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Implementation of Electronic Nose Technique In Explosives Detection

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ABSTRACT

Detection of explosives has become a very important issue in the last few years. The number of terrorist attacks, and suicide bombings in particular, has risen dramatically in the last few years, the explosives used by terrorists and insurgents only give off incredibly small amounts of detectable gas. Existing systems which are capable of detecting compounds in the gas phase at such low levels are large, unwieldy and very expensive, they also have limited sensitivity and selectivity - there is no way to be certain which explosive substance has been detected. As nanomaterials become more readily available for commercial devices, great interest has been shown in using them to develop trace-level detection systems for explosives which overcome all of these issues. Because of the unique nature and properties of nanomaterials like carbon nanotubes, nanowires, and other nanostructures, handheld or portable systems which are sensitive down to the molecular level could well be possible. Therefore this work focuses effort in the use of electronic sensors and pattern recognition technology to imitate the sensing capabilities of the human nose. With the addition of nano-enhanced sensors and heuristic algorithm E-Nose was simulated that can detect and identify incredibly quantities of explosive chemicals.

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I. INTODUCTION

Detection of explosives has become a very important issue in the last few years. The number of terrorist attacks, and suicide bombings in particular, has risen dramatically in the last few years. A significant number of the casualties in Iraq and Afghanistan have been caused by IEDs (Improvised Explosive Devices). Early detection of hidden explosive devices therefore has the potential to save many lives. The explosives typically used by terrorists and insurgents only give off incredibly small amounts of detectable gas. Existing systems which are capable of detecting compounds in the gas phase at such low levels are large, unwieldy and very expensive. They also have limited sensitivity and selectivity - there is no way to be certain which explosive substance has been detected.

The concept of an "electronic nose" has been in development since the 1980's - the aim is to use electronic sensors and pattern recognition technology to imitate the sensing capabilities of the human nose. With the addition of nano-enhanced sensors and advances in artificial intelligence technologies like neural networks, electronic noses have been developed which can detect and identify incredibly small quantities of explosive chemicals.Electronic nose is mainly composed of chemical sensor system, sampling system and a pattern recognition system as a neural network. This composited detector can sense the odour difference caused by explosives and converts it to signals. For instance electrical conductivity in a nanotube changes due to interacting with molecules of an explosive analyze, as a result of highly selective adsorption. Nanomechanical effects induced by molecular adsorption offer unprecedented opportunities for trace explosive detection.

II. THE ELECTRONIC NOSE SYSTEM

Electronic Nose is a smart instrument that is designed to detect and discriminate among complex odors using an array of sensors. The array of sensors consists of a number of broadly tuned (nonspecific) sensors that are treated with a variety of odor-sensitive biological or chemical materials. This instrument provides a rapid, simple and non-invasive sampling technique, for the detection and identification of a range of volatile compounds. The key function of an electronic nose is to mimic human olfactory system (figure 2.4). the human nose is still consideration the primary tool employed in industry to characterize the odor of a variety of consumer products.

Several type sensor materials are currently used in artificial nose technology such as metal oxide, conductive polymer, piezoelectric crystal and fiber optics. An odor stimulates generates a characteristic fingerprint from this array of sensors. Patterns or fingerprints from known odors are used to construct a database and train a pattern recognition system so that unknown odors can be subsequently be classified and/or identified. Typically an electronic nose consists of three elements: a sensor array which is exposed to the volatiles, conversion of the sensor signals to a readable format and software analysis of the data to produce characteristic outputs related to the odor encountered (figure 2). the output from the sensor array may be interpreted via a variety of methods such as pattern recognition algorithms, principal component analysis, discriminate function analysis, cluster analysis and artificial neural networks to discriminate between samples. This technology is a user-friendly, inexpensive and intelligent laboratory diagnostic device [1]

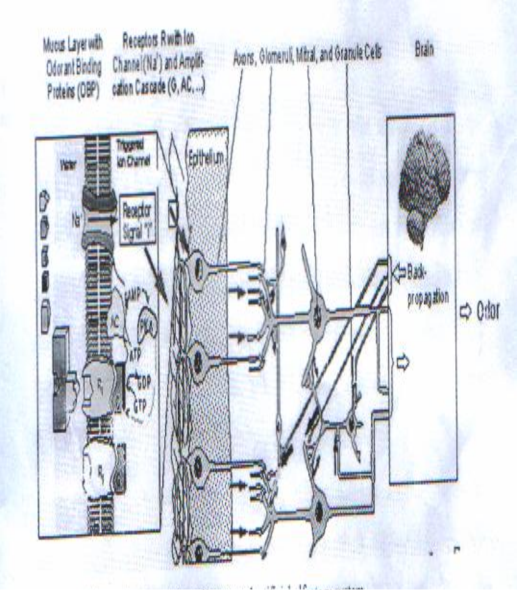


Fig 1 Schematic representation of human and

artificial olfactory system

2.1.Electronic Nose and Bomb Detectors: Comparison and Analysis

Staples[4] analyzed and compared e-nose with bomb detectors as follows: conventional bomb detectors are designed to responds to only energetic materials e.g nitrates and not to detect other background chemicals in odors. Conversely electronic nose are designed to respond to all chemical with an odor. Based upon these distinction electronic noses might not be considered good bomb detectors where there are strong background odors.

Electronic nose have the ability to recognize an almost limitless number of chemical vapor threats while bomb/chemical agent detectors provide the ability to detect specific target chemical at trace levels while not being affected by high ambient concentration of non-target compounds. Electronic nose provide a different screening capability with inherently more information gathering power than bomb detectors and help to resolve ambiguities by using a library of aroma signature. The Znose^{TM} uses a patented method of olfactory images called VaporPrint. This high-resolution 2-dimentional image is specific and determined solely by an object's aroma chemistry.[2]

2.2.Working Process of the E-Nose

The mechanism devised through the sensor technology is fast and indeed comprehensive to prevent terrorist attacks. Yet you can't bet that terrorist threat can be completely put off. But the day is not far when such violent and destructive missions will be made numb and those involved will fear of hysteria forever. We all want peace. That is the ultimate mission for making the world better and happier.

III. IIIDESIGN AND METHODOLOGY

- Computer system: This was used to simulate the system and serve as an interface used to communicate with the software in order to detect bomb using electronic nose.
- Knowledge- based intelligence software: This is the program written to detect bomb incorporated with artificial neural network.

- Chemical composition of sampled bombs: Since there are different types of explosives and each of them consist of different chemical compositions, some of these chemical compositions are gotten from the internet in order to know what makes up a bomb.
- Modelled electronic nose sensor: Modelled electronic nose sensor was used to sniff and detect bomb within the vicinity.

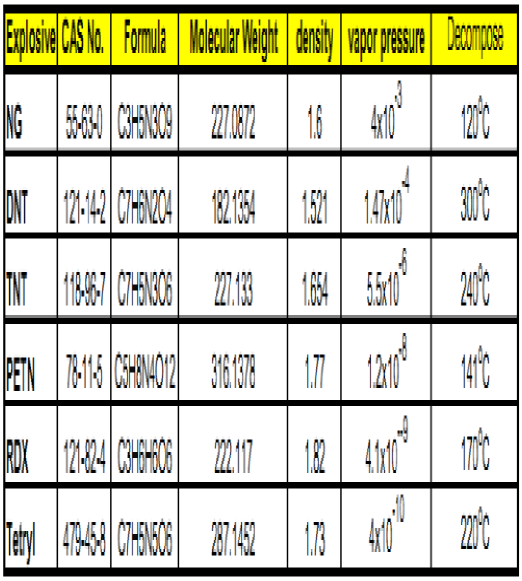
3.2 METHODOLOGY

An electronic nose sensor was modeled by using an object-oriented programming language called C# to detect any explosive compound in vapor.

3.2 Energetic Compounds

The chemistry of explosives involves what are called energetic compounds because they readily decompose with shock or high temperature[5]. Some important characteristics of six common energetic compounds found in explosives are listed in Table 1.

Table. 1: Common energetic compounds found in explosives.



Explosive	CAS No.	Formula	Molecular Weight	density	vapor pressure	Decompose
NG	55-63-0	C3H5N3O9	227.0872	1.6	$4x10^{-3}$	120°C
DNT	121-14-2	C7H6N2O4	182.1354	1.521	$1.47x10^{-4}$	300°C
TNT	118-96-7	C7H5N3O6	227.133	1.654	$5.5x10^{-6}$	240°C
PETN	78-11-5	C5H8N4O12	316.1378	1.77	$1.2x10^{-8}$	141°C
RDX	121-82-4	C3H6H6O6	222.117	1.82	$4.1x10^{-9}$	170°C
Tetryl	479-45-8	C7H5N5O6	287.1452	1.73	$4x10^{-10}$	220°C

For detection purposes perhaps the most important characteristics are the vapor pressure and decomposition temperature. Low vapor pressure compounds tend to adhere to cool surfaces and require careful control of instrument temperatures. However, if temperatures are too high compounds like NG and PETN will decompose before they can be detected.

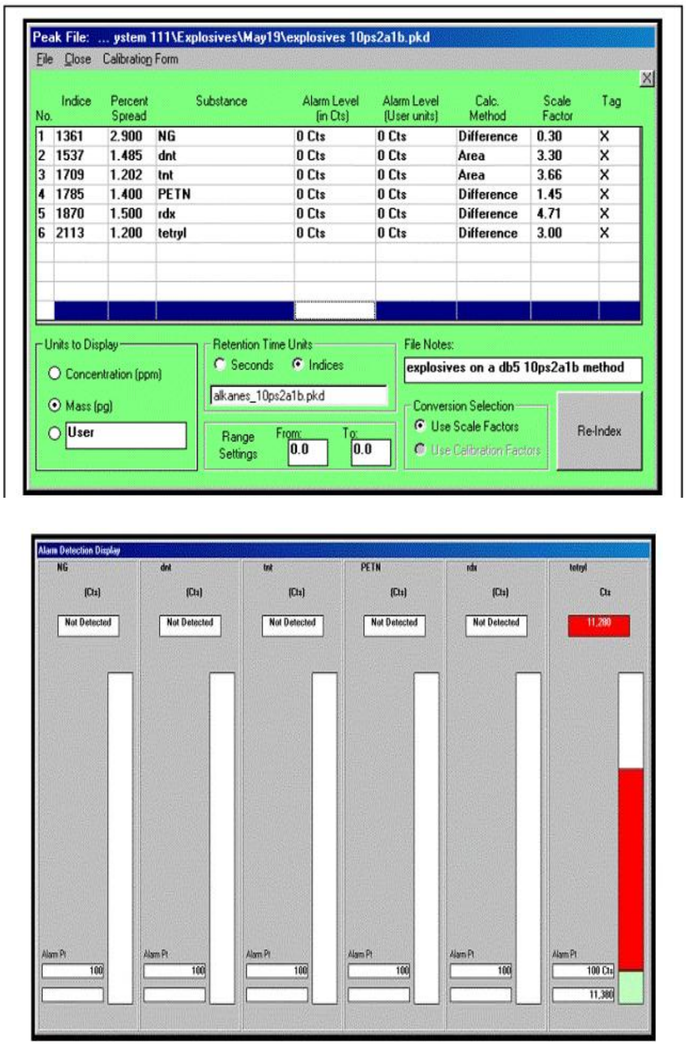
3.3.Kovats Indices of Common Explosives

The retention times and Kovats indices of energetic compounds were obtained by Direct desorbtion with a methanol solution containing known concentrations and measuring the resulting odor chemistry with a zNose™. The Kovats indices for each of the 6 common explosives are tabulated in Table 2.

Table 2; Kovate indices of the six energetic compound

3.2. Virtual Chemical Sensors with Alarms

These indices, tabulated in Table .2, provided the basis for creating alarms or virtual sensors for each of the compounds. Because the retention times are relative to N-alkane vapors they are machine independent and only require knowledge of the N-alkane retention times to create a library of explosives which applies to all zNose™[2] instruments.



Peak File: ... ystem 111\Explosives\May19\explosives 10ps2a1b.pkd

No.	Indice	Percent Spread	Substance	Alarm Level (in Cts)	Alarm Level (User units)	Calc. Method	Scale Factor	Tag
1	1361	2.900	NG	0 Cts	0 Cts	Difference	0.30	X
2	1537	1.485	dnt	0 Cts	0 Cts	Area	3.30	X
3	1709	1.202	tnt	0 Cts	0 Cts	Area	3.66	X
4	1785	1.400	PETN	0 Cts	0 Cts	Difference	1.45	X
5	1870	1.500	rdx	0 Cts	0 Cts	Difference	4.71	X
6	2113	1.200	tetryl	0 Cts	0 Cts	Difference	3.00	X

Units to Display: ○ Concentration (ppm) ● Mass (pg) ○ User

Retention Time Units: ○ Seconds ● Indices

alkanes_10ps2a1b.pkd

Range Settings From: 0.0 To: 0.0

File Notes: explosives on a db5 10ps2a1b method

Conversion Selection: ● Use Scale Factors ○ Use Calibration Factors

Fig 2 virtual chemical sensor

Tabulated data listings as shown in Figure1 are used to define retention times by index rather than retention time in seconds. Response factors of each sensor and alarm window widths are also defined. Thus defined, chromatographic measurements are reduced to a simple user display of six virtual sensors for the common explosive compounds together with their individual alarm levels.[6]

IV. IMPLEMENTATION

Figure 4 below is the first screen that will be displayed when the system is opened, it is the user interface for the simulated bomb detection system. On this interface, there is a text box, menu bar and picture box.

TEXT BOX: this is a box on the interface which is there for the purpose of displaying some text when the system detect any explosive.

PICTURE BOX: this box is on the interface too, it is a picture that is there for the purpose of signaling whenever the system detect any explosive. The picture box is attached with a sound to raise alarm when the explosive is detected by the system.

MENU BAR: this bar will later consists of menus that navigate to some other screen when the system detected any explosive, but it does not consist any menu presently since the system has not detect any explosive.

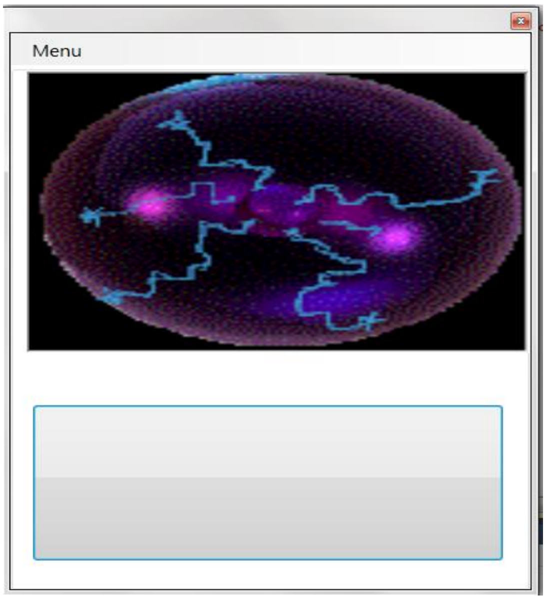


Figure 2 Simulated bomb detected system.

Figure 2 below is another screen that will be displayed when any explosive is detected, just a button is added to the figure 1 above and the button is RESET button.

TEXT BOX: this box will display this sentence: "Bomb is detected." to the user what is happening when the system raise alarm.

PICTURE BOX: this is a box which involves a picture that changes color from blue to red and gives an alarm sound to alert the system user of any explosive detected by the system.

MENU BAR: this bar consists of menus that navigate to some other screen, the menus are:
1 Check/update substance and
2 Check detected bomb detail.

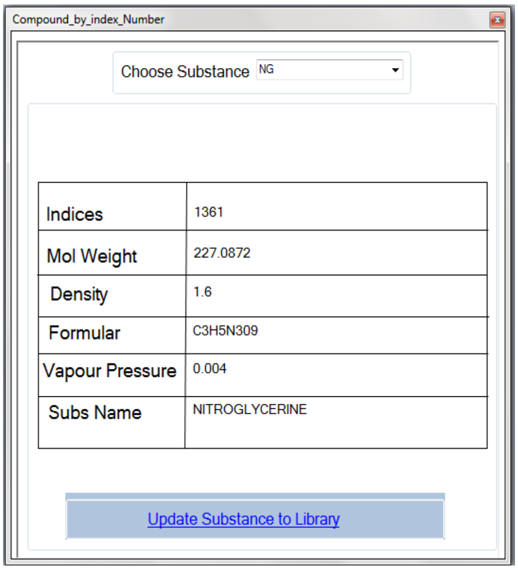
RESET BUTTON: this button, when clicked, enable the user to stop signaling and return to the normal screen when no explosive is not detected.

Cyclotrimethylenetrinitratemine explosive substance has be discoverd

Figure 3 Bomb discovered

Figure 3 is displayed when the Check/Update Substance menu in figure 2 above is clicked, it shows sampled explosives with their information.The first text box space is attached with combo box that contains those sampled explosives, any one of the information can be clicked and the following text boxes are provided to display information about that particular explosive. The information are indices number, molecular weight, density, chemical formula and vapor pressure. Each of these has text box in their front that contain those information.

UPDATE SUBSTANCE TO LIBRARY: This is the button that navigates a new screen to update the information about the substances in the library. Another button on top of this interface is to close this screen and back to the normal screen when any explosive is not detected.



Choose Substance NG

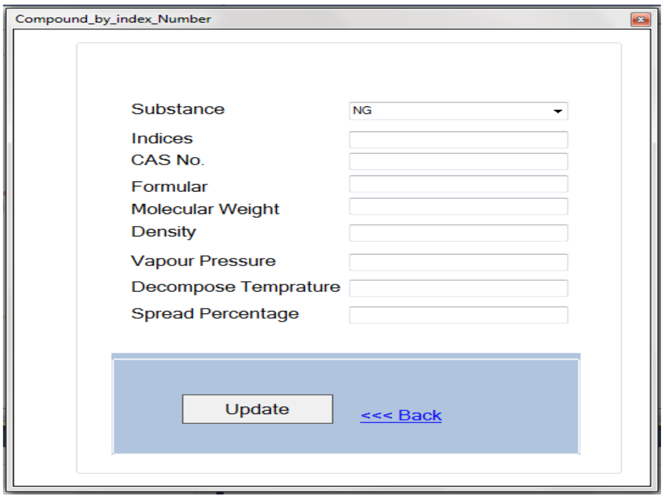
Indices	1361
Mol Weight	227.0872
Density	1.6
Formular	C3H5N309
Vapour Pressure	0.004
Subs Name	NITROGLYCERINE

Figure 4: check and update substance

Figure 4 is displayed when the Update Substance to Library button in figure 3 above is clicked, this interface enable the user to update the substance in the Library.
The first text box is attached with combo box that contain those explosives so that any one that is to update can be clicked and those information with each text box space is provided to enable the use to input new data for those information.

UPDATE BUTTON: this button when is clicked update the substances with new data that the user just entered.

BACK BUTTON: This button enable the user to leave this interface for previous interface.Another button on top of this interface is to close this screen and back to the normal screen when any explosive is not detected.



Substance NG

Figure 5: Library update

Figure 4 is displayed when the Check Detected Detail menu in the figure 3 above is clicked, this interface is provided to enable the user to check which type of explosive is detected by the system some detail about that particular explosive.

This interface shows alarm percentage and spread percentage of the explosive detected. The alarm percentage is set to be 100%, and it is constant but the spread percentage of each explosive is varied and the proximity of the explosive to the system also affect this spread percentage.Another button provided in this interface is indicated by ‘<<’, this button is there to enable the user to back to previous interface.

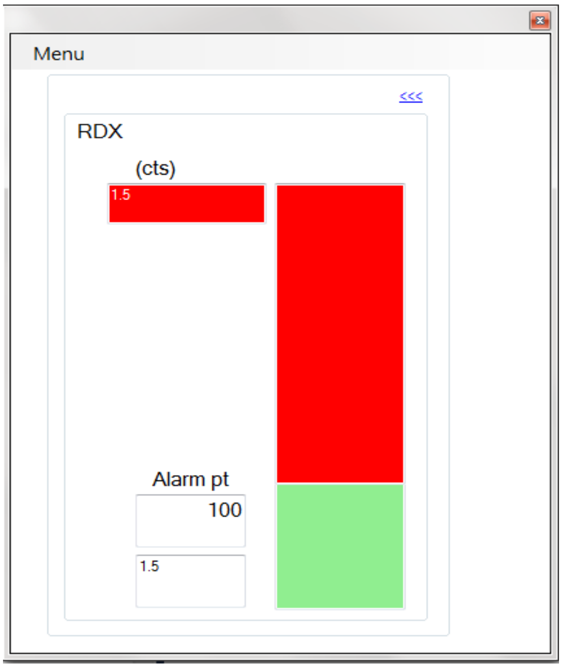


Figure 6: The spread percentage and alarm percentage.

V. DISCUSSION

Explosive detected system was modeled using C#. In this model, chemical composition of sampled explosives are entered into C# working environment to do this. The sampled explosives can be detected by the user by merely looking at the modeled system and even alarm sound is attached to alert the user if the user is a lay man. But as for an expert who may want to know more about the particular type of the explosive, the detail about the explosive and probably he/she want to update the substance in the library, the modeled system provides opportunity for all these to be accomplished.
The table 3 below shows different explosive with their details.

TABLE 3 SUBSTANCES BY THEIR INDEX

SUBSTANCES	NG	DNT	TNT	PETN	RDX	TETRYL
INDICES	1361	1537	1709	1785	1870	2113
MOL WEIGHT	227.0872	182.1354	227.133	316.1378	222.117	287.1452
DENSITY	1.6	1.521	1.654	1.77	1.82	1.73
FORMULAR	C3H5N3O9	C7H6N2O4	C7H5N3O6	C5H8N4O12	C3H6N6O6	C7H5N5O6
VAPOUR PRESSURE	0.004	0.000147	5.4E-06	1.2E-08	4.1E-09	4E-10

V. CONCLUSION

In this project, an electronic nose technique in explosives detection has been implemented. Through this modeled system, explosive chemicals can be quickly and appropriately detected so that lives can be rescued before the explosion of any explosive.The system has the advantages that the designed program is user friendly and the result can be easily understand by any user even, a lay man user who cannot read can easily understand it since the modeled system can alert the userthrough an alarm sound and changing of the picture's color in the interface of the system. Also the required output is displayed in a human understandable form.

Conclusively, the system modeled in this project has a capability to detect explosives hidden in luggage, vehicles, under clothes, mail or any hidden places, and alert the user.

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