know the wind direction (**Error! Reference source not found.**).

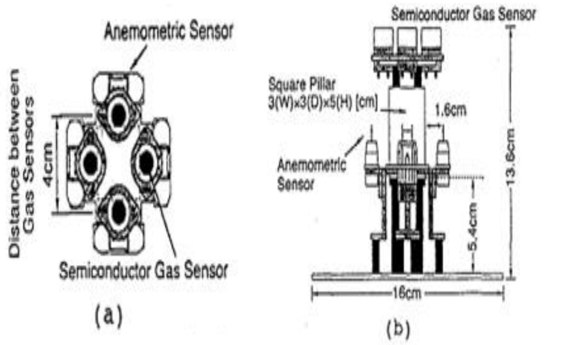

Figure 3: Probe for determining direction to Source (a) Top view, (b) side view

Hexanol and ethanol were ejected at 75 ml/min, from distance of 2-3 meters, were used as the odor source. A fan was used to form the plume, and the robot speed was set to 1cm/s. First, by gradient search, the robot is directed towards the plume and once in plume, robot moves toward the source upwind. Gas sensor response above set threshold is used to reach the source.

Also, the Kalman filter has been used in the processing algorithm. An odor compass (**Error! Reference source not found.**) to detect direction of odor has been implemented with the help of a small fan and two semiconductor gas sensors.

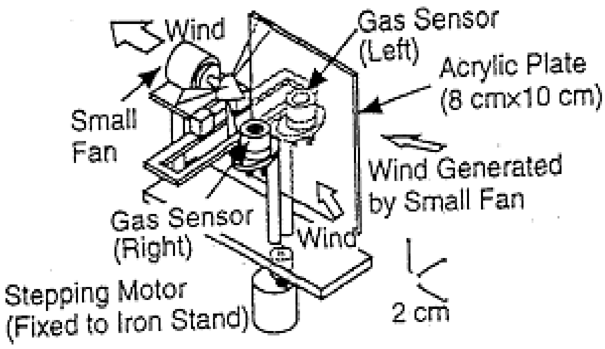

Figure 4: Structure of odor compass

They changed the position of odor compass to see the ability of localization. The experiments show the robot's capability to reach the source in 399 seconds pointing to advantage of three dimensional data collection system for better localization.

Hiroshi Ishida, et al,2001,[21] analyzed the response pattern of plume distribution, in the case of Upwind surge and casting based on proposed sensor array. Beside they tried to copy the fanning behavior of silkworm moths. They proposed use of eight sensors in an array 1 cm apart and air flow direction detector with hot wire sensors for navigation towards the odor source as in (See **Error! Reference source not found.**)

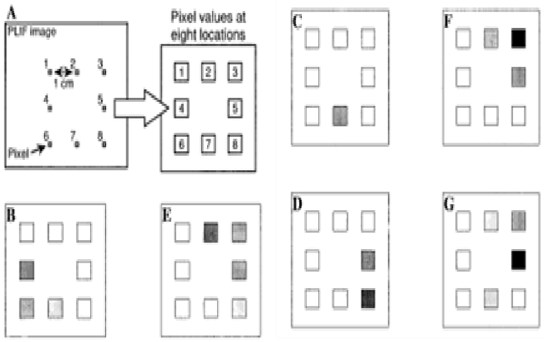

Figure 5: Proposed sensor array

Russell , 2001[22]; tested their strategy, in the open and obstacle free environment (2.82 m ×1.620 m × 0.27m), built using cardboard boxes covered by plastic and a fan with the speed of 1.75 m/s. They used the RAT robot, ultrasonic airflow sensor and QCM chemical sensor for tracking the odor plume.

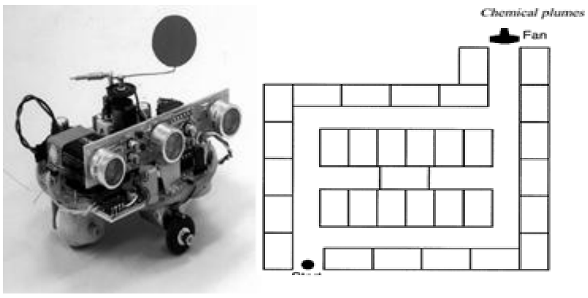

Figure 6: The Rat robot platform (b) the tested environment

They used the upwind as well as collision avoidance algorithms to follow the plume with the minimum number of sensors detecting ethanol leaks for odor localization has been performed by Amy Loutfi and Silvia Coradeschi, 2002 [23] on KOALA (Fig 7 A) robot with two metal oxide sensors, TGS 822, mounted one in front and one at the back ,along with the IR sensors to detect obstructions. The gas sensors are positioned 180 degree across the robot length, with a fan to increase the sensor response to 1.5meters. The strategy is based on sensing the odor and rotation flipping on detection to prevent the sensor saturation. The robot takes decision in 10.2seconds with speed set to 0.035 m/s.

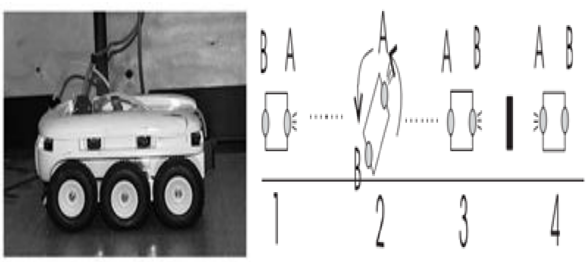

Figure 7: A) the localization strategy B) KOALA side views with the IR sensors

The robot sends the sensor data via RS232 to the computer server and the ethanol is selected as the odor. In their arena 20 experiments totally conducted. The results are reported with respect to the number of runs and the average distance from the source. (**Error! Reference source not found.**).

R. Andrew Russell, etal, 2002[24] reported the use of humanoid robots. Their work indicates importance of air flow information in odor localization, design of the sensor array and novel airflow sensing systems for a humanoid robot in order to have the odor discrimination. Their sensor array consists of TGS2600, TGS2610, TGS2611 and TGS2620 along with the temperature sensor (LM35), humidity sensor (SMRTH 05) and the fan. 20 samples from different concentration of aromas like (acetone, ammonia, camphor, ethanol, ground coffee, espresso coffee, mocha coffee, cinnamon tea, peppermint tea, room fragrance oil, red musk oil, eucalyptus oil, Vegemite (a concentrated yeast extract) and incense was used. The recognition accuracy was between 98% and 100%.

Lino Marques, et al (2002)[25] implemented the bacteria chemo taxis, silkworm moth and gradient tracking algorithm to determine the odor source in the turbulent phenomena's as well as multiple sources of odor. They used the gas sensor array on left and right, of four Figaro metal oxide gas sensors (TGS 2600, TGS 2610, TGS 2611, and TGS 2181) and three algorithms for steering their robot platform named Super Scout II.(Fig 8)

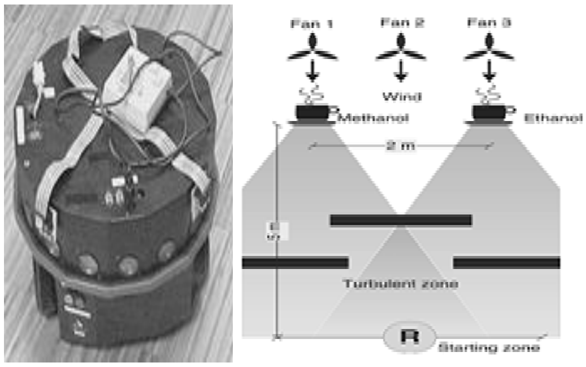

Figure 8: . A: Super Scout II platform B: the experiment arena

They used laboratory with dimensions of 5m ×2m with the two different sources of methanol and ethanol with 2 meters distance from each other and three air flow fan (Fig 8 B). They have reported the robot's ability to find odor source in less than10 minutes. They concluded that the gradient ascent algorithm performed better than the others, but not much better than the silkworm moth algorithm

Kiatweerasakul, M.; Stonham, T.J ,2002[26] used four TGS 2620 in array shown inFig 1 and isopropyl alcohol (C3H8O) as their odor .The wind of 40 cm/s is switched on and off randomly in environment size 3 m ×2.75 m as shown in **Error! Reference source not found.**.They used the nearest neighbor classifier (NNC) technique based on quantity of odor as the feature. The city block, based on the absolute value of different concentrations at the current position, gives the robot, tracking direction forward, left or right direction. PIC 16f 873 controller and “real robot” platform is used with 2 ppm as the lowest threshold concentration. (See **Error! Reference source not found.**.)

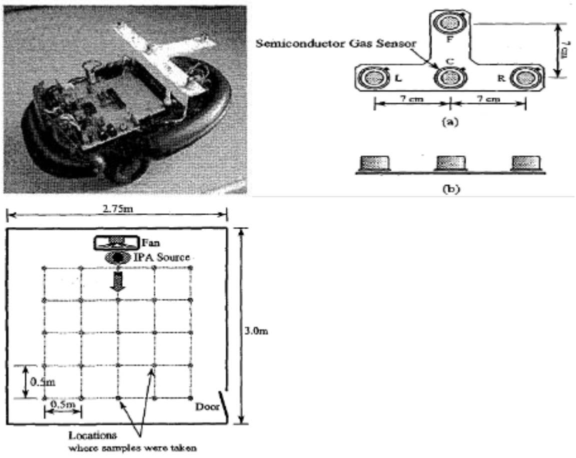

Figure 9.:Odor plume tracker Gas sensor array (a) The top (b) front view (c) The environment map

Russell et al (2003) [6] implemented three reactive chemotaxies algorithms (E.Cole, Bombyx mori, dung beetle) for odor localization on a platform named RAT. They used pyrole sensors along with air flow system and tactile whiskers to detect obstacles. Table is used as the environment and the odor is bubbled by a fish tank, 2.5 l/m through conical flask of 5% ammonia solution. Their work reported, the E.cole algorithm is the simplest, with minimum requirement of control and sensing robot movements. The E. coli algorithm needs one sensor and a small scale robot, capable of moving in a straight path and making a random turn without making turbulence and disturbing the environment. The silk worm moth algorithm has better result, especially for rapidly fluctuating chemical plume, at the cost of increased path length.

The robot has two chemical sensors to detect side nearest to the odor and the capability to detect airflow direction, to orient itself towards wind after it loses track of the odor plume. The dung beetle algorithms works for homogenous plumes. Herein a single chemical sensor is used with the robot continually orienting itself to the airflow direction.

Lilienthal, A. 2003[27] tried to modify and implement the behavior of silk worm moth Bombyx mori, on the robot platform with the hypothesis of overcoming the anemometer limits on a robot platform for the motion. They proposed the asymmetric motion pattern, which has the principle based on the higher concentration on sides. The mobile robot ARTHUR (Fig 10) is armed with two sets of three gas sensors (TGS 2600) at height of 21 cm on each side in the front with velocity of 4 cm/s. All tests were performed in a 15. 4 m×5. 1 m closed room at their University.

Ethanol is used as source and is injected from a cylindrical vessel with a diameter of 40 millimeter and a height of 25 mm. for visibility by the range finder the structure positioned above the vessel. The termination of experiment is done based on the average length between source and robot. They stated that their modified (Bombyx mori) strategy to random walk, increase the success to reach the source and decelerate the source zone.

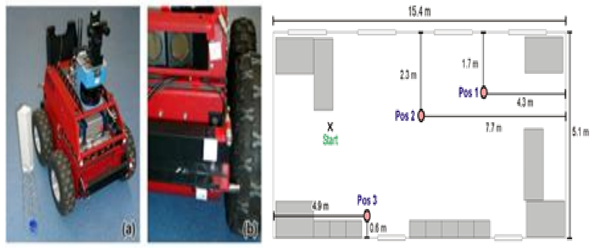

Figure 9: The ARTUR and tested environment

Lilienthal, A. 2004[28]; tried to implement Permanent Love and Exploring Love models of the BRAITENBERG vehicles theory for the indoor environment with natural ventilation. The koala platform with the Mark III (shown in Fig 11) and two sets of 6 Figaro sensors (TGS 2600, 2610, 2620) with 40 cm separation is used. In Mark II the fan was used to deliver the odor on the gas sensors.

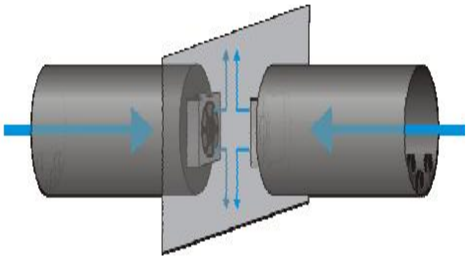

Figure 10: The Mark II model

The environment of 10.6m × 4.5 m and ethanol was used as source with 8 m^3/h airflow generated by fans. Cameras on top were used for Robot position monitoring. They concluded the inhibitory connections (exploring Love mode from BERETAINBERG) decreases the robot movements and localization time has a direct relation to the area. Use of three sensors, instead of two shows better localization.

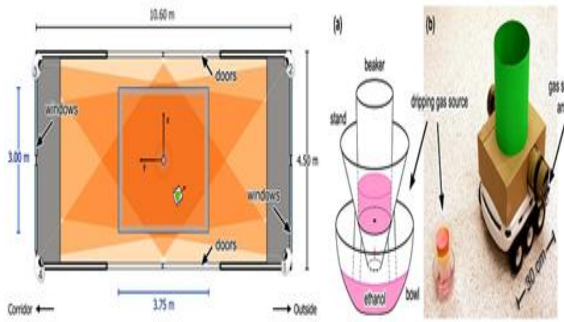

Figure 11: :(a) the testing showground (b): the robot and odor

Amy Loutfi et al, 2005,[29] used the PIPI platform running Linux equipped with the CCD camera and E nose (See Fig 12). 12 sonars and 12 bumpers for are used for obstacle avoidance. Headspace sampling method (HSM substance) and open space sampling method (OSM) - has been done. A lab room with the constant temperature and humidity was used for experimentation with octanol, hexanoic acid, and hexanal, used as the odor. In their strategy, vision is used in priority to navigate to a potential odor and odor sampling is done when close to an object. Their result shows success discrimination between odors.

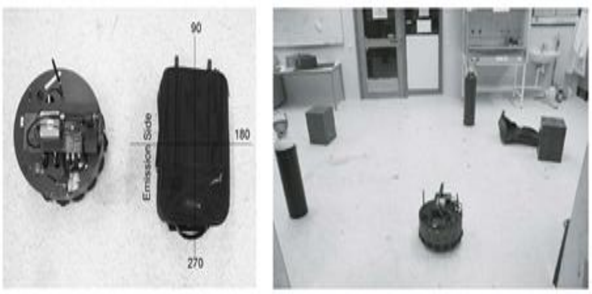

Fig. 12. The robot plat form and testing arena

Hiroshi Ishida (2005) [30] in his experiment used a room (5.9m×83.2 m ×2.7m) without any artificial airflow. TUAT robot platform, equipped with six gas sensors (TGS 2620 type) and an ultrasonic anemometer is used to track the odor-laden airflow for mapping three-dimensional gas distribution (see Fig 14). The robot speed was 10 cm/s and ethanol odor is used with the rate of 200 ml/min

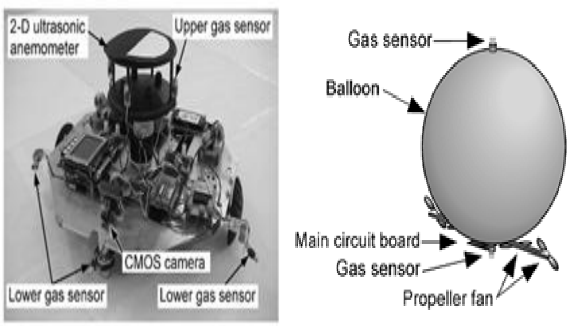

Figure 13: (A) The TUAT robot (B) Blimp plat form

Also, he proposed the blimp robot to sense the odor distribution in 3D form with a balloon 1.17 m in diameter filled with helium. The blimp robot uses two semiconductor gas sensors (TGS2620, Figaro Engineering), one on the top of the balloon and the other at the bottom to map the gas distribution in upwind direction. The blimp robot was programmed to fly randomly every 5 seconds and the robot navigated with the help of cameras and external PC for transmitting the sensor data. The experiments show the effect of Sunlight to make the air flow/plume shape unstable and effect of large obstacles on the gas distribution.

Ishida, Nakayama,et all, 2005,[31]; proposed an algorithm based on transient responses of gas sensors and tried to model Moths behavior for finding mate. The proposed algorithm uses gas sensor as well as wind direction. Then switching between these two information for navigation. In their algorithm the robot executed fast action when the sensor starts to detect change.

They used the GaPTR-II robot platform with the speed of 10cm/s equipped with TGS822 and thermistor airflow sensors (Fig 15 A).

Their array includes sensors on right (RR), left (RL) and at Center with two air flow sensors FL and FR mounted on the robot. The output of RL and RR are used for tracking a plume and when out of the plume, the robot tries to come back inside the plume with the spiral movement. In the transient-response-based algorithm, the switch over between upwind tracking and local search is made at a response on set and a state of recovery. Their algorithm based on upwind traverse in 2×4.8 m2 environment and ethanol as the odor source. The result shows the robot's ability to locate the source within the distance of 2 m in 32 s. (Fig 15 B)

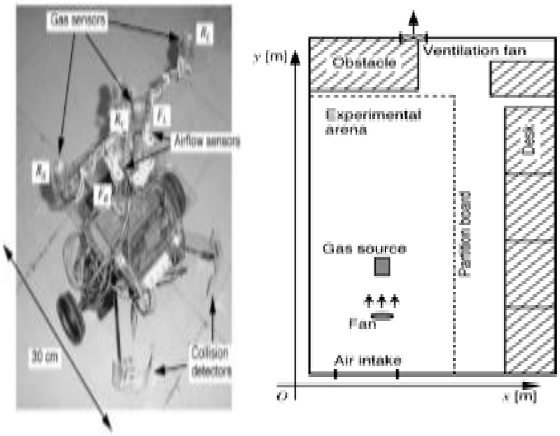

Figure 14: :(a) GaPTR-II robot platform (b) the experiment environment

Bailey, Willis, and Quinn 2005 [32]; used the Koala robot as their platform and proposed to use a dual Photo ionization detector (PIDS) to overcome slow recovery time of gas sensors. Also the PIDS is sensitive to organic chemicals. In their platform a PIC controller is used with the acoustic anemometry for the wind direction.(See Fig 16)

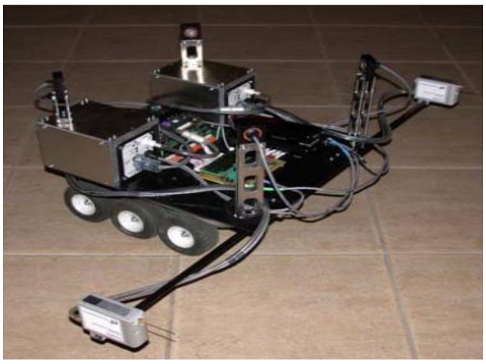

Figure 15: The odor tracking robot

Willis ,2005[13]; has done chemical plume tracking study of robot and insect. In their experiment the ionized air instead of a chemical plume and strategy based on flying moth tracking is used. The sensors are mounted on the positioning system (See Fig 2 – 17), which provides movement in altitude and lateral position, and a conveyor belt controls the position of the plume and robot source with the name of Rob-moth. Their system has a suite of sensors (ion detecting antennae) similar to the moth including: visual system, wind detecting systems, and odor detection system.

They have mentioned the significance of wind in odor direction prediction. In the flying method; wind information is extracted from the visual sensors and in the walking system, the wind information is obtained via mechano sensory structures.

Figure 16: Positioning system

Dominique Martinez , et al (2006) [33] Proposed and implemented their strategy on their robot platform Koala, see **Error! Reference source not found.** based on comparison of the gas sensors arrays mounted on two-sides of the robot. The robot has two electronic noses (E-noses: Figaro TGS 2600, 2602, 2610, 2611 and 2620) mounted inside of the chamber, along with two inlet pipes diaphragm pumps (SERCOM 2002 0.35 l/min) positioned at the both sides of the robot .The robot speed is 2.5 cm/second and the environment 2.40m×1.20 m with the wind in the x-direction from right to left is used to release the ethanol at 0.35 l/min. The robot is set at specified initial location in all 16 runs and 13 runs were successful.

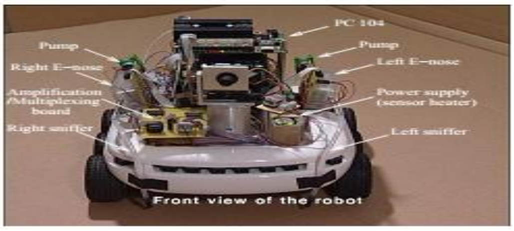

Figure 17: The Koala robot

Russell, 2006 [34], tried to study the plume and odor in three dimensional in the indoor arena. He tried to overcome the traditional way of data collection in 2D form and catch the plume at some height from the ground. His robot platform (see Fig 19) could be rotated as azimuth and elevation. Wind vanes, tin oxide gas sensor (TGS 2600) and infrared range finder sensor are used. One wind vane delivers azimuth information and the other elevation. An air pump bubbling 1.5l per minute of air in flask containing ethanol is used as odor source. The proposed algorithm is based on detecting edges of the plume by moving across to plan the trajectory and location of the center of the plume. The path length and robot angle for 8 trials (5successful try out of 8) during tracking are reported.

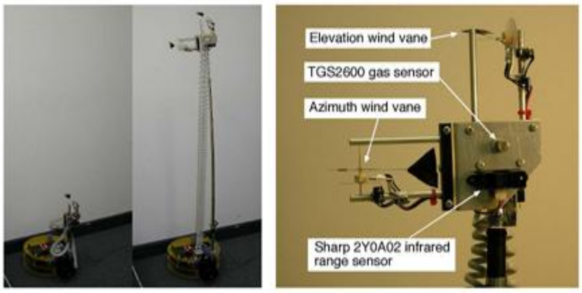

Figure 18: :(A) ROBOT PLATFORM (B) THE SENSOR POSITION ON ROBOT

Lochmatter et al, in their series of work have done plume tracking and odor localization with the help of various algorithms implemented. They used the beretainberg method to avoid the obstacles [6, 35, 38- 37] and have tested their robot equipped with wind sensor and ethanol gas sensor. A wind tunnel with dimension of 16m×4m is set up with laminar wind flow (1 m/s) to make the plume shape almost straight and ethanol is used as odor source. The kepera III robot platform and a small pump to bring the fresh air to improve sensor response are used.

Ten experiments were carried out in 16m×4 m tunnel with the effective area of 12m×3 m. The parameter considered were Time; distance to reach the source and the speed in the upwind direction. As a conclusion they mentioned that the spiral surge algorithm has better results than casting algorithm. The simulation with the help of WEBOTS (realistic simulator) has also been done by Lochmatter, et al [6], to compare three bio odor localization algorithms (casting, surge-spiral and surge-cast).

The plume model which they used was based on a filament propagation model by Farrell [34, 35]. The algorithms are compared in terms of success rate and the distance over head when tracking the plume up to the source with the robot speed of10cm/s. Two parameters the success ratio and the distance overhead of the runs were compared. As they observed the localization performance is mainly affected by the upwind angle. Small angles yields a low distance overhead, but also a low success rate. Finally, they concluded that the algorithms based on upwind surge have better performance than pure casting (Fig 20).

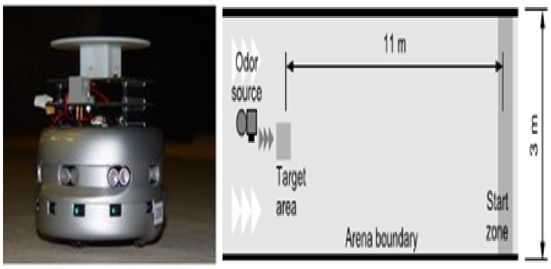

Figure 19: .(a) KEPERA III robot platform (b)The experiment arena

Lochmatter et al, analyzed three algorithms of casting, surge spiral, surge cast to support their prior works in laminar flow. They showed that pure casting is not enough for large upwind angles and not very robust for small upwind angles. They mentioned that wind direction identification and spiraling algorithms make the search upwind strategy robust and casting is very fast if directional information is available.

(Lochmatter et al , 2009) [38]; they continued their experiments series with obstacles of cylindrical and V shapes placed at different distances in the environment (see Fig 21). The obstacles affect shape of plume and if at the center, the plume gets divided into two lobes and affects distance overhead and success ratio. The wind tunnel of 16 m×4 m, wind speed of 1 m/s(laminar type) and kepera robot with the same sensor assembly was used. They have reported that both Braitenberg obstacle avoidance and wall following are able to deal with convex obstacles. Simple obstacle avoidance yields slightly better results and surge spiral is a good algorithm for tracking.

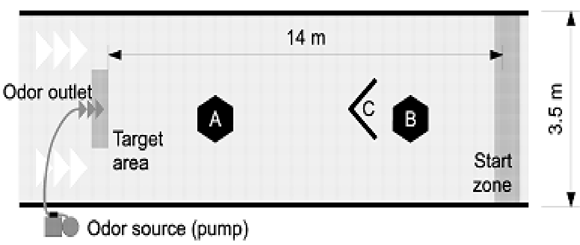

Figure 20:. The obstacle and experiment arena

Botre, et al 2009 [39]: used the initial stage of odor tracking system with their platform (see **Error! Reference source not found.** 22) consisting of ATMEGA 32 as the controller and 3 types of TGS 8xx gas sensor with DC fan to boost the sensor response. Two sets of IR detector were used to avoid collision in a 3m × 3m area selected as the environment. Their algorithm is based on odor concentration and distance to control the speed of robot in the direction of odor source.

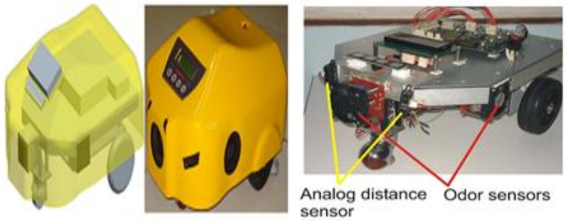

Figure 21: The robot platform

Waphare, et al 2009, [40] tried to implement and devise a new algorithm for odor tracking system, by using three sensors (one in front and two left and right). Their Sniffer Robot included the 3 Metal Oxide Gas sensors of TGS series, and four NTC thermistors as the wind vane In their experiment casting, surge spiral and surge cast algorithm with the newly proposed the surge spiral x and surge cast x algorithms are compared.

In surge spiral x, the sensor values are compared and instead of only Upwind surge, differential surge is implemented. When the robot is inside the odor plume it moves upwind and at the same time it runs the correction loop, by comparison of right and left sensors values and turns towards the sensor with maximum values. When the robot comes outside of plume it searches the plume signal by spiral manner.

In surge cast x the movement is based on right and left sensor values and when out of the odor plume it follows crosswind casting. The cross wind has the orthogonal direction and sensor values define the robot turns. Each algorithm has been tested with 10 experiments. They have done their experiment in 10 m × 3m width wind tunnel with robot at 8 m distance from odor source . The experiments were repeated with odor and wind orthogonal to each other. The main aim of this part was to separate the plume molecules from wind. Finally, their success ratio showed that Surge-Spiral and Surge-Spiralx algorithms have good performance in terms of success ratio, while Surge-Spiralx algorithm has advantage of less distance overhead (see Fig 23).

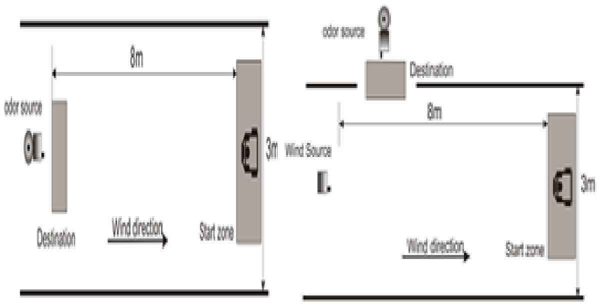

Figure 22: THE EXPERIMENTS ARENA A: THE ENVIROMENT 1

Gomez-Marin, et al, 2010 [18] have done studies with three different robot platforms based on Braitenberg ideas. They tried to model E-coli, larval Drosophila and adult Drosophila. The E-coli model used one sensor and one motor, the larval Drosophila used two motors with rotating antenna with two sensors and adult drosophila used two motors and two sensors.(see Fig. 24).

A set of 10 experiments was performed in the 3m ×4m indoor area and methanol vapor as the odor source. The algorithms are evaluated based on three parameters: explored area in percentage, distance traveled, and time spent. They have reported direct relation between threshold set and all three parameters. Finally, they concluded the PPE algorithm had the better result compared to PP algorithm.

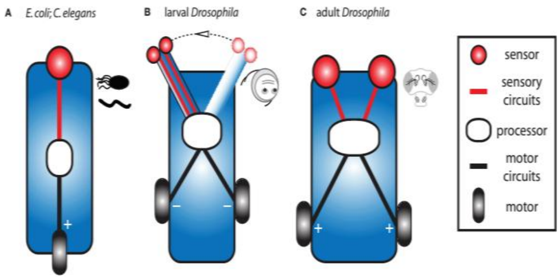

Fig. 23. The biological behavior on robot platform

Bennetts, et al,2012 [42] have been working on the Ethane leak in the outdoor environment. Their robot platform (ATRV-JR) integrated two laser scanner (LMS200), Tunable Laser Absorption Spectroscopy (TDLAS) sensor, GPS module (MTi-G), with a novel gas distribution algorithm. The two different environments, underground corridor (15 m×2.5m) and landfill (18 m×11m) is used to test the algorithm as well as the platform. For the corridor a leak in pipe lines (%90 CH_4) and in the second environment, continuous emission of methane is used for localization.

Role of wind and integration of wind data with gas sensors to predict emission rate and the critical leak area is highlighted. (See Fig 25) Also the same platform with the same target is used in, [86] with tomography principle for spatial gas distribution. The recent model has better odor localization capability.

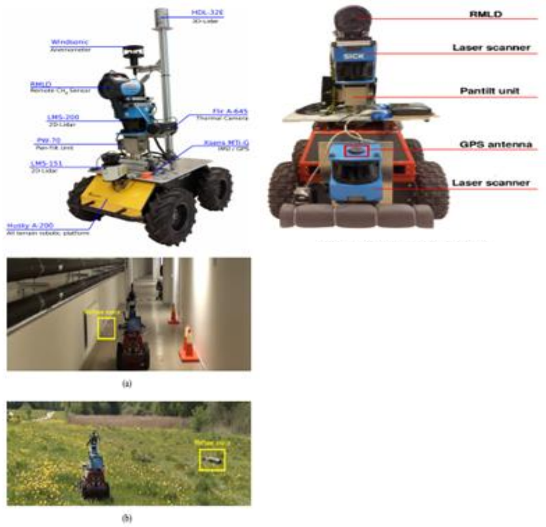

Fig. 25 (a): the GasBOT robot platform (b) the indoor and outdoor experiment arena

Recently Tien Fu Lu 2013 [43]; has studied effect of initial robot location and robot's movement, surge distance using simulation as well as real experiments. The office environment is simulated with the help of fluent with location of Ion generator odor source at x=4. 2m and y=3. 8m and constant wind speed of 5 m/s with direction between -22.5 to 22.5 degrees. Besides, during experiments, a cylinder and rectangular prism at varied locations are used as obstacles.

The robot is programmed to remember present, pervious and the maximum preset concentration to stop the robot and finish the experiment. He concluded that, there is no direct relation of robot initial stage and the success ratio of finding the source.

When the surge distance increases, the ratio of success decreases in spite of increasing the time of exploring. He proposed an algorithm named ISCA taxis based on inverse relation between chemical level and safe distance. They concluded that surge distance affects the time for reaching the source as well as the success rate and ISCA-has the better response.

Neumann et al, 2013 [44], tried to localize the odor source, with the gas sensor and UAV robot and implemented the probabilistic approach based on plume tracking and a particle filter (PF). Two anemometers were used as the PF-based algorithm uses integration of wind and gas detectors. They report success rate of 83.3%. and 92.3% with predefined sweeping trajectories. They concluded that different gas sensors used, did not impact success rate and localization error

Pomareda et al, 2013[45] Chose the gas distribution mapping methods for gas localization task based on probabilistic mapping approaches both event-based and concentration-based. 20 experiments were conducted with the help of a mobile robot having a PID and an ultrasonic anemometer in indoor and outdoor arenas with forced ventilation with and without obstacles and with one or two chemical sources (acetone, ethanol and 2-propanol) at the same time. The robot has random movement to explore and localize the gas source, and is equipped with 3D laser range finder and a remote gas sensor to obtain the gas distribution.

III. CONCLUSION

The review presented the work done in the area of odor source localization. Researchers have tried to localize the odor using various strategies based on behavior of insects. Some groups are working on simulation studies in order to introduce the models and formulate [46, 47] the odor behavior to implement the searching strategies. The gap between theoretical and actual environments makes the simulations job difficult. [48].The major areas of exploration in this exciting field are the applications, types of odors, sensors and strategy used as shown in Fig 26.

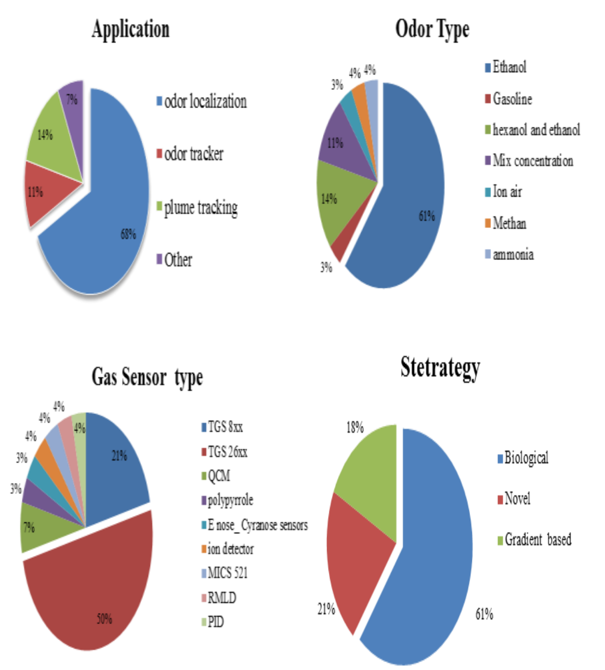

Figure 24: GRAPHICAL Overview of work done

As shown in Fig 26, the main application targeted is Odor localization and some application like the humanoid robots as well as gasoline leak detector are reported. Major work has been done using Ethanol as the odor source due to its ease of availability and other advantages. Experiments have been carried out using varying concentration of odor, odor mixtures, methanol and .gasoline.

The most used sensors for odor tracking are the 26XX devices. Other sensors can be listed as TGS800XX, MIC, ion detectors, Polymer, QCM sensor arrays and readymade E nose. Active research on various strategies for odor localization is being carried out. The plume/ odor localization algorithms can be broadly classified into reactive plume tracking and gas distribution mapping approaches [49][50].The odor algorithm searching for the reactive plume/odor tracking area consists of various methods derived from biological studies and statistical (probabilistic) methods. [48].

One of the most successful algorithms implemented is related to the Silk moth, the main reason is its behavior for odor localization which can be copied by robots. Various robot platforms have been used to implement odor localization system. Besides, the review of systems shows use of varied platforms as shown in Fig 27.

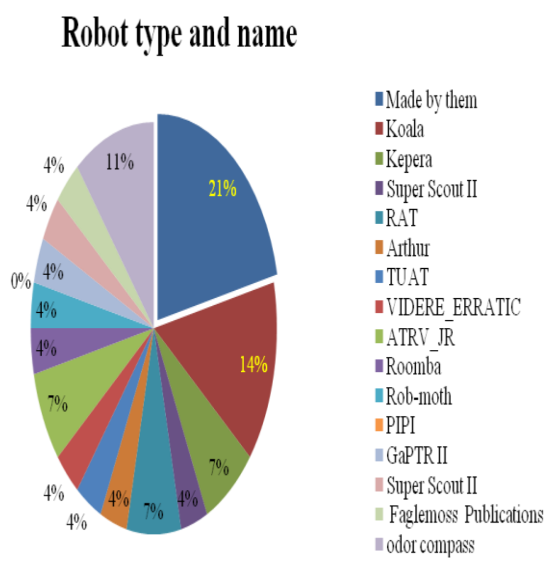

Figure 25: THE platforms rate used for odor localization

The study shows many researchers have designed their own platforms. The Koala and Kepera commercially available robots. have been used by many scholars. The table gives an overview of the work done since 1996.The numerous strategy and robot platforms along with different environment size and nature of plume made the evaluation between the researchers' works difficult [51].The odor localization activities are summaries in Table 1.

The table gives an overview of the work done since 1996. It started with development of odor compass –direction detector and then with simple algorithms to determine the location of odor. The variation in number and type of sensors used for the purpose was done.

The applications for systems designed ranged from simple alcohol odor detection to Gasoline leakage as well as foul smells from landfills recently.

The environments chosen initially were closed with dimensions varying from few meters to tens of meters. Later the experiments are reported in corridors and open air, Various strategies like gradient based, chemo taxis, anemotaxis, nearest neighbor etc have been implemented and their performance studied. Algorithm which used the wind vane or wind sensor have better robot navigation.

The numerous strategy and robot platforms along with different environment size and nature of plume make the comparison between the researcher works difficult [51]. A number of robot platforms have been used for experimentation. Some groups have designed their own robots for the purpose. For tracking and localizing task, the animals generally need two type of information, odor presence and wind flow direction [13].

G	F	E	D	C	B	A	
ROBOT NAME	STRATEGY	SIZE OF AREA	TYPE OF SENSOR	ODOR TYPE	APPLICATION	YEAR	No
made by researchers	Model male silkworm behavior, gradient based	40 ×70 cm, 5.8 mX 7.3m	TGS 822, TGS800, TGS813 and airflow sensor	Ethanol, Hexanol	Odor Localization	1996-97	1
RAT, Koala, super scout II	Upwind, gradient based, chemotaxis, neural network,Nearest neighbor classifier	47cm * 27cm * 27cm,2.45X2.5, 5mX2m	Air flow and a QCM, TGS sensors	Ethanol, methanol, iso propyl alcohol	Odor Plume, source localization	2001-2	2
RAT, Arthur, Koala	algorithm (E. Cole, Bombyxmori, dung beetle),	15. 4 m×5. 1 m, 10.6m × .5 m	Polypyrrole and TGS sensors	ammonia solution, ethanol	Chemical plume tracking, odor source localisation	2003-4	3
PIPI, TUAT, GaPTR II	OSM and HSM +visual, Upwind Tracking And Local Search	LAB, 5.9m83.2 m ×2.7m, 2m×4.8 m	Cyranose sensors, TGS sensors, QCM, PIDs	ethanol	odor-source localization system	2005	4
Koala, Robo Moth, Kaperall, sniffer , ATRV-Jr	casting, spiral surge, Bio inspired Particle Plume (PP) ,Particle	24m×12cm, 12mX3m,3mX3m	TGS sensors, ion detector, mics 5521	Ethanol, ions	odor-source localization system, 3D , plume tracking	2006-11	5
ATRV-JR	gas distribution mapping probabilistic plume mapping	15 m×2.5m) and landfill(18 m×11m), 6X3m	RMLD PID (sampling frequency 1Hz)	Methane, acetone, ethanol and 2-propanol gasoline	leak localization system, odor localization	2012-13	6

The main challenges in this area are due to limitations of sensors and complicated behavior of the odor plume. Less selectivity and slow sensor response, limited sensing area (few centimeters) [42] [52] which determines the efficiency of algorithms and makes the tracking process slow. [21] [32]. This problem has forced some researchers to use the insects, directly to navigate the real robot [46].On the other hand the second group of algorithm gas distribution mapping methods worked independently on tracking the odor/ plume for the source localization. [26] [45]. Herein, the other factor which affects the algorithm performance is the ratio of robot and arena dimension, especially for the gradient based algorithm using one sensor. Besides, after using multiple sensors, matching their response, may cause problem [34].

The slow rate of molecular diffusion in comparison to the air flow, forces the plume to form in the downwind direction from its source [52].

IV. OUTLOOK OF THE REPORTED RESEARCH WORK

Odor localization task is the activity which tries to localize, find and sometimes explore the source of odor. The tracking can be employed in many applications, such as the detection of toxic gas, fire at its initial stage and unexploded bombs. In general we can say it’s applicable from chemical leakage detection to mine finding systems.

As said in conclusion in this review, the Table1 and Fig 26 shows 68 % of reported work focused on odor localization and for the 61 % of these application's ethanol as the odor, is selected. The TGS 26xx gas sensor used in 50% of reported work and biological strategies have a good success ratio. Recently the localization task is for the multiple odors with multiple robot platforms are reported [55] but the common problem even by using the multiple robot remains in this field.

The main demerit of volatile component is the lack of clear picture from odor like smoke. We can conclude that ethanol can be safe odor with respect to the number of experiments that should be followed during the odor localization task. The TGS 26XX by the availability and reliability performance can be used as the gas sensor. The method which relays or have some aspect of biology may bring more success.On the other hand using the assembly can overcome the drawback of gas sensor response and help them to boost up the response. Looking to the odor molecules in the 3D form instead of 2D by proposing the sensor's arragnment as well as data acquiring method will help the robots to have the more success in the real environment and studies the environment better

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