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Rapid Picking System for Chemical Logistics & Warehousing Based on Raman Spectroscopy

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The logistics industry has seen phenomenal development in recent years, but hazardous articles such as inflammable and explosive goods carried in the logistics process may pose great hazards that seriously restrict the development of industry concerned, even threaten the safety of people's lives and property. Traditional X-ray examination has fallen short of what' s needed for accurately determining liquid and dust, while Raman spectroscopy, as an emerging technology, can judge the construction features of cargo molecules based on relative position and the intensity of atomic function groups in Raman spectrum. This paper builds a rapid picking system for dangerous goods warehousing based on the Raman spectroscopy and the translation-invariant wavelet threshold denoising algorithm. The findings reveal that the system will print the electronic labels on suspicious goods and access to the channel for secondary detection using the Raman spectroscopy. A Raman spectrum is then available for suspicious goods. It can also detect them by atomic function groups of different substances. With automatic picking system, it enables timely supervision on the whole picking process by the monitor, and control it by the controller. The study in this paper sheds light on application value of the rapid picking system based on Raman spectroscopy has certain.

1. Introduction

With the boom in the country’s online shopping, the logistics and ecommerce industries have seen a dramatic development, especially the express industry, which has now ushered in a new development opportunity (Tanackov et al., 2018). But unfortunately, this brings the surge in the accidents due to the presence of dangerous goods in logistics, including alcohol, liquefied gasoline, explosives and dust, etc., which are prevalent in the logistics industry. Dangerous goods not only perturbs the development of logistics industry, but also injuries the health of couriers in the logistics industry (Fazio et al., 2016; Huang, 2017). Due to substantial proliferation in express transaction volume, the traditional X-ray examination has been obsolete in the exact identification of dangerous goods in current logistics industry, thus resulting in frequent occurrence of relevant logistics accidents (Zhang et al., 2016). There are traditional test models on dangerous goods in logistics industry including the X-ray examination, the Raman spectroscopy and manual unpacking check (Frandes et al., 2011; Zafra et al., 2018). In foreign countries, the 2D code, X-ray and aided supervision systems in logistics express industry are effectively integrated into one to complete the detection of dangerous goods. Even better, the picking system is fully automated and intelligent (Li and Dang, 2015).
Raman spectroscopy can accurately determine the composition of goods that X-ray examination fails to do, especially in the fields of some new types of dangerous products such as liquids and powders. To a large extent, it has filled in the gaps of the traditional X-ray examination (Luisier et al., 2011). The rapid picking system is designed for chemical logistics warehousing based on the RFID (Radio Frequency Identification) technology of X-ray examination and Raman spectroscopy which make it possible to identify dangerous goods in logistics process (Tsai et al., 2011). Rapid picking system using the Raman spectroscopy can accurately measure dangerous materials as seen every day, visible liquids and dusts, and enable the system stability and adaptability in complex environments (Wang et al., 2016; Siemaszko, 2015). In relation to the X-ray examination technology, this paper builds a rapid picking system for dangerous goods warehousing based on Raman spectroscopy and the translation-invariant wavelet threshold denoising algorithm, which provides the clues to the rapid picking of dangerous goods in logistics and warehousing industry.

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2. Analysis of testing technology

2.1 X-ray examination

X-ray tube may produce X-rays used for testing logistics goods, while a part of energy is scattered, the other part contributes to produce photoelectric effects or is converted into the heat energy. There is also a part of energy which penetrates the goods to continue to spreading out (Mazzelli et al., 2018). When X-rays radiate the goods, they interact with each other, so that the image of the goods under test can be displayed via the detection interface (Marek et al., 2008). Different goods will interact with X-rays in a different way, while the sorption of dose of X-ray radiation is also subjected to the density and the thickness of the goods. What it displays is the image with clear distinction between black and white lines and even with different aberration. Some studies have shown that dangerous goods available currently are represented in red, orange, green and blue (Zhao et al., 2017). Therefore, suspicious goods in the express logistics can be detected by X-rays.

2.2 Raman spectroscopy

When the logistics goods are delivered by the detection machine, they are exposed to high-frequency monochromatic radiation, where the photons and electrons interact strongly to cause the light frequency and the relative nucleus position of the electron cloud to change, so that the Raman scattering phenomenon occurs (Withers et al., 2014). The energy level of the diatomic molecules from the Raman and Rayleigh scattering sources is shown in Fig. 1. When the molecules of goods are radiated by light, Raman and Rayleigh scatterings occur. In the figure, the Rayleigh scattering can transfer the energy. There is a spectral line phenomenon of the diffused light of Raman that will appear at a low frequency, and an anti-Stokes phenomenon appeared on the high frequency side. Raman spectroscopy not only enables a definite detection on all of different goods but also judges the construction features of the cargo molecules in light of the relative position and the strength of the atomic function groups of the goods in the Raman spectrum. Refer to Fig. 2 for the overall architecture of the Raman spectrometer. When the laser beam irradiates onto the goods under test, the Raman information in different depths from anywhere on the surface of the tested goods will be transmitted to the CCD detector, to complete the micro-area zero damage analysis in one dimension of goods.

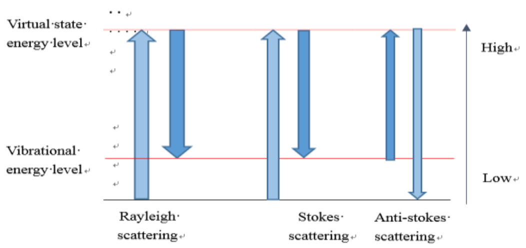

Figure 1: Energy level diagram of diatomic molecules derived from Raman scattering and Rayleigh scattering

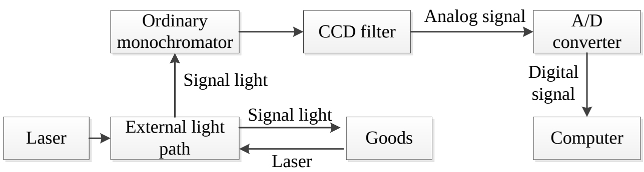

Figure 2: The overall structure of the Raman spectrometer

3. Process of Raman spectrogram

3.1 Detecting suspicious dangerous goods

During the cargo inspection, the strong noise signal will cause delay or accumulation of the scanning signals. The Raman spectrogram is denoised using the averaging method. Simulated denoise cycle should be different from what it is originally, and the white noise is set during the simulation. Denoise analysis method currently used is Raman spectrum Fourier transform spectrum analysis. In this section, we attempt to use the Raman spectrum wavelet transform to reduce noise. Wavelet transform can be used to denoise and reconstruct signals, if:

$$g(t)=f(t)+n(t) \tag{1}$$

Where: g(t) represents the captured signal; f(t) represents the initial signal; n(t) represents Gaussian white noise.
Before Wavelet transform is used to denoise, discrete sampling is adopted to capture WTs of N discrete signals, it follows that.

$$W_s(j,k)=\frac{2^{-j}}{2\sum_{n=0}^{N-1} f(n)\psi(2^{-j}n-k)} \tag{2}$$

However, ψ(t) in formula 2 cannot be calculated. To obtain a recursive algorithm that satisfies the WT, a two-scale formula can be used:

$$W_g(j+1, k)=S_g(j,k)*f(j,k) \tag{3}$$

$$S_g(j+1, k)= S_g(j+k)*h(j,k) \tag{4}$$

Where: *f* represents a high pass filter; *h* represents a low pass filter. Sg(j,k) is defined as the primary coefficient of the scaling function, that is, the wavelet transform reconstruction formula is:

$$S_g(j-1, k)= S_g(j,k)*h(j,k)+W_g(j,k)*f(j,k) \tag{5}$$

As shown in Fig. 3, it is a flow based on the translation-invariant wavelet threshold denoising algorithm. First, the noisy signal is recurrently translated, and the captured signal is denoised and recurrently translated by using the threshold of the wavelet transform, up till to where it has the same phase as the original signal. The target signal is captured by averaging the target.

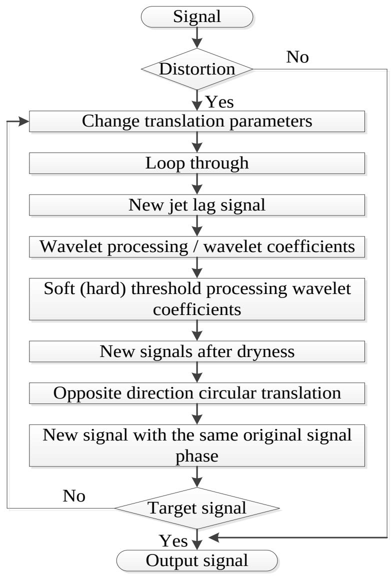

Figure 3: Flow chart based on translation invariant wavelet threshold denoising algorithm

3.2 RFID

The architecture of a Raman spectroscopy system is shown in Fig. 4. It includes the cargo channel, temperature control system, power module, data center, and optical system. Among them, the optical system uses a laser as a light source. Lasers given in Table 1 are commonly used in dispersive Raman spectroscopy. The selected lasers are monochromatic. The Raman spectrograms in Fig. 5 and Fig.6 are given for the alcohol respectively after denoising by the wavelet denoising function and by the translation-invariant wavelet threshold denoising function. As can be seen obviously, the latter obtains a more accurate signal and has more obvious denoising effect. The composition of electronic tag system is shown in Fig. 7, where the core module includes antenna, voltage regulator, modulator, demodulator, logic control unit, and storage unit. The RFID can receive and recognize the reader command and analyze current working state to satisfy the command execution conditions.

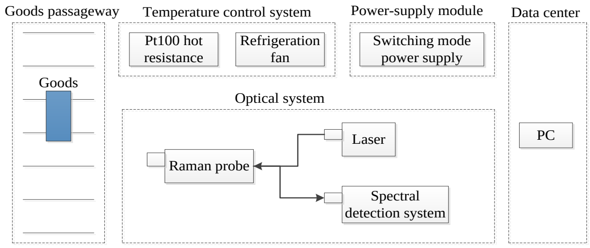

Figure 4: Raman spectroscopy system structure

Table 1: Lasers commonly used in dispersive Raman spectrometers

Laser	Wavelength/nm	Output power/nW
He-He	641.9	60-90
Ar^+	523.6	600-1200
Kr^-	652	200
Semiconductor	795	280

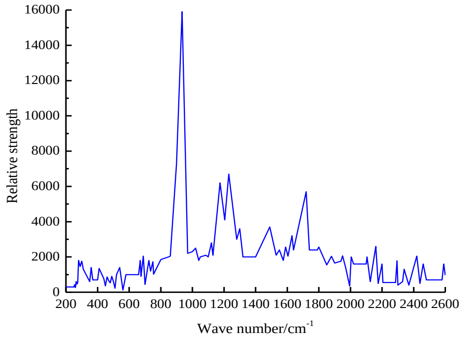

Figure 5: Alcohol Raman spectroscopy after reduction noise reduction by wavelet denoising function

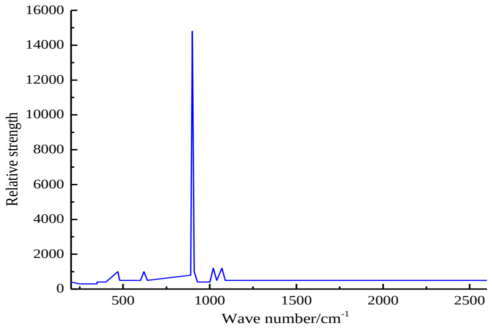

Figure 6: Raman spectroscopy of alcohol after noise based on translation-invariant wavelet threshold denoising function

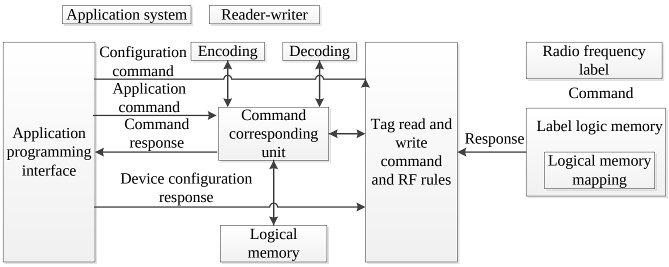

Figure 7: Composition of the electronic label system

4. Rapid picking system for chemical logistics and warehousing

4.1 Detection picking system

As shown in Fig. 8, a detection picking system is available for the dangerous goods in logistics and warehousing. First, the goods should be inspected once to filter out and dispose the relatively obvious danger things. X-rays should be used to detect unidentified dangerous goods. The system will print RFID tags labelled onto the suspicious goods, and automatically pick out them and allow them access to the secondary detection channel. Raman spectroscopy is used for secondary detection to get the Raman spectrum for the suspicious goods, and classifies the types of suspicious goods according to different atomic function groups. The match information of Raman spectroscopy includes characteristic frequency, spectral peak, polarization peak and peak width, etc. Based on these information (flammable, explosive, toxic and dust), picking of dangerous goods in different channels is completed.

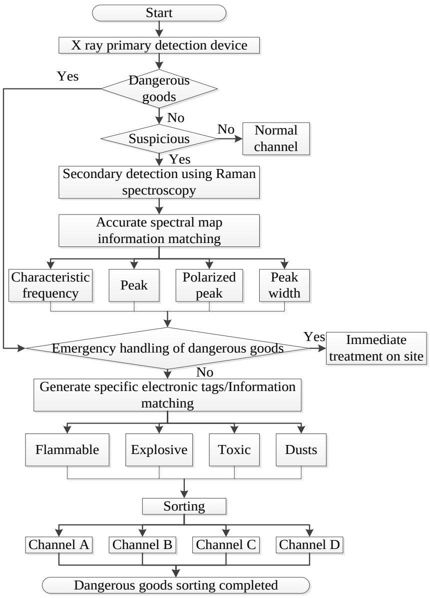

Figure 8: Dangerous goods logistics warehouse inspection picking system flow chart

4.2 Automatic identification system for dangerous goods logistics

As shown in Fig. 9, there is a communication between the simulation software and the PLC controller, where input and output systems can communicate the signal processing module with the programming control; the signal processing module interact with the object simulation software via the switch and analog. The picking supervision system includes five parts: downloading data, running monitor, equipment monitoring, information query and system setting. For a schematic diagram of the real-time monitoring process of the supervision system, refer to Fig. 10. The control monitor supervises the picking process in real time, and acts on the entire inspection process; the controller controls the picking process.

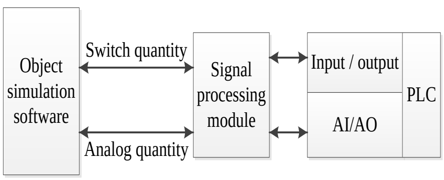

Figure 9: Schematic diagram of communication between simulation software and PLC controller

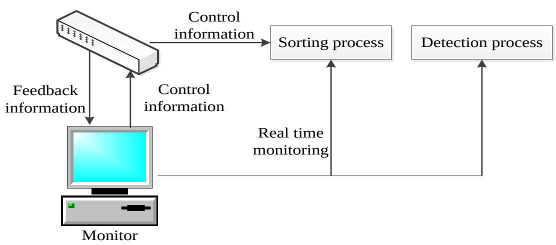

Figure 10: Schematic diagram of monitoring system real-time monitoring process

5. Conclusion

Compared with the X-ray examination technology, this paper builds a rapid picking system for dangerous goods warehousing based on Raman spectroscopy and translation-invariant wavelet threshold denoising algorithm. The specific conclusions are drawn as follows:

(1) Raman spectroscopy can definitely detect all of peculiar goods, and judge the construction features of the goods molecules according to the relative position and strength of the atomic function groups of the goods in the Raman spectrum.

(2) It is found by analyzing the Raman spectrum of alcohol before and after denoising that the signal available based on the translation-invariant wavelet denoising function seems more accurate, and the denoising effect is more obvious.

(3) The match information of Raman spectroscopy includes the characteristic frequency, spectral peaks, polarization peak and peak width, etc. The picking will be done based on the match information of dangerous goods (flammable, explosive, toxic and dust) in different channels to complete appropriate detection.

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