Measurement of dust concentration based on VBAI

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Abstract. There are almost no economic and management solutions in automated measurement of dust concentration of magnesium oxide smelting electric arc furnace mouth. Nearly a thousand degrees of heat and the strong magnetic fields created by high-current constitutes a serious interference with the sensor. This makes close-contact measurement method becomes almost impossible. To solve the above problem, this paper proposes a measurement scheme based on VBAI (Vision Builder for Automated Inspection, a software developed by National Instruments) to calculate the dust concentration. It uses visual analysis of the means to calculate the number of dust particles per unit volume of. And then it calculates the dust concentration. Though the analysis of the actual photo of the smelting site, the relative dust concentration in the mouth of the furnace is calculate. This method will be applied to the precipitator 70 kW motor inverter control and has a high recognition rate and significant application prospects.

1. Introduction
A lot of researches on dust concentration measurement technology have been done around the world. And a series of monitor machine for dust concentration have been made, such as dust sampling machine, direct reading dust measurement device, dust concentration sensor and so on [1]. However, the main principle of these sensors is light scattering theory. The dust concentration is changed into 4 to 20 mA current signal. And then these signals are transmitted to the computer terminal to deal with. These are all belonging to the contact measuring method. So they can not be applied to the measurement of dust concentration of electric arc furnace mouth, where the temperature is quite high (1800 degree centigrade). In response to these issues, we propose to directly collect of the images of electric arc furnace mouth. And then we can use the image processing ability of VBAI to calculate the number of dust particles accurately on PC. In this way, the on line detection of dust concentration in the high temperature can be achieved.

2. Software and hardware platform for the dust particles calculate based on VBAI
VBAI (Vision Builder for Automated Inspection) is a fully interactive configuration of machine vision developing software launched by National Instruments. It has the image acquisition, processing algorithms, the full set of visual output control module. VBAI can be used to configure and modify the real time parameter and build machine vision applications.

In recent years, more and more machine vision applications in large-scale has automated production line as well as higher manufacturing equipment in order to achieve the reliability, accuracy,
and degree of automation, which can not be achieved in the past. Machine vision applications often involve special algorithm development and system environment, however, this development is relatively complex. Therefore, in this paper we chose Vision Builder AI NI interactive visual development software to quickly build a machine vision system to calculate the dust concentration. In fact VBAI is quite simple to use, its configuration interface just contain 4 main parts, main window, overview window, inspection steps palette and state configuration window. In fact the users do not have to write any program, they just need to configure the parameters and drag each block to the state configuration window.

According to actual needs, we chose the latest NI smart camera as the target hardware object to collect the real-time conditions in the mouth of the electric arc furnace.

The NI 177x smart cameras offer a range of sensors, a powerful Intel Atom 1.6 GHz processor, IP67 housing, M12 connectors, a lens cover, and multiple I/O options to perform in the most demanding applications. This high-performance hardware is paired with a real-time operating system to create a high-performance, deterministic machine vision system. In addition to high-performance image acquisition and processing, you can use built-in digital I/O and industrial communication options for dynamic, real-time communication and integration with industrial automation devices including programmable logic controller (PLC), human machine interface (HMI), robotics, sensors, and industrial machinery. NI vision software, including vision builder for automated inspection and the vision development module, provides a menu-driven or graphical programming option to develop application for the NI 177x smart cameras [2].

In order to analyze the experiment result as well as to monitor and control the dust concentration from the real Arc furnace, a NI PXI embedded controller instead of PC was selected to build the experiment platform together with the smart camera. PXI-8106 controller with PXI-1042Q Chassis with universal AC source has internet Ethernet interface, therefore it can communicate with the smart camera in a long distance (about 100 m) very conveniently. What is more, with the help of network routers, the PXI-8106 controller even can communicate with several smart cameras at the same time. And a PXI-6259 multifunction data acquisition board is also added to the platform so the arch furnace’s working state can be controlled according to the dust concentration if it is needed, just shown as figure 1.

![Figure 1. NI embedded controller.](image)

Finally, we have the basic structure of the dust concentration measurement platform. It is shown as figure 2.
As figure 2 shows, firstly, the smart camera takes a picture of the dust from the mouth of the arch furnace every 10 minutes (the interval can be longer or shorter). And then the PXI embedded controller (in fact, it can be used as a normal PC) deals with the picture with the help of VBAI, in addition, the signal of the picture is transmitted through the Ethernet cable in a distance which can be as long as 100 meters. Last but not least, the result is shown on the screen, and we can also add a feedback to the arch furnace system to control the dust concentration if it is required.

3. Algorithm flow of dust measuring based on VBAI

There are generally three steps to complete the calculation of the dust concentration. They are image acquisition, binarization processing and object detection.

Image acquisition, in VBAI, the acquire images tab contains several acquisition steps you can use to acquire images from many different types of cameras. The tab also contains a simulate acquisition step, which simulates image acquisition by loading images from file. The select image step enables you to switch to a previously acquired image that you need to process later in the algorithm [3]. In this application, a group of real industrial site photos of the actual dust image in the smelting site is imported in the form of simulation to the main window of VBAI. It is shown as figure 3.

Binarization processing, it is the technique of converting a gray scale image to a binary image by using threshold selection techniques to categorize the pixels of an image into either one of the two classes [4]. In this application, binarization processing is used to change the dust picture of the industrial site into image that only contains black and white pixels. This is a very critical step in the whole algorithm, which is laying the groundwork for the following object detection. However it is not complicated in VBAI. It is so simple that it is just need to drag a small black called vision assistant
and configure the parameters as binarization processing. VBAI will automatically deal with the complex calculation process. In figure 5 it is obvious that the colour of the dust showing bright white. So it is appropriate to add filter function to filter out the dim background colour. And then the result after binarization processing is as follows, white dots represent the dust and black parts represent the background. It is just like figure 4 shows in the VBAI.

Object detection, if some kind of object is wanted to be detected from a binary image, the simplest and the most effective mean maybe setting the minimum and the maximum pixel value of the objects. Actually this simple theory is tried in this application and seems quite effective. That is to say:

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\begin{align*}
\text{If } & N_{\text{min}} < N < N_{\text{max}}, \text{ the object is a dust} & (1) \\
\text{Else } & N > N_{\text{max}}, \text{ or } N < N_{\text{min}}, \text{ the object is not a dust} & (2)
\end{align*}
\]

- \(N\) is the size of the object the unit of which is pixel;
- \(N_{\text{min}}\) is the minimum pixel value;
- \(N_{\text{max}}\) is the maximum pixel value;

The main question is how to find minimum and the maximum pixel values. And maybe they are not unique. In our application several groups of values have been tried. In return, the group with the best results is selected as the minimum and the maximum pixel values. The minimum value for the dust is 20 pixels while the maximum is 500 pixels. In this way, the number of the dust is successfully detected. As figure 5 shows.
And the total algorithm flowchart is as shown below.

![Total Algorithm Flowchart](image)

**Figure 6.** The total algorithm flowchart.

4. The result and the application of the measurement of dust concentration based on VBAI

**Figure 7.** Melting site with higher density.

**Figure 8.** 290 dusts detected.
If the dust number is divided by the volume of the smelting site, the dust concentration will be got by the controller. And then it is very easy for the controller to control the dust concentration through the PXI bus. At least it is possible to distinguish whether the dust concentration has changed, that is very important to control the dust concentration automatically, just as shown below.

![Figure 9. Melting site with lower density.](image9.png) ![Figure 10. 100 dusts detected when density decrease.](image10.png)

From figure 7 to figure 10, it is obvious that the detected dust changes when the density changes. In figure 8, 290 dusts are detected from figure 7, but in figure 10 only 100 dusts are detected when the density decreases. So it is easy to use this result to monitor the change of the dust density.

5. Conclusion
This paper gives a new method of the real time measurement of the dust concentration. And through calculating the dust concentration of the photos from the real smelting site, it is proved that this new method is feasible and effective. Measurement of dust concentration based on VBAI is also a new non-contact measurement method, which is going to be used in the control system of high-temperature plasma arc furnace control system to control a 75 kW main motor for the bag filter.

Acknowledgments
This work is supported by The National High Technology Research and Development Program of China (“863”) under Grant No 2011AA060103.

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