Abstract

The darknet is a chaotic place that is widely misused by criminals. Illicit drug markets host on darknet are a prominent feature which generate significant revenue each year. Existing studies on these illicit markets focus on the market sites only, and there has been very limited research on the internal discussion forums of the illicit markets. This qualitative research investigates discussions being held on the Agora forum, which was the internal discussion forum of the largest illicit drug market hosted on the darknet from 2013 to 2015, using data from an open-source dataset created by Branwen. It aims to understand the role of the discussion forum in market transactions and the nature of the phenomenon of drug trafficking. In particular, three research questions are answered, namely: 1) what topics have been discussed in the Agora forum; 2) what function does the Agora forum have; and 3) in what way does the Agora forum facilitate drug trafficking. Limitations and suggestions for future reserach are also discussed.

Contents

1. Introduction

The darknet is a chaotic place which has been intentionally hidden from the surface web. It can only be accessed through certain browsers, such as Tor or I2P (Greenberg, 2015; Chertoff & Simon, 2015). An important property of the darknet is anonymity: darknet users can only be identified by their unique usernames and their true identities are unknown (Hardy & Noragaard, 2016). Because of this anonymity, the darknet is widely misused by criminals to share experiences and techniques, and to exchange gains from crimes. The existence of such a virtual community not only facilitates cybercrime, but can also extend traditional crime to cyberspace, which imposes an additional threat to law enforcement (Wehinger, 2011).

Illicit drug markets are undoubtedly a prominent feature on the darknet. There are eBay-like websites with a decentralised structure, where vendors offer to sell their illicit drugs on the platform in exchange for cryptocurrencies (e.g. bitcoins) and provide a shipment service by post (Hardy & Norgaard, 2016; Tzanetakis et al., 2016). The first illicit drug market hosted on the darknet was the Silk Road, which was seized by law enforcement in 2011. Before its seizure, more than 1000 active vendors were found in the market and the annual revenue was estimated to be over 90 million dollars (Aldridge & Décary-Hétu., 2014). Since the success of Silk Road, the number of illicit drug markets on the darknet has experienced rapid growth. The business model of the markets has also been developed and has now become a 'professional and organised underground industry' (Franklin et al., 2007; Spitters et al., 2015). As well as providing 'business-to-customers' transactions, they also form a significant part of the drug supply chains of the world (Barrett & Aldridge, 2016): for example, many types of drug, such as cannabis, attract huge amounts of purchases in these markets, which is a sign of redistribution (Barrett & Aldridge, 2016). Moreover, with advanced encryption technologies and shipment methods considerably weakening law enforcement agencies' detection ability, the online transaction also largely reduces the risk of physical violence, making the business model increasingly popular; the growing number of transactions has reflected a trend whereby this

alternative model takes the place of traditional street distribution (Broséus et al., 2016; Tzanetakis et al., 2016; Demant et al., 2016).

Various studies have taken place around different illicit drug markets on the darknet in relation to the ecosystem of such marketplaces, focusing on areas such as the fluctuation of price (Demant et al., 2016), the efficiency of the rating system (Janetos & Tilly., 2017) and the product quality (Bancroft & Reid, 2016). However, most studies focus on the market sites only, and there has been very limited research on the internal discussion forums of these illicit markets. Since participants of the forum are also highly likely to be users of the illicit market, information being exchanged in the discussion forum can also reflect the dynamic of the whole market, investigating the role of the forum in the market transaction can significantly contribute to an understanding of this market ecosystem. Therefore, there are strong reasons to conduct research to explore the content held on the discussion forums of the darknet illicit drug markets.

In this study, a content analysis was conducted on the discussion forum of the Agora market, which was the largest illicit drug market hosted on the darknet from 2013 to 2015. The aim was to explore and characterise the discussions being held on the forum, aiming to understand the role of the discussion forum in market transactions and the nature of the phenomenon of drug trafficking. In particular, three research questions were proposed:

1) What topics have been discussed in the Agora forum?

2) What function does the Agora forum have?

3) In what way does the forum facilitate drug trafficking?

This research paper is set out according to the following structure. In section 2, a review of relevant literature is presented, followed by an introduction to the proposed methodology adopted by this research in section 3. After that, findings of the research are demonstrated in section 4 and the derivational discussion is detailed in section 5. Finally in section 6, conclusions of the research and suggestions for future research are presented.

2. Background and Related Works

Traditional illicit markets generally operate in the form of underground forums, which are established by participants in the hacking scene (Wehinger, 2011). These underground forums enable criminals to provide illicit services and sell illegal goods (Haslebacher et al., 2016). They typically incorporate numerous sub-forums for different types of services and goods in relation to the forum's business matters, including stolen credit cards (Haslebacher et al., 2016), malicious software (Chu et al., 2012) and other sensitive data (Zhuge et al., 2009; Franklin et al., 2007). The common business model of these underground online forums is as follows: vendors post a thread with the price and description of their merchandise on the forum and wait for potential buyers to contact them. The transaction is conducted outside the forum depending on the negotiation (Motoyama et al., 2011; Wehinger, 2011). Most of the time communication happens through interaction posts and the private message service, although some vendors prefer to use an instant messaging service, such as ICQ (Haslebacher et al., 2016). Among the users, there are administrators who guarantee the security of the forum and monitor users' compliance with the forum rules (Wehinger, 2011).

Compared with traditional underground forums, the Agora marketplace adopts a different business model: it is an eBay-like market hosted on the darknet (Deepdotweb, 2015). After paying the registration fee (of around $500), vendors can set up their store front in the market site and customers can place orders directly in the store without further negotiations about the transaction method (Afilipoaie & Shortis, 2015). Moreover, to secure the transit and prevent scams, the Agora market implements an auto escrow system, meaning that, at the point of purchase, the money is kept in the 'wallet' of the marketplace. After the customer announces that the goods have been received, the money will then be released to the vendor. In the case of fraud, the buyer will be refunded by the escrow service and will lose only the service fee (Hu et al., 2004; Rhumorbarbe et al., 2016). The review system is also a critical function embedded in the market site. Customers, while finishing a

transaction, are allowed to rate the transaction from 0 to 5 stars, accompanied by a brief comment explaining their reasons (Hardy & Norgaard, 2015). Customer reviews form an extensive part of a vendor's reputation, which was found to have a positive relationship with the ascending price and number of sales, and therefore has a great impact on the vendor's business life (Janet & Tilly, 2017).

Although all transactions are completed in the Agora market, and its trading functions are relatively well-developed, due to the design of the market website, its reputation system and policing mechanism is incomplete (Hardy & Norgaard, 2015). In online transactions, buyer's and seller's user profiles provide a good indication of their reputation. This reputation reflects the honesty of the person and has a significant impact on the other person's willingness to conduct business (Houser & Wooders, 2006). Thus, the reputation system provides a mutual recognition between the vendor and buyer in a transaction. Yet, in the Agora market site, the power is imbalanced: whilst buyers can easily establish the reputation of vendors by viewing previous buyers' comments and the overall rating score, vendors have no right to leave comments about buyers in transactions. Moreover, to protect buyer anonymity, unlike eBay or Amazon, in many of the darknet markets there is an absence of individual identification attached to the message when a buyer leaves a review (Hardy & Norgaard, 2015). As a result, it is difficult for a vendor to distinguish a dishonest buyer purely based on information provided on the market site, nor can other vendors be alerted through comments or ratings. Therefore, vendors must rely on external sources to leave feedback or manually check the potential buyer's reputation. The discussion forum thus becomes an ideal place for vendors to achieve these purposes. On the other hand, since the reviews and ratings build the reputation of the vendors and play a vital role in vendors' business careers, while registering a buyer account is easy in the Agora market, there is a risk that vendors could forge feedback (Janetos & Tilly, 2017; Afilipoaie & Shortis, 2015). Even in legitimate online e-commerce websites like eBay, this seems to be a common business strategy for sellers (Luca & Zervas, 2016). Therefore, the Agora discussion forum remains the best place for customers to receive honest reviews and identify scammers. In this regard, as Wall & William (2007) notice, the

combination of social control and public shaming take the role of law to regulate user behaviours in the darknet marketplaces. The discussion forum of the Agora market seems to form an essential part of the self-regulation mechanism in the marketplace.

Moreover, as a discussion forum of the commercial website, the Agora forum may assist vendors in business promotion. This assistance can be two-fold: first, as discussed above, the reputation reflected from the customers' reviews has a significant impact on the buyer's purchase decision-making process, but building reputation in such a market is a time-consuming process. To start the business, advertising products with lower prices, or even providing free samples to attract customers, in the forum can be a prevalent marketing strategy for new vendors (Mackey & Liang, 2013; Afilipoaie & Shortis, 2015). Moreover, since vendors who pursue consistent businesses often establish their own brand identity and operate in various markets, making advertisements on social platforms is necessary to promote their brand (Afilipoaie & Shortis, 2015; Haslebacher et al., 2016). This may also be true for migrant vendors who are forced to move to a new market site due to exit scams or law enforcement interventions (Buxton & Bingham, 2015). Secondly, the discussion forum could contain substantive customer information, or electronic word-of-mouth (eWOM), which is defined as 'any positive or negative statement made by potential, actual, or former customers about a product or company, which is made available to a multitude of people and institutions via the Internet' (Henning-Thurau et al., 2004). The eWOM plays an important role in the age of online shopping: on one hand, other customers' reviews about products make a tremendous impact on a potential buyer's decision-making; it is suggested by eMarketer (2009) that about 45% of consumers are heavily influenced by eWOM when they make purchase decisions. On the other hand, as Xun and Reynolds (2010) argue, vendors often learn from customer reviews to adjust the marketing strategy and product quality. In this sense, forums offer sellers a great insight into the virtual space in relation to customers' needs.

Furthermore, despite the Agora forum being hosted on the darknet, it may still share some social functions with an ordinary online discussion forum. According to Walther and Boyd (2002),

the most important attribution of an online disunion forum is for participants to seek social support. Social support is widely defined as the exchange of verbal and nonverbal message, conveying emotion, information, or referral, to help reduce someone's uncertainty or stress, and whether directly or indirectly, communicate to an individual that she or he is valued and cared for by others (Barnes & Duck, 1994). Walther and Boyd (2002) further classify four types of social support, namely informational support, emotional support, esteem support and social network support: informational support is expressed in the form of intelligence sharing and suggestions or advice to help other members make decisions. The messages cover a wide range of domains, such as legal and medical advice; emotional support through the expression of caring, including statements of emotional understanding and affection; esteem support is given through admiration and complimentary statements about other members' abilities; and social network support refers to directing a person to another member or group who share similar experiences. This type of support helps an individual to find the local group, satisfy their social need and enhance their self-recognition. Correspondingly, it also enables the local group to absorb new members and increase their impact on the community. Moreover, gaining social support is found to be one of the main purposes of joining discussion forums for many social minority groups, as they are unable to receive enough understanding from society (Cutrona & Suhr, 1992; Burri et al., 2006; Deryakulu & Olkun, 2007). For example, Burri et al.'s 2006 study on a discussion forum for recent ex-smokers shows the forum is used mainly by people who want to quit smoking to obtain informational and emotional support. Within the forum, people provide encouragements, share their experiences and provide practical advice to each other. A majority of forum members find the forum helpful to relieve their pain and stress. Similarly, Derykulu and Olkun's 2004 investigation on a Turkish computer teacher's discussion forum suggests that 87.9% of the messages posted on the forum are identified as seeking understanding from other members about their occupational problems.

In addition to having an impact on market operations, the existence of drug-related discussion forums of this kind can also encourage drug trafficking. Various research has found that crime

motivation is often connected to the environment that the criminals inhabit (Cohen & Felson, 1979; Rosenstock et al., 1988; Wortley, 2008). In the case of the Agora forum, there may be environmental factors that drive drug users to actively engage in drug distribution. Stemming from rational choice theory, Wortley (2008) proposes a two-stage criminal decision-making model: the first stage involves a motivation process which psychologically prepares an individual for crimes; the second stage involves a rational assessment of presented opportunity – if the benefits are determined to outweigh the cost, the motivated individual will commit a crime. Environmental forces come into play in the first stage of the decision-making process and often induce individuals to commit crimes they might not otherwise have committed.

Four types of precipitators that can influence individuals in the criminal decision-making process are summarised by Wortley (2008): these are prompts, pressures, permissions and provocations. Prompts are factors that encourage individuals to perform criminal behaviours. Two kinds of environmental prompts should be noticed here: the first kind of prompt is models, which are behaviours of peers and other observable people in the same community. Research has found that people have a tendency to imitate other people's behaviours through observation: for example, students are more likely to commit computer crime if they have observed their teacher doing so (Skinner & Fream, 1997). Similarly, people are more likely to use drugs if their peer associates have been involved (Johnson et al., 1987). These models will have an effect even if they are merely represented symbolically in the media (Wortley, 2008). The second kind of prompts are expectancies, which are preconceived ideas about an environment. For example, people visiting certain nightclubs have an anticipation of being involved in fights, as the particular environment has presented a state of lawlessness which invites criminal behaviours (Wilson & Kelling, 1982, Wortley, 2008). Pressures are social forces that may compel individuals to perpetrate crimes. Pressures can come in various forms. As social animals, individuals often act in accordance with group norms and standards of behaviour even if these contradict their personal values. Individuals in a group also tend to follow commands from people who are perceived to be a legitimate

authority, even if these commands are unreasonable (Milgram, 1978). Moreover, legitimate requests expressed in a tough way can impose pressures to individuals and lead to defiance. The effects of pressure can be amplified in an anonymous environment, in which people tend to have less regard for personal opinions but follow the others (Colman, 1991). As for permissions, in the light of social cognitive theory, Wortley (2008) explains that environmental factors can allow individuals to make excuses, allowing them to redefine their behaviours and justify their actions. For example, an environment and culture of corruption conveys a message to individuals that 'everyone does it' and individuals who immerse themselves within this environment may come to accept bribery as normal (Greenberg, 1997). Moreover, environment can make individuals minimise the consequences of their behaviours and deny causing harm. For example, Greenberg (1997) finds that many offenders who steal property from large companies take the view that the property is redundant to the company and that the stealing behaviour does not cause significant loss. Lastly, provocations are elements that arouse criminal responses. They often happen when individuals are in crowded spaces, or places where they have a sense of territoriality or feel frustrated. Individuals will also react to environmental factors that threaten their well-being, such as temperature (Harries & Stadler, 1988).

The encouragement effect in the motivation stage varies between individuals: the stronger the individual's anti-social commitment, the more likely it is he will react to the environment. When an individual with high criminality enters a highly criminogenic environment it may create a 'perfect storm', which indicates a strong probability of crime (Wortley, 2012). Moreover, in a capsule environment where individuals come together for a specific purpose, the nature of the environment can create a pressure-cooker condition where the influence of precipitators will be maximised (Wortley, 2008). A typical example of this effect is in prisons, where numerous individuals with strong anti-social commitments are brought together into a capsule environment and the effect of environmental contributors is strongly amplified, which leads to a high rate of crime. The Agora discussion forum can be perceived as a similar capsule environment where participants are drug

users with relatively high antisocial commitments. Therefore, it is more likely that they will actively react to environmental contributions and conduct further criminal activities (e.g. drug selling) when opportunities are presented.

3. Methodology

Data collection

The Agora forum data used in this research was taken from an open-source dataset created by Branwen (2013), which contained data of 89 DNMs operating between 2013 to 2015. This data was scrapped by Branwen on an approximate weekly basis. The forum data of the Agora market covered a one and a half year period from the date the market started operating (2014-01-02) to the date the market was closed by the operator (2015-07-06) due to security concerns. The data included forum user profiles and threads, which began when a forum user created a post that was followed by numerous responding posts. Each time the crawler ran, it mirrored existing threads and user profiles on the forum and stored it in a folder named with the date of the operation. For example, 'folder 2014-01-02' contained all threads and user profiles mirrored on that day.

For the purpose of this research, only the data representing the threads of the Agora forum were used. The forum threads extracted along with the first 50 responding posts were stored in html files, with each thread being given a unique ID number (e.g. topic 1). If a thread had more than 50 responding posts, after the 50th post, each following 50 posts would be stored in separate html files, using the same ID number, with a suffix. For example, topic 348.50 refers to the 50th-100th responding posts of the thread 348.

It has been found that in the past, some threads appearing in earlier dates were not included in the later folder. For example, topic 563.0 was found in the folder '2014-02-19' but did not exist in the folder '2014-02-25'. This was possibly due to the deletion of certain threads by the forum administrator or the original poster. Therefore, in order to maximise the complexity of the dataset, the html files stored in the folder with the name of the earliest date (2014-01-02) were manually copied and pasted to the next folder (2014-01-09). Files with the same name were skipped. This process was repeated until all html files were copied and pasted to the last folder (2015-07-06) to

make sure all deleted threads remained intact while all threads were kept in their newest versions. Consequently, the final folder contained 136,487 html files.

Next, for the convenience of further analysis, scripts based on python 2.7 and 3.6 were developed and used to further clean up the dataset (see appendix). Firstly, since one thread might be stored in multiple html files with suffixes depending on the number of responding posts of each thread, html files with the same ID number were merged to ensure each html file represented only one thread. Secondly, by using the Beautiful Soup Library for python 2.7, the content from each thread was extracted and written into a txt file, so that it was easier to read manually, as well as by computer programmes. At the end, 47,745 txt files remained in the dataset, representing all threads that had been left during the market operation period.

TF-IDF and LDA topic modelling

Since the dataset contained a large quantity of data, within it there was also a significant proportion of spam and meaningless posts (Haslebacher et al., 2014), making it difficult to manually extract useful information. Therefore, the TF-IDF algorithm and LDA model were applied to assist in filtering spam and meaningless information (Biro et al., 2009).

TF-IDF: TF-IDF is the abbreviated term for 'term frequency – inverse document frequency'; it is an effective numerical statistic which is often used for text mining (Rajaraman, 2011). It is also widely applied today in a text-based recommender system (Beel et al., 2015). The algorithm generates a TF-IDF score for each word in a collection of documents, reflecting the importance of the word to the document it is embedded within. The TF-IDF score is calculated by term frequency multiplied by inverse document frequency. The former represents the frequency of a word embedded within the documents, based on the idea that 'the weight of a term that occurs in a document is simply proportional to the term frequency' (Luhn, 1957). The latter can be obtained by the logarithm of the frequency of documents in the corpus containing the word, based on the probable assumption that
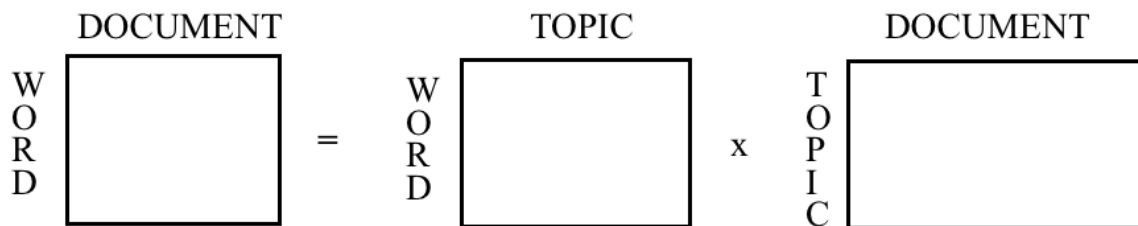
'the specificity of a term can be quantified as an inverse function of the number of documents in which it occurs' (Jones, 1972; Robertson, 2004). The higher the TF-IDF score is, the more important a word is to the document in a corpus. To put simply, if the letter 'w' appears a lot of times in only one document, but 'd' rarely presents in other documents in the corpus, the TF-IDF algorithm will regard the letter 'w' as important to the document 'd' in the corpus.

LDA: is the abbreviated term for Latent Dirichlet Allocation, which is a probabilistic model based on Dirichlet distribution (Blei et al., 2003). The main objective of the model is to learn the distribution of potential topics in a given collection of documents from the text data. The model assumes that a document is a mixture of numerous topics and each word in the document is taken from a particular topic. In other words, it presumes that a document is generated by repeatedly selecting a topic and a word under the topic with a specific probability, as shown below:

$$p \text{ (word | document)} = \Sigma \, p \text{ (word | topic)} \times p \text{ (topic | document)}$$

This probabilistic equation can also be presented through the matrix below:

Figure 1: The LDA probability matrix

The 'document-word' matrix represents the frequency of each word occurring in each document, whilst the 'topic-word' matrix represents the probability of each word appearing in each topic. The 'document-topic' matrix represents the probability that each topic occurs in each document. By giving a collection of documents and counting the frequency of each word in each document, the first matrix can be easily established. After that, by applying the LDA model, the

other two matrixes can be inferred (Blei et al., 2003). The ultimate purpose of applying LDA in this research is to generate numerous topics with potential key words representing them, so that meaningful threads can be readily identified and extracted in order to conduct further analysis (Biro et al., 2009).

Application

Firstly, through manual inspection among the threads with extremely large amounts of responding posts, it was found that their content were all seeking referral links for registration on the Agora marketplace. Since the filtering of spam is the ultimate goal of this process, they were manually removed. Hence, 147 threads embedding 3257 posts were removed.

For the rest of the threads, the NLTK library base on python 2.7 was imported to conduct tokening, stemming and to stop words from removing each txt file. Next, the Gensim library was imported and the TF-IDF algorithm was applied to identify important words in each document. Words were then assigned TF-IDF scores and organised in descending order. After that, the top 1/3 of words for each document were regarded as meaningful words for programming the LDA model. As a result, 30 topics were generated through the training, with each topic represented by the 10 key words with the highest probability (see appendix).

The trained model was then applied to test each thread in the dataset to discover underlying topics. At this stage, the probability of 0.2 was set as a threshold: topics with over 0.2 probability with respect to a thread were regarded as potential topics of such threads. However, if the probability of all topics with respect to a thread were below 0.2, the topic with the highest probability was regarded as the underlying topic of the thread. Finally, an Excel sheet was created, recording 30 topics and the threads embedded within them.

Content analysis

Since the purpose of the research was to investigate, characterise and interpret the DNM discussion forum, it subjected to an in-depth study of the dynamic of a minority group rather than making a numerical description or prediction about any particular value. As such, a qualitative criminological examination was appropriate for such research (Bryman, 2012, Berg, 2007).

In Chu et al.'s (2010) study on 10 malware discussion forums, the idea of grounded theory was adopted to conduct qualitative research for the purpose of investigating the subcultural values and norms of the malware forum users. The coding process consists of three stages, as suggested by Corbin & Strauss (1990): open coding, axial coding and selective coding. Through the three-stage coding, emerging categories are repeatedly examined in line with the context of the data, and then linked to each other. Consequently, a series of categories and subcategories were established under a 'core category' of the phenomenon being studied. Similar coding strategy was followed in this research.

With respect to the 30 topics generated from the LDA topic modelling, topics represented by foreign languages and 'mean' words were treated as spam and therefore removed, such as topic 13 and 27, detailed below:

Table 1.   Filtered topics with keywords

Topic 13	Topic 27
ich	onion
die	http
nicht	topic
ist	php
der	index
ein	lacbzxobepressrfx
auch	pgp
es	sec
und	htmlbecomehtmln
da	ewb

Consequently, 10 topics were identified as meaningful. To reduce selective bias and maximise the external validity, 50 threads were randomly selected from each meaningful topic. The selected 500 discussion threads, containing 2578 posts, were analysed individually by manually reading all posts within the threads. After carefully examining all posts, the posts were then coded in a word document.

4. Findings

Through the three-stage coding process, the discussions in the Agora forum were grouped into 4 themes: (1) *Invitation to treat*, (2) *risk management and social control*, (3) *drug-related knowledge exchange* and (4) *community support*. The emerged themes are displayed below in detail, with representative quotations from the thread.

Invitation to treat

This theme consisted of posts relating to forum users' business activities—1629 posts were found to belong to this theme. It supported the Agora market by playing the role of a traditional underground forum, serving as a social platform that enabled users to exchange their goods and promote their business (Motoyama et al., 2011). Similar to traditional underground forums, many vendors placed advertisements of their products with descriptions and prizes and attached links of their store in the Agora market to attract customers. In particular, many new vendors sought to build up their own brand identities by providing free samples in order to start positive review feeds (Afilipoaie & Shorties, 2015). For example, one vendor posted: '*We are a new Australian domestic only vendor on the market and wish to hand out some 100mg+ MDMA caps as samples to each Australian forum member*.' This thread attracted many positive reviews by forum users, with some of them writing in persuasive language, showing that the strategy was effective: '*I received a sample of PeachFuzz strain Cannabis (WEED - Peach Fuzz) Described as a mid range Indica Strain … (detailed product review). So really go buy any of his strains you have my word you won't be disappointed.*'

Advertisements to buy were also found in the Agora forum, with many users placing advertisements to look for uncommon products, such as: '*I just need one bottle of*

Tussionex hydrocodone, would like to pay $100 for 4oz bottle.' Moreover, it appeared that some vendors also attempted to use the forum to replenish the stock of merchandise, including vendors from other marketplaces: '*I am a vendor on Evo with a new rep. I am looking for some NICE unbroken not all dried out MJ LEAVES. Hoping some grower or something would be willing to help me out.*' The appearance of 'foreign vendors' seemed to suggest the existence of cross-market operations (Haslebacher et al., 2016).

In addition, it was observed that forum users expressed a common interest in engaging with the drug business. Model effect as a situational prompt was widely observed in the Agora market (Wortley, 2008). Some buyers indicated that they wanted to sell drugs 'like others': '*I was looking into it for personal consumption first, but if I could get multiple bottles at a decent price, I would be able to sell it like others*.' There was also evidence suggesting that some users actively learned from vendors and tried to imitate the process: '*I have tried to get as much information as possible by reading the existing threads, shipping product, stealth etc. But, I'm looking for some specific information on dealing with the shipping. I know about the packaging, vacuum sealing, printed addresses, and making the envelope look 'standard', but how do I deal with the post office? How do I get stamps and mail the letter anonymously?'*. Moreover, social pressure in the form of persuasive speech was also found to have 'pushed' users to engage in drug selling (Wortley, 2008; Colman, 1991). For instance, in a discussion about how to obtain Promethazine, a forum user replied: '*I don't know about the Country/State you reside in, but here in my State in the US you can get it over the counter without a script. You have to show an ID, but there isn't an inter-pharmacy tracking system so you could hit every pharmacy once a week here and get 10 + bottles a week without an issue.*' This post promptly attracted a lot of replies, expressing their urgent demand and asking him to open up a store, such as: '*You should fucking buy some bulk, and open up a vendor account. Whatever you decide to charge in order to profit, I think you'd still get buyers, no matter the price.*' And consequently, the user posted: '*Okay, I will try to open a vendor account and start selling lol. I will have to look into what it takes to be a vendor*.'

Risk management and social control

Along with business activities, the Agora forum was also used by users to manage risk in transactions and exercise social control (Wall & William, 2007). 2452 posts fell under this theme. Overall, transactions in the Agora market presented a high risk, as one user expressed: '*Anything and everything can happen here. 90% scammers, 10% ok, 0% total trust*.' In contrast to Wehinger's (2011) finding, the risk-control effect of the escrow system was minimal in the Agora market. In most policies provided by vendors, finalised early (FE) – which means that the buyer has to release the fund kept in the marketplace's wallet to the vendor before the goods were actually shipped – was required. As one vendor said: '*Sorry but you must "FE" before your order will ship. My reasons for this is Agora goes down or is taken down or anything happens to the site your order will still ship because you released you funds*.' Using the escrow service without asking for 'FE' seemed to be rare, as one vendor advertised: '*We have 90% pure, reagent-tested MDMA for less than $40/gram, with NO FE required. OMG - NO FE REQUIRED!*'. If funds held on the marketplace's wallet were released to the vendor before the goods had arrived, the intervention of the market administrator in the case of the scam was minimal. Therefore, the responsibility to control the risk of scam fell on users themselves.

Highly detailed product reviews were found in the Agora forum, which consisted of buyer's experiences from various angles, including communication, product quality, speed and covertness. Ratings were assigned to each factor and reasons were given to explain the rating. This covered the shortage of the feedback system in the Agora market site (Hardy & Norgaard, 2015). As one user complained: '*The feedback character limit in the Agora market is too short. A fix to this problem would help with more accurate feedbacks.*' The reviews in the Agora forum did not only serve as eWOM, which influence the purchase decision making process of the buyers (Henning-Thurau et al., 2004), but the accumulative reviews also formed an indicator of vendors' reliability, which was largely relied on by users to control risk; as one user said: '*I just always do my research in the forum before buying from any vendor that is 'new to me' it was just a precaution.*' Moreover, negative

reviews which involve dishonest buyers alert other users and can cause public shaming as a social control method of the Agora market (Wall & William, 2007); as one buyer posted, '*Do Not Order From This Guy, he has been jacking me around for a week shy of a month, same thing over and over again. Says he is going to do something and does not do it, then repeats the process. Full of excuses. SCAMMER! BEWARE*!'

Nevertheless, risk still exists while purchasing from reputable vendors; as one user claimed, '*I've been scammed out of many thousands from 'legit looking profiles really on new FE buys it's like a 50/50 crapshoot on here.*' Another buyer also held: '*Don't underestimate the apathy of "legit" vendors on here. I hope it's not the case with you, but myself and 4 (and counting) other buyers on here got shafted by a legit vendor*.' Moreover, the bargaining power between buyers and vendors has been found to be imbalanced. While being scammed by a 'reputable' vendor, some buyers were afraid of complaining. For instance, in a discussion about a dishonest vendor, a buyer who did not receive the product said: '*But vendor seems legit and I think he will want to resolve the situation rather than have me complaining all over forums.*' In some extreme cases, buyers were even threatened by the vendor: '*Seller marks as sent but did not send my order for four days - bought on a Wednesday and did not arrive till Tues but marked as posted Wed night, refuses to provide tracking as promised, gets abusive and threatens me with my address when I query.*' As a result, in the case of not receiving products, most buyers are able to cope with it and hope for the best; as one buyer said: '*I shall cross my fingers, while wishing I had a bitcoin to my name not tied up in waiting games'.*

Drug-related knowledge exchange

As a discussion forum on the illegal drug marketplace, drugs per se were widely discussed by the users. 848 posts were found to include discussions regarding drug-related knowledge. Such knowledge being shared in the discussion forum covered a wide range. Some users posted step-by-step guidance on how to produce particular types of drugs: '*Cocaine is cut with levamisole at the*

source and it has been difficult, if not impossible, to separate until recently. The process goes like this: Cocaine HCl --> freebase with ammonia --> dissolve in hexane --> wash with water 5 times --> convert back to cocaine HCl (detail guidance)…'. These guidelines were followed by many users, and specific technical questions were discussed: *'I used 4ml of 96% ethanol and mixed it with 1g… now have a sticky lump which just doesn't seem to be drying at all. When I tasted the tiniest little bit on my tongue it tasted very strong of coke so I know the coke is in this sticky lump I now have.... What went wrong?'* Also, users were sharing methods to store different drugs. For instance, one user said: '*MDMA is a remarkably stable chemical. If you store it in a sealed container in a dark area at room temperature you should be fine for years.*' Moreover, how to consume particular types of drugs was discussed. Users shared creative ways of mixing different drugs to obtain the best effect. For example, one user posted: '*what you could do is orally potentiate with curcumin. Get the jarrow brand 95% curcumin extract. Saturate 1.5x the amount of fish oil or omega oil with, say, 7-10 grams of curcumin, or around a third or a quarter of the bottle. You can add some piperine if you have it, or cut up some hot peppers, grind up black pepper in it or whatever. Drink it and about an hour later smoke the DMT.*' Some users also shared environmental settings while they took the drug: '*I'd also have some weed on hand if you know it calms you down, ass xaxan can take a lil to kick in. Also have an uplifting happy Playlist of your favorite music on stand by. My Safety Playlist always helps bring me back, I just laydown out side and listen.*' In addition, dosage was found to be a recurring topic in discussions. Suggestions and instructions about the safety amount of intake each time for different drugs were stated, for instance: '*Most benzo users don't have 0.01g scales to accurately dose. Most benzo users like the familiar pharmaceutical pills. It's marketing imagine trying to sell aspirin as a powder, all you need to do is use the little spoon included, make sure you fill EXACTLY on the line or you will OD.'*

The effects of different drugs were also commonly discussed. Most of the discussions consisted of users' positive experience of drugs. These experiences were described from both the psychobiological and psychological aspects. For example, one user said: '*It was a very relaxing*

strain that gave me a really good buzz I smoked a bowl full on the comedown of an MDMA roll and it helped me relax as well as see some nice geometry and visuals and eventually get some well needed rest.' At the same time, the potentially long-term negative effects were also shared to alarm users: '*The danger here is that one begins to think the LSD effects are apart of everyday life. One would start to slip in to psychosis. The best example I have is a friend did this for a month. At the end of the month, he would rant about seeing individuals' energy, and being able to determine their attitude/perspective on life. All sorts of LSD talk, but once you start believing that you're in trouble*.'

Community Support

Similar to ordinary online discussion forums, social support was found to be an important attribution of the Agora forum (Walther & Boyd, 2002). This theme consisted of 891 posts, where various types of support were identified. First of all, new forum users were always warmly welcomed by existing users. For example, in a vendor review thread posted by a new user, they said: '*Hi, new here and just completed my first purchases*.' His posts were replied to by many users, sending welcome messages, such as: '*welcome to the dark side young padawan*.' and '*thanks for your review sir — and welcome*!'. Technical questions with regard to forum functions posted by new users were also kindly answered in detail, which reflected some degree of social network support in helping users to integrate into the community and enhance their self-recognition (Walther & Boyd, 2002; Curtona & Suhr, 1992).

Users also organised online social events in the Agora forum to satisfy their social need (Walther & Boyd, 2002). For example, a music game was found that attracted a lot of response: '*I would like to start a game, I saw this on another forum so I will not take credit: Rules: 1. On your post name a song title and artist 2. The next poster takes any word in song title artist and uses that for his/her song title/artist on their post 3. NO WINNERS, Just a fun way to pass the time in the forums. HAVE FUN EVERYONE!'*.

Moreover, information and emotional support were also found in the Agora forum. Users often asked for help in relation to psychological problems after taking certain drugs, such as: *'A friend of mine is dealing with some pretty bad chronic pain. Does anybody here have any suggestions to help her out?'.* Medical suggestions were given by experienced users: *'You should try CBD pills or CBD edibles, it's a cannabanoid, a marijuana that is strictly for pain, no High at all if in fact that is a concern.*' They also expressed their need for support with respect to problems in life in general: *'I have been battling a lot with loneliness lately as I embark on a different journey than others around me. It's for the better, though. A lot has been brought to the forefront of my mind and has really woken me up.'* Emotional support and encouragement was then provided by fellow users, showing their understanding and affections (Barnes & Duck, 1994): *'Always keep in mind that EVERYTHING in life is always only a question of time ;-) These words helped me often when waiting for something or someone... guess why? As the coming itself is sure anyways, and it´s only about the time-factor, which is not worth if it´s a little bit earlier or later at the end…'.* Interestingly, apart from seeking medical suggestions and assurance, the negative effects of drugs were ignored by users. They commonly denied the harm and advocated the legitimacy of drugs: *' it's just a matter of how you prefer to spend you time - the brain is awash with chemicals anyway, and people have different metabolisms - what's wrong with some added chemical ingredients to provide some stimulus to life?'.* Moreover, while users complained about their problems in life, no one had mentioned any negative impact of drugs on their life. Rather, some users claimed their life had been ruined because they could not get enough drugs: *'All of the xanax sellers are gone, my life is ruined!'.* This created a community value that 'permitted' drug using and selling by minimising the consequences and normalising the behaviours (Wortley 2001; Wortley 2008; Greenberg, 1997).

5. Discussion

Business facilitation, order maintenance and social support

Stemming from the findings, three main functions of the Agora forum were identified; namely, business facilitation, order maintenance and social support. As for the business facilitation function, the discussion forum assisted the transactions in three ways. First of all, the Agora forum played a supplemental role to the Agora market site in allowing users to place advertisements to attract customers or look for particular products. Specifically, advertising free samples was an essential step of the brand building process for new vendors (Afilipoaie & Shortis, 2015). Enabling advertisements also made the Agora forum a good exchange platform which allowed users to look for particular products in demand. To some extent, this broadened vendors' supply channels and facilitated cross-market operations, since advertisements to buy materials were placed by vendors from various marketplaces (Haslebacher et al., 2016). Secondly, the 'buy and sell' discussions in the forum revealed the market demand, which provided business opportunities to users. The findings suggested that users had taken advantage of their local policy to catch the opportunities and started operating businesses. Lastly, akin to other discussion forums of commercial websites, in making up the deficiency of the feedback system of the market site, the Agora discussion forum contained more accurate and detailed product reviews, serving as eWOM, guiding users towards making purchase decisions (Hardy & Norgaard, 2015; Henning-Thurau et al., 2004). Interestingly, in contrast to Xun and Reynolds' (2010) study, finding that sellers often learned from customer reviews to improve their marketing strategy and product quality, vendors in the Agora market tended to react negatively towards the feedbacks; most of them kept silent under the review threads and some even threatened the buyers.

Moreover, the Agora forum had a fundamental role to play in market orders maintenance,

which was essential to the market operation. Since there was a lack of official control in the Agora market due to the futility of the escrow system, the importance of reputation in online transactions was amplified to a great extent (Houser & Wooders, 2006; Wehinger, 2011). The reputation indicated the quality of products and the honesty of the vendor. In line with Hardy and Norgaard (2015), the findings suggested that the reliability of feedback in the market site was prejudiced due to the character limit, which reduced the accuracy, therefore the users' product reviews in the Agora formed the core of the marketplace's reputation system. Accumulative good reviews built up the reputation of the vendors, while negative reviews caused public shaming which impaired the vendors' reputation (Wall & William, 2007). Since buyers in the Agora market always conducted research in the forum before making purchases, the discouragement effect of negative reviews in the forum could be significant. Because of this, the reputation system based on user reviews formed an invisible mechanism that weeded out dishonest vendors. Nevertheless, disagreements often happened despite a vendor being reported as a scammer, especially when a reputable vendor was involved. Couple this with the fact that various buyers had claimed that they were scammed by reputable vendors, the reliability of the reviews remains in doubt. The imbalanced bargaining power between vendors and buyers further undermined the control effect. Consequently, the actual effect of the self-regulation mechanism in the Agora marketplace appeared to be weak and the market order still presented a chaotic state.

Furthermore, similar to ordinary discussion forums, the Agora discussion served as an online habitat and a social platform for a social minority group – namely, drug users, of whom various forms of social supports were identified (Walther & Boyd, 2002; Barnes & Duck, 1994). Users treated the forum as an intelligence exchange platform, where a huge amount of drug-related information, including drug production, storage and dosage, was shared in the forum. Vendors' reputations and product qualities were also shared between users, together with medical suggestions with respect to physical and psychological consequences, reflecting the information support function of the discussion forum (Walther & Boyd, 2002). In particular, the drug-related

information being shared in the Agora forum largely corresponded to topics occurring in drug discussion forums on the surface web, which indicated that the findings applied to online drug discussions in general, too (Soussan & Kjellgren, 2014). Moreover, through sharing drug-related knowledge with others, users often received commendations and appreciation, which they might otherwise not have acquired in the real world, thus giving them a certain degree of esteem support (Walther & Boyd, 2002). Emotional support was also found as users often received understanding and encouragement from others whilst expressing difficulties in life, which helped them to relieve stress (Barnes & Duck, 1994; Derykulu & Olkun, 2004). Lastly, the friendly atmosphere and various online social activities satisfied forum users' social needs and enhanced their self-recognition as an accepted member of the community, representing the social network support of the Agora forum (Walther & Boyd, 2002).

Through these functions, the Agora forum supported the marketplace operation to a large extent. The business facilitation function increased the market scale by providing business opportunities and increased chance of survival to new vendors; the order maintenance function acted as core to the market order, although the actual effect seemed to be weak; and various social supports existed in the Agora forum that not only attracted new users but also enhanced user loyalty. This might provide an explanation of why the Agora market was more successful than other marketplaces. What is more, it may also indicate that taking down or disrupting the forum could have had a significant impact on the marketplace, although the actual effect has not being examined.

Motivation and opportunities

The findings of the present study also provide an explanation of how the online drug discussion forum facilitates drug trafficking from the environmental criminological aspect. As Wortley (2008) suggested, certain environmental settings could impose an influence on people's consciousness that motivates criminal behaviours, encouraging people to commit crimes that they

would not have committed otherwise. Various situational precipitators were found which collectively influenced forum users, inducing them to participate in selling drugs. In this section, the term 'criminals' has been defined narrowly, referring to drug vendors, whilst 'users' refers to ordinary members of the Agora forum who are not vendors.

First of all, the very existence of a drug marketplace reflects a state of lawfulness and the existence of crime (Wilson & Kelling, 1982). Therefore, just like entering a nightclub, while visiting the marketplace, users have already acquired a certain degree of expectancy of the criminal event (Wortley, 2008). Next, as numerous research suggests, merely watching other people committing crimes could increase the possibility of the observer committing the same types of crime, as there is a modelling effect that makes people more likely to imitate behaviours that they have frequently observed (Skinner & Fream, 1997; Johnson et al., 1987; Wortley, 2008). Vendors' activities of selling in the Agora forum could produce similar effects. By interacting with vendors in the Agora forum, users frequently observed vendors selling drugs and also how they did so through various advertisements and discussions. These made forum users more likely to imitate their behaviours. Moreover, discussions in the Agora forum also convey a signal of 'permission' to sell drugs (Wortley 2001; Wortley 2008). On one hand, the large number of 'buy and sell' discussions reflected a 'culture of crime' and transmitted a message that 'everyone does it'. This message lowered the moral standards of participants and normalised the criminal behaviours (Greenberg, 1997). On the other hand, discussions in the Agora forum often minimised the consequences of drugs and advocated the legitimacy of drugs. Many users also complained how difficult their life was without drugs. These discussions formed a community value, integrating into the community could make users redefine their behaviours and justify drug-selling (Wortley, 2008). Furthermore, it was observed that when users expressed that they were able to acquire scarce drugs or components of drugs in the forum, they were often asked by other members if they could sell them. Requests from peers formed social pressure which had a strong persuasive effect, as being in a community, people tended to concern themselves less with personal opinions, but follow others (Colman, 1991).

In addition, as Wortley (2012) claimed, the reaction to the environment had a positive correlation with the degree of anti-social commitment. Since most users in the Agora forum have lower moral standards and a higher degree of criminality, the influence of environmental factors could be amplified. In order words, in the Agora forum there was a 'perfect storm' situation where the crime inducement affect was significant.

Not only did the Agora forum motivate users to sell drugs—the functions of the forum also created criminal opportunities. First of all, during the drug-related discussions, every user contributed a piece of knowledge which was subsequently accumulated to form part of a comprehensive community knowledge base of drugs. These resources were accessible to every user, which could allow a motivated user to acquire almost all information and knowledge needed to become a vendor. Secondly, the Agora forum was a virtual space where the routine activities of 'offenders' and 'victims' highly overlapped (Cohen & Felson, 1979). Almost every user in the Agora forum that was a drug user indicated that there were a lot of potential customers. The social networking function of the Agora forum enabled users to meet potential buyers, through the sell and buy discussions in the Agora forum, meaning that market demand could be identified. To a large extent, these helped a motivated seller to set up a business. Lastly, as already discussed, the Agora forum provided opportunities for new vendors to build their brand identities and create a relatively certain market order, significantly helping them to run drug businesses in the Agora marketplace. Accordingly, the Agora forum imposed an impact on both stages of the two-stage criminal decision-making model, which played a facilitation role in transitioning ordinary drug users into drug dealers (Wortley, 2012).

Limitations

It should be noted that the present study is subject to limitations. Overall, as qualitative research, the results were inevitably influenced by the researcher's subjectivity, including the background knowledge and previous understanding of the research topic of the researcher. In

particular, although a random sampling strategy was taken, this study adopted manual data selection in several stages: both the determination of the meaningful topics and the coding process involved manual operation. This could lead to the possibility of ignorance around valuable data and cause selection bias, undermining internal validity. Moreover, despite efforts being made to maximise the completeness of the data (as stated in the Methodology section), the original dataset contained significant amounts of missing data (Branwen et al., 2015). The operation crawler was influenced by the internet connection and the status of the Agora forum, as it went down often. During each crawling time numerous threads and posts could also be removed, which further weakened the internal validity.

Furthermore, this study was based on a case study on a forum which operated between 2013-2015 and the Agora forum was selected purposefully. In light of the fact that the darknet was a rapidly developed area and different marketplace had different structures, the external validity of the study was also impaired. Notwithstanding the fact that, instead of making generalised predictions or conclusions, the purpose of the study was to shed a light on the dynamics and content of the internal discussion forum of the darknet marketplace, which had never been empirically investigated by a researcher before. The result served as an inspiration for further research in this area. Thus, the existing threat to external validity should be less concerning.

6. Conclusion

The present study has investigated the role that the Agora forum played in market transactions and the phenomenon of drug trafficking, from the environmental criminology perspective. Based on the interlinked themes identified through the content analysis, three important roles were found, which were business facilitation, order maintenance and social support. Specifically, the business facilitation function increased the market scale by providing business opportunities and increased chance of survive to new vendors; the order maintenance function acted as core to the market order, although the actual effect seemed to be weak, and various social supports existed in the Agora forum that attracted new users and also enhanced user loyalty. It was believed that these functions supported the Agora marketplace to a large extent and helped it become the most successful marketplace at the time.

Moreover, various situational factors were found in the Agora forum: the existence of drug dealing in the forum provided users with expectancy which psychologically readied them to get involved; the selling process of the vendor produced a modelling effect, forming 'prompts' that encourage individuals to perform criminal behaviours; the discussions about drugs formed a community value which minimised the consequences of drug dealing, redefining and 'permitting' the behaviours; and requests from peers caused social 'pressure' that pushed the users to sell drugs. These effects of situational factors were amplified due to the high anti-social commitment of the forum users, who actively responded to them and were consequently motivated to become drug dealers. Furthermore, the Agora forum created various opportunities for drug selling, including knowledge acquirement and customer attraction and brand building, which made the drug selling convenient. As a result, it was believed that the Agora forum played a significant role in encouraging ordinary drug users to sell drugs.

The present study is an exploratory research project on a darknet internal discussion forum,

which has been long ignored by existing empirical research. Therefore, future studies are encouraged to conduct further research in greater detail in this area. In particular, as this research indicated that the market order maintenance function was largely attached to users' reviews in the forum, the effect of the reviews had not yet been assessed. For example, to what extent does a bad review or report of scam influence the seller's reputation? Does the effect associate with the buyers' reputation? Also, in the circumstance where some people claim a vendor is a scammer and some users take different views, how do the users react and how do they decide who to trust? An investigation into these issues helps to further understand the regulation mechanism of darknet marketplaces and can contribute to the potential disruption of the markets by law enforcement.

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Appendix: Relevant codes and LDA results

Thread mergence

```python
import os

os.chdir('D:/index.php')    #dir

in_filenames = os.listdir()

def join(out_filename):

    outName = 'D:/post/' + out_filename

    out_file = open(outName, 'w+', encoding = 'utf-8')

    for file in in_filenames:
        i = file.strip('topic,.html')
        j = i.split('.')

        if int(j[0]) == n:
            try:
                in_file = open(file,'r', encoding = 'utf-8')
                out_file.write(in_file.read())
                out_file.write('\n\n')
                in_file.close()

            except IOError:
                print ("error")
    out_file.close()

    print ("Post ",n," merged")


n = 47542
while n < 136500:    #n
    name = "post,"+str(n)+ ".html"       #topic

    print (name)
    join(name)
    n=n+1
```

Html to txt conversion

```python
import os
from bs4 import BeautifulSoup
import nltk
import re,os

os.chdir('D:/1')

filenames = os.listdir()

for file in filenames:

    html = open (file,'r', encoding='utf-8')

    soup = BeautifulSoup(html,"html5lib")

    # Remove html format
    [script.extract() for script in soup.findAll('script')]

    [style.extract()for style in soup.findAll('style')]

    # Extract post
    posttxt = soup.find_all('div', class_="inner")
    text = str(posttxt)

    # Remove html format
    reg1=re.compile("<[^>]*>")
    content = reg1.sub('',text)

    #Name
    f = os.path.basename(file)
    ff = f.strip('html')
    fff = ff+'txt'

    # write content into a txt file
    f = open(fff,'w+', encoding='utf-8')
    f.write(content)
    f.close()

    print (fff,"done")
```

Stop words filtering

```python
# coding=utf-8
from __future__ import print_function
import os
import re
from collections import defaultdict

from gensim import corpora
from nltk.corpus import stopwords
from nltk.stem.porter import PorterStemmer
from nltk.tokenize import RegexpTokenizer

my_stopwords = ['get', 'got', 'shit', 'see', '\u0e2a', 'would', 'use', 'think', 'like']


def safe_mkdirs(path):
    try:
        os.makedirs(path)
    except OSError:
        pass


def list_files(dir_path):
    """
    List absolute paths of files under a directory path.
    :param dir_path: path of the directory.
    :return: a list of absolute paths.
    """
    res = []
    list_dirs = os.walk(dir_path)
    for root, dirs, files in list_dirs:
        for f in files:
            res.append(os.path.join(root, f))
    return res


def token2corpus(tokens):
    # transfer into bag of words.
    """
    Transform lists of tokens into corpus.
    :param tokens: a list of token lists, each list representing a document.
    :return: a list of Bag of Words, and a dictionary from id to word.
    """
    dictionary = corpora.Dictionary(tokens)
    print("Converting documents to bag of words...")
    corpus = [dictionary.doc2bow(doc) for doc in tokens]
    print("BOW prepared!")
    return corpus, dictionary


def doc2corpus(documents):
    # tokenize.
    """
    Transform documents into corpus.
    :param documents: a list of strings, each representing the content of a document.
    :return: a list of Bag of Words, and a dictionary from id to word.
    """
    tokenizer = RegexpTokenizer(r'\w+')
    tokens = [tokenizer.tokenize(doc.lower().decode('utf-8'))
              for doc in documents]

    # remove pure number with length leq 2.
    tokens = [[token for token in doc if not (len(token) <= 2 and re.search('[a-z]', token) is None)]
              for doc in tokens]
    # remove words with only one character.
    tokens = [[token for token in doc if len(token) > 1]
              for doc in tokens]

    # remove words that appear only once.
    frequency = defaultdict(int)
    for doc in tokens:
        for token in doc:
            frequency[token] += 1
    tokens = [[token for token in doc if frequency[token] > 1]
              for doc in tokens]

    # perform stemming
    print("Performing stemming...")
    porter_stemmer = PorterStemmer()

    def safe_stem(word):
        """
        Performming stemming on the given word safely (ignores the IndexError).
        :param word: the word to perform stemming on.
        :return: the stemmed word.
        """
        try:
            return porter_stemmer.stem(word)
        except IndexError:
            return word

    tokens = [[safe_stem(token) for token in doc] for doc in tokens]
    print("Stemming finished!")

    # remove stop words.
    print("Removing stop words...")
    stop_words = set([porter_stemmer.stem(word) for word in stopwords.words('english') + my_stopwords])
    tokens = [[word for word in doc if word not in stop_words]
              for doc in tokens]
    print("Stop words removed!")

    return token2corpus(tokens)
```

LDA Training set

```python
# coding=utf-8
from __future__ import print_function

from gensim.models.ldamulticore import LdaMulticore
from gensim.models.tfidfmodel import TfidfModel

from utils import *

if __name__ == "__main__":
    # find all documents under the "posttxt" folder.
    doc_paths = list_files("posttxt")
    print('Found {} documents!'.format(len(doc_paths)))

    # read all documents.
    print('Reading documents...')
    documents = []
    for d in doc_paths:
        # read the whole file
        with open(d) as f:
            content = f.read()
            documents.append(content)
    print('Documents read!')

    # transfer the documents into corpus.
    print('Preparing corpus...')
    corpus, dictionary = doc2corpus(documents)
    print('Corpus prepared!')

    # apply tfidf to filter insignificant words.
    print("Performing TD-IDF...")
    tfidf = TfidfModel(corpus, id2word=dictionary, dictionary=dictionary)
    filtered_corpus = []
    for doc in corpus:
        res = tfidf[doc]
        res.sort(key=lambda tup: tup[1], reverse=True)
        # take the 1/4 significant words as meaningful.
        meaningful = [t[0] for t in res[0:len(res) / 4]]
        filtered_corpus.append([t for t in doc if t[0] in meaningful])
    corpus = filtered_corpus
    print("TD-IDF finished!")

    # train a new model.
    print("Training model...")
    lda = LdaMulticore(corpus,
                       num_topics=30,
                       id2word=dictionary,
                       passes=100,
                       iterations=100000,
                       batch=True)
    print("Model trained!")

    # save the trained model.
    print("Saving model...")
    safe_mkdirs('model')
    lda.save('model/lda_model')

    # save the trained model.
    print("Saving model...")
    safe_mkdirs('model')
    lda.save('model/lda_model')
    print("Model saved!")

    # print('\nDocuments and their topics:')
    # for doc in corpus:
    #     print(lda[doc])

    topics = lda.show_topics(num_topics=-1, formatted=False)
    print('Topics and their related words:')
    for topic in topics:
        print(topic)
```

LDA testing set

```python
# coding=utf-8
from __future__ import print_function
from gensim.models.ldamulticore import LdaMulticore

from utils import *

if __name__ == "__main__":
    # create directory for storing results.
    safe_mkdirs('results')

    # load the trained model.
    lda = LdaMulticore.load('model/lda_model')

    # show and save the topics.
    topics = lda.show_topics(num_topics=-1, formatted=False)
    print('Topics and their related words:')
    with open('results/topics.csv', 'w') as f:
        for topic in topics:
            print(topic)
            f.write(str(topic[0]) + ', ')
            for key_word in topic[1]:
                f.write(key_word[0] + ',')
            f.write('\n')
            f.write(str(topic[0]) + ', ')
            for key_word in topic[1]:
                f.write(str(key_word[1]) + ',')
            f.write('\n')

    # find all documents under the "posttxt" folder.
    doc_paths = list_files("D:\posttxt1")
    print('Found {} documents!'.format(len(doc_paths)))

    # read all documents.
    print('Reading documents...')
    documents = []
    for d in doc_paths:
        # read the whole file
        with open(d) as f:
            content = f.read()
            documents.append(content)
    print('Documents read!')

    # transfer the documents into corpus.
    print('Preparing corpus!')
    corpus, dictionary = doc2corpus(documents)
    print('Corpus prepared!')

    # apply the loaded model on every document,
    # then find out which topics does each document contains,
    # and in which documents is each topic contained.
    docs_containing_each_topic = [[]] * len(topics)
    topics_each_doc_contains = [[]] * len(doc_paths)
    with open('results/topics_each_document_contains.csv', 'w') as f:
        for i in range(len(corpus)):
            # apply the loaded model on every document,
            possible_topics = lda[corpus[i]]

            # find out which topics does each document contains,
            for tup in possible_topics:
                if tup[1] > 0.2:
                    topics_each_doc_contains[i].append(tup[0])
            if len(topics_each_doc_contains[i]) == 0:
                topics_each_doc_contains[i].append(max(possible_topics, key=lambda t: t[1])[0])
            # record to file
            f.write(str(i) + ', ' + doc_paths[i] + ', ')
            for topic in topics_each_doc_contains[i]:
                f.write(str(topic) + ', ')
            f.write('\n')

            # find out in which documents is each topic contained.
            for topic in topics_each_doc_contains[i]:
                docs_containing_each_topic[topic].append(i)

            if i % 1000 == 999:
                print('Processed ' + str(i + 1) + '/' + str(len(doc_paths)) + ' documents.')
    # record which documents is each topic contained to file.
    with open('results/documents_containing_each_topic.csv', 'w') as f:
        for i in range(len(topics)):
            f.write(str(i) + ', ')
            for doc in docs_containing_each_topic[i]:
                f.write(str(doc) + ', ')
            f.write('\n')
    print("Results all written!")
```

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LDA result

Topics and their related words:

(0, [(u'buy', 0.046492709498447943), (u'pill', 0.041839982384794153), (u'onlin',
0.027520773673068495), (u'price', 0.020596933576550833), (u'cheap', 0.020527877940139976),
(u'mg', 0.015509028575621534), (u'gener', 0.014681205263342874), (u'usa',
0.014017798870600607), (u'offer', 0.011761905009995846), (u'usd', 0.010406833009031219)])

(1, [(u'pgp', 0.059844368801532093), (u'messag', 0.039977196638987196), (u'account',
0.03816142332405674), (u'key', 0.036891527971200676), (u'vendor', 0.023702377666279625),
(u'agora', 0.023218058672252639), (u'pleas', 0.023062776644503222), (u'market',
0.019586378691069928), (u'click', 0.018044442327462634), (u'help', 0.01645257038563679)])

(2, [(u'bitcoin', 0.11925428947537901), (u'www', 0.057349783108761397), (u'com',
0.047194423158186435), (u'test', 0.033191482346285175), (u'drug', 0.024303772349808826),
(u'cocain', 0.022595216565185754), (u'mtgoox', 0.020568502647737023), (u'strevo',
0.013557420690428658), (u'result', 0.011829243493558683), (u'mmo4sal',
0.011196835939299623)])

(3, [(u'order', 0.026577622595347791), (u'ship', 0.020517185052985575), (u'vendor',
0.012830774929815197), (u'day', 0.012802466720616102), (u'good', 0.012601639138341577),
(u'record', 0.012038856327967131), (u'bud', 0.011574114512843115), (u'macro',
0.011455813258539966), (u'jitbit', 0.011404233099383349), (u'weed', 0.010838710882304687)])

(4, [(u'septemb', 0.031530920812987036), (u'2014', 0.031348226415822585), (u'key',
0.018543728593069284), (u'quot', 0.012502668785025654), (u'file', 0.012177975885190727),
(u'book', 0.010328561898493138), (u'win', 0.0089079498866309493), (u'guess',
0.0077965039217012134), (u'pmquot', 0.0077095899454633328), (u'public',
0.0076096567050691032)])

(5, [(u'flax', 0.07902127261420451), (u'onion', 0.053201156112737062), (u'100',
0.034147518292596435), (u'agorabasakxmewww', 0.0248130449629969794), (u'10ml',
0.022772308746905199), (u'testosteron', 0.017659761720095236), (u'10mg',
0.015705392452006146), (u'100mg', 0.014942798887696779), (u'cycl', 0.01470971706240333),

(u'weight', 0.014608286321972176)])

(6, [(u'order', 0.0227986004199924004), (u'vendor', 0.015583966913731493), (u'good', 0.013077547119776579), (u'time', 0.011553341035327078), (u'quot', 0.010833531996708222), (u'day', 0.010544695903454922), (u'2014', 0.01026736152951554), (u'product', 0.010154397289401261), (u'one', 0.0096563626832763295), (u'go', 0.0089119925504360532)])

(7, [(u'signup', 0.16589879854719372), (u'a8y8xsy5ax', 0.060585944620980443), (u'vobiscum', 0.059867175505646915), (u'pax', 0.055156207399442797), (u'humil', 0.043320238577360247), (u'phish', 0.041383394695494034), (u'peac', 0.039939320148177956), (u'toler', 0.034476774917363985), (u'paradis', 0.031591616480814065), (u'ticket', 0.030649351426117487)])

(8, [(u'vendor', 0.066222204902332521), (u'account', 0.03184072491680412), (u'scam', 0.022511118254472044), (u'buyer', 0.017076020009612905), (u'forum', 0.016994549993861064), (u'scammer', 0.013550667695619446), (u'peopl', 0.013234890565710093), (u'agora', 0.012268192838505897), (u'post', 0.010608953149007696), (u'fuck', 0.0096760699368195445)])

(9, [(u'uscur9o91ahttp', 0.11659636297646422), (u'coke', 0.037362500256180965), (u'cocain', 0.030391404501316364), (u'gram', 0.0225674440960325223), (u'uk', 0.0162928748766606793), (u'sampl', 0.01370570432961319), (u'product', 0.013056760373764085), (u'meth', 0.012530322279137576), (u'cut', 0.012196868584789257), (u'qualiti', 0.011845853271076089)])

(10, [(u'2014', 0.0301972617008800381), (u'fuck', 0.023558512465875668), (u'quot', 0.021791886422106995), (u'peopl', 0.018111631931695085), (u'know', 0.017326785783790127), (u'go', 0.012316985273568264), (u'one', 0.0114077762608327729), (u'say', 0.010986008887514156), (u'make', 0.0095178303738958272), (u'time', 0.0068769849399364699)])

(11, [(u'1burgerk', 0.079265496337876384), (u'2015', 0.071560603161075709), (u'registerhttp', 0.044228757293542913), (u'al6jp5dun3', 0.044132954424585875), (u'pmclick', 0.029994891871987946), (u'novemb', 0.028867802826271084), (u'appl', 0.028476151046190647), (u'januari', 0.0182834308253653), (u'card', 0.016059252248324773), (u'amclick', 0.015204136222322997)])

(12, [(u'com', 0.086436510643642633), (u'www', 0.050814699684808583), (u'clarison', 0.048342934155920905), (u'jordan', 0.045536064928537616), (u'blog', 0.040504378494501926), (u'http', 0.035944027690787583), (u'baron', 0.026496877272799518), (u'oo123bb', 0.024950848554180123), (u'mia', 0.020770364780414673), (u'php', 0.017585396023120321)])

(13, [(u'da', 0.035443493232626577), (u'und', 0.033085837666970548), (u'ich', 0.032249459816511866), (u'die', 0.031583241776764616), (u'nicht', 0.021941969102800416), (u'ist', 0.021357092623422291), (u'der', 0.018801723817778088), (u'ein', 0.018594110007982743), (u'auch', 0.01734061142479049), (u'es', 0.016160498937354457)])

(14, [(u'order', 0.078973082470763969), (u'vendor', 0.035840358221343148), (u'fe', 0.031967870179468873), (u'feedback', 0.030968624747182556), (u'day', 0.023108485502525644), (u'scam', 0.022754806816207684), (u'scammer', 0.016731096856856927), (u'refund', 0.014840644925855821), (u'messag', 0.010564464314511331), (u'escrow', 0.0098399065820285771)])

(15, [(u'milna2031', 0.074668716014557296), (u'juli', 0.071622045530100126), (u'xixspxxguu', 0.05248743837606782), (u'2014', 0.040487851447020932), (u'escrow', 0.022843378423761829), (u'onsit', 0.02131031125942668), (u'support', 0.020881827477134018), (u'fast', 0.020545564371282063), (u'11000', 0.02023055298208588), (u'list', 0.018868379911918483)])

(16, [(u'regist', 0.31172481544503389), (u'agorahooawayyfo', 0.21848991637461246), (u'fxyww2tnchagora', 0.097325879628655895), (u'huxcykatk2http', 0.088891987089120952), (u'aeqyrdbgcvregist', 0.084699289748907919), (u'aeqyrdbgcv', 0.030746796536167596), (u'j9jhwfsz1phttp', 0.022352214031453477), (u'jm5z2aovpl', 0.0126896066619712319), (u'onion', 0.0081264633289390379), (u'coupon', 0.0069334606883303838)])

(17, [(u'gt', 0.66168838039517408), (u'referr', 0.15602586354811837), (u'nyatktjnli', 0.14571734748737236), (u'4wnmr6rsuy', 0.0041662674214112084), (u'amabraxasdegupusel', 0.0041593925187154938), (u'pleasehttp', 0.0015744437909022537), (u'dsx', 0.0010863097672526268), (u'round', 0.00056732282580535301), (u'mayweath', 0.00043338000674500264), (u'floyd', 0.00041542657909226702)])

(18, [(u'mdma', 0.016904982231504544), (u'lsd', 0.012615829244998638), (u'time', 0.011339789954022995), (u'trip', 0.010442986111222616), (u'gkovka3ssi',

0.010038649070248019), (u'one', 0.0097841315466722836), (u'take', 0.0089787875358388562), (u'dose', 0.0088397762433359388), (u'tri', 0.008484298004799976), (u'drug', 0.0083716538034193464)])

(19, [(u'com', 0.090108670371143354), (u'http', 0.044344943665376557), (u'blog', 0.0442379312169267\35), (u'www', 0.039803133472649244), (u'23isback', 0.035150108767087525), (u'releas', 0.032435526787435331), (u'date', 0.030217910984553422), (u'baron', 0.024523833035536839), (u'jordan', 0.016209144999923892), (u'conindomp', 0.015106385858297804)])

(20, [(u'2014', 0.11731597299413089), (u'quot', 0.099744064906664071), (u'octob', 0.074033211661903284), (u'spam', 0.067881678148433364), (u'post', 0.06591485588394469), (u'obamar', 0.060772208642925242), (u'nyatktjnli', 0.04183464299145645), (u'amhttp', 0.032892071205486116), (u'amp', 0.027398013751225817), (u'pm_____', 0.021104994487018639)])

(21, [(u'link', 0.10289931474341388), (u'invit', 0.070645014237759846), (u'offici', 0.066962943902852873), (u'agora', 0.062725127659101168), (u'welcom', 0.045833258279730539), (u'registr', 0.04114646507847905), (u'member', 0.02222484715227516), (u'lt', 0.0220946708859\22874), (u'market', 0.020161487283303602), (u'verifi', 0.019021750250517746)])

(22, [(u'regist', 0.30291112780978408), (u'agorahooawayyfo', 0.27387825732795446), (u'xixspxxguuhttp', 0.13921921359771056), (u'onion', 0.12787783260811403), (u'fw24c7rm0qhttp', 0.090308709543932428), (u'xixspxxguu', 0.039142392370133179), (u'fbzkuwvnxnhttp', 0.0062351791823776394), (u'11000', 0.0020150628047747657), (u'milna2031', 0.0011469681906404925), (u'septemb', 0.00090406049610729331)])

(23, [(u'onion', 0.19097719383850517), (u'http', 0.17505985896103377), (u'regist', 0.16109202184402155), (u'agorahooawayyfo', 0.1427825470012177), (u'mfu7pzjasq', 0.0463435997510225), (u'b3rumtqvzm', 0.040347284923553557), (u'link', 0.02194970673326806), (u'new', 0.019552910112038503), (u'agora', 0.017107789522056303), (u'referr', 0.015661389863174599)])

(24, [(u'regist', 0.1710019206351536), (u'agorahooawayyfo', 0.11195913888576381), (u'referr',

0.1095221345322287), (u'onion', 0.1081482038634855), (u'link', 0.10542713322535091),
(u'jdtclkfbvshttp', 0.061595150949997381), (u'nyatktjnlihttp', 0.030403600400446546), (u'user',
0.019991684103279311), (u'linkhttp', 0.0158734678521174528), (u'error',
0.015836345931591153)])

(25, [(u'packag', 0.016308060133351863), (u'tor', 0.01489514313166561), (u'address',
0.013697401486805613), (u'mail', 0.0116466751119853745), (u'drug', 0.0072472852088956421),
(u'tail', 0.0067921174800427402), (u'secur', 0.0064604839195880805), (u'one',
0.0059464362202087118), (u'servic', 0.0057377464848156132), (u'box',
0.0054137883017115794)])

(26, [(u'huxcykatk2', 0.13630753135477425), (u'onion', 0.1092229524306583), (u'regist',
0.061640692184980882), (u'agorabasakxmewww', 0.046075449149452358), (u'marketplac',
0.041313357486409442), (u'market', 0.021667170750047975), (u'free', 0.020490633907231128),
(u'agora', 0.020417813595914189), (u'n9aw1scu2p', 0.01465633814443648), (u'come',
0.013542578949607051)])

(27, [(u'onion', 0.1451132287672233), (u'http', 0.14230157452013206), (u'topic',
0.12026839573360613), (u'php', 0.1171116221669771), (u'index', 0.10405560252802171),
(u'lacbzxobeprssrfx', 0.097850567887413434), (u'pgp', 0.0369046662320442864), (u'secur',
0.036736578379619612), (u'htmlbecom', 0.017451836420463825), (u'htmlnewb',
0.017446744075100142)])

(28, [(u'agora', 0.035478778585341667), (u'coin', 0.028492683879662924), (u'site',
0.025171207919977612), (u'btc', 0.024980911590472433), (u'wallet', 0.021799095612376553),
(u'deposit', 0.016352754169093039), (u'market', 0.015224598695727983), (u'account',
0.011575082594029817), (u'bitcoin', 0.011101462452632847), (u'money',
0.010974018710526631)])

(29, [(u'bar', 0.017780986461946573), (u'xanax', 0.015347898464575932), (u'price',
0.012498666824037295), (u'make', 0.011157894132719627), (u'powder',
0.0099160281201278126), (u'2014', 0.0090456308619637771), (u'sell', 0.0072118354815888285),
(u'list', 0.0071329453802459813), (u'fentanyl', 0.0065498498832250139), (u'quot',
0.0059093758699791804)])