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Managing knowledge in the construction industry through computational generation of semi-fiction narratives

ABSTRACT:

Purpose – Narratives are useful to educate novices to learn from the past in a safe environment. For some high-risk industries, narratives for lessons learnt are costly and limited as they are constructed from the occurrence of accidents. This study aims to propose a new approach to facilitate narrative generation from existing narrative sources in order to support training and learning.

Design/methodology/approach – A computational narrative semi-fiction generation (CNSG) approach is proposed and a case study was conducted in a statutory body in the construction industry in Hong Kong. Apart from measuring the learning outcomes gained by participants through the new narratives, domain experts were invited to evaluate the performance of the CNSG approach.

Findings – The performance of the CNSG approach is found to be effective in facilitating new narrative generation from existing narrative sources and to generate synthetic semi-fiction narratives to support and educate individuals to learn from past lessons. The new narratives generated by the CNSG approach help students learn and remember important things and learning points from the narratives. Domain experts agree that the validated narratives are useful for training and learning purposes.

Originality/value – This study presents a new narrative generation process for a high-risk industry, e.g. the construction industry. The CNSG approach incorporates the technologies of natural language processing and artificial intelligence (AI) to computationally identify narrative gaps in existing narrative sources and proposes narrative fragments to generate new semi-fiction narratives. Encouraging results were gained through the case study.

Keywords: Construction Industry, Knowledge Management, Narrative Semi-fiction, Narrative Generation, Artificial Intelligence, Training and Learning

1. Introduction

Individuals always learn from predecessors in order to benefit from lessons learnt and to support decision-making processes. McKenzie et al. (2011) proposed a guide for managers to improve their decision-making capability. Alexeis et al. (2015) developed a new approach to elicit knowledge from experts to support decision-making processes in railway industry. The narrative is regarded as one of the important means to facilitate people to reflect from their lives and gain lessons learnt (Biesta et al., 2008). Learning from previous experience is important in high-risk industries as it is one of most the proactive methods in preventing problems from occurring and preventing potential harm to individuals (Carroll, 2002). However, lessons learnt are limited and expensive as they are formed from the occurrence of accidents which may lead to injuries or fatalities. Investigators usually take 3 to 6 months to compile publications with 3 to 6 short narrative texts for lessons learnt (Hospital Authority, 2015). The traditional approach to construct narratives for lessons learnt is labour-intensive and a time-intensive task. In high-risk industries, narratives are produced after people suffer from incidents. An alternative method to facilitate construction of narratives regarding lessons learnt is needed nowadays.

Kennedy and Lawton (1992) used fiction in teaching and learning. In organizational studies, fiction has been used to educate management staff. Complicated cases were found in fiction so as to motivate staff to engage in and to gain knowledge. Since human natural languages are ambiguous, traditional computers are not adequate in understanding and interpreting natural languages directly. Natural language processing (NLP) has been being investigated to program a computer to understand ambiguous human natural language and to respond to it (Negnevitsky, 2011). Cambria and White (2014) indicated that NLP has been applied to facilitate the communication and interaction between human beings and computers. The current narrative generation approaches have limited power in understanding and analyzing narrative texts. NLP can help analyze texts from narratives or texts from the responses of participants. Dictionaries and statistical approaches are examples of NLP methods (Cambria and White, 2014; Günel and Aşlıyan, 2010).

2. Literature Review

2.1 Knowledge management in organizations

Organizations are paying increasing attention to managing knowledge in order to maintain their competencies (Bollinger and Smith, 2001). Knowledge management

(KM) is recognized as a systematic approach to manage organizational knowledge. Apart from retaining knowledge, KM can help organizational workers to retrieve useful knowledge from organizations in order to make qualified decisions and facilitate learning during the decision-making processes. Wee and Chua (2013) indicated that knowledge processes definitely exist in organizations but a limited number of organizational workers recognize their importance and pay proper attention to them. Alavi and Leidner (2001) stated that a framework for organizational KM which includes four main elements: knowledge creation, knowledge storage and retrieval, knowledge transfer as well as knowledge application.

For knowledge creation, Leonard and Sensiper (1998) advocated that tacit knowledge plays an important role in innovation management. Seidler-de Alwis and Hartmann (2008) also suggested that future knowledge creation processes in innovation are greatly dependent on the tacit knowledge management in organizations, which includes interaction with other knowledge management processes such as identifying relevant knowledge, retaining and transferring knowledge. It is vital for organizations to consider how to leverage tacit knowledge.

Knowledge retention is one of the important knowledge processes in organizations. Organizational knowledge is regarded as the memory retained in organizations. Since the retirement tsunami started in 2012, retaining organizational memory in organizations has become a hot and key issue among management staff (APQC, 2008). Different databases and management systems have been developed for large enterprises to retain organizational knowledge (Alavi and Leidner, 2001). For small and medium enterprises (SMEs), staff are reluctant to build or maintain knowledge repositories for organizing knowledge due to limited resources and technical support. Staff possess organizational knowledge in their minds. They consult their colleagues with the relevant expertise or know-how directly when they need particular information (Wong and Aspinwall, 2004).

Knowledge accumulated in organizations generates positive impacts on management performance. It assists individuals to eliminate obstacles and inefficiencies in their work and decision-making (Lee et al., 2005). Pinho and Rego (2012) indicated that different Information Technology (IT) tools have been developed to provide greater support in knowledge storage and retrieval. However, some organizations still cannot leverage the benefits gained by IT tools due to various constraints. Apart from the adoption of IT infrastructure, it is important to investigate other means to facilitate people to retain individual knowledge or organizational memory.

Regarding knowledge transfer, Easterby-Smith et al. (2008) and van Wijk et al. (2008) focused on investigating intra- and inter-organizational knowledge transfer. Paulin and Suneson (2012) investigated how to facilitate the knowledge transfer process in different situations. Cabrera and Cabrera (2002) as well as Wang and Noe (2010) advocated the development of fairness in decision-making and an open communication environment for future knowledge sharing. Instead of emphasizing the mistakes made, management should support staff to share the lessons learnt (Teo, 2005). How to facilitate staff to learn from the lessons learnt is another important issue in organizations.

Knowledge application is a knowledge process which applies identified knowledge or best practices in organizations or other leading enterprises (Wong and Aspinwall, 2004; Lee et al., 2005) in order to derive value from them. The application of knowledge attempts to make the knowledge more available for organizations with respect to value creation (Bhatt, 2001; Mills and Smith, 2011). Wong and Aspinwall (2004) identified four critical factors in the effective utilization and application of knowledge. These are a clear understanding of personal roles in organizations, an opportunity to use knowledge, a need to take action and an awareness of the benefits to be gained from its application of knowledge. Once staff realize their important roles in organizations, and they are authorized to use the knowledge to improve the organizations, they are willing to take the opportunity to use the knowledge and observe the changes and benefits it generates.

Staff in smaller firms have more motivation to apply the knowledge as they can see the results or receive feedback in a shorter period of time (Struebing and Klaus, 1997). Senior staff gain experience by a trial-and-error approach and they may rely mainly on their professional judgment or experience to make decisions (Wong and Aspinwall, 2004). They may neglect published theory or knowledge (Dalley and Hamilton, 2000), and may lead to wrong decisions or actions. Apart from the visualization of the identified knowledge, assisting staff to apply correct knowledge in the organizations is much needed.

It is well-known that a narrative is useful in sharing, transferring and retaining both explicit and tacit knowledge. Apart from retaining human knowledge from predecessors, narratives are useful in assisting tacit knowledge management and facilitating workers' understanding, learning and applying knowledge from previous lessons. Boyce (1996) conducted a critical review related to organizational narratives

and storytelling. She indicated that organizational narratives and storytelling have been used in multidisciplinary research for a long time.

Whyte and Classen (2012) adopted storytelling to retain tacit knowledge from subject matter experts in the Information and Communications Technology (ICT) Industry. A systematic approach was proposed to represent the collected narratives so as to support future applications in organizations. Harvey (2012) also investigated the use of storytelling to transfer organizational knowledge in the healthcare industry. He reported that it was helpful to acquire experienced workers' knowledge through the sharing of documents prepared by them. Participants in the experiment valued the importance of storytelling in tacit knowledge transfer.

Ofri (2015) pointed out that storytelling is a good means to interpret and transfer tacit knowledge, especially in the healthcare industry. Experienced workers have to facilitate students to understand the stories and apply the knowledge mentioned in the stories. Since unpleasant stories may cause harm to patients, the stories cannot be shared publicly without the consent of the patients. Bar-On and Kassem (2004) indicated it is time- and energy-consuming to produce a new narrative for storytelling. The quality of the narrative is highly dependent on the capability of storyteller. Generating semi-fiction narratives from original narratives is needed in order to handle the privacy and quality issues related to the narratives.

In order to facilitate knowledge retention, transfer and application regarding narratives, Chun (2000) and Snowden (2002) started to investigate how to manage narrative knowledge in a systematic way. Snowden (2002) proposed that a narrative database be built to capture day-to-day stories in a person's mind. In a workshop for the British Council (Cheuk, 2007; Skyrme, 2011), Snowden used several techniques such as interviews, telephone calls and workshops to facilitate the organization to capture narratives from individuals and groups. During the interviews, questions including i) the situation, ii) help needed, iii) gaps in knowledge, iv) the person's role, v) reflections and lessons were used to extract narrative data.

After converting the oral narrative to explicit narrative texts, the narratives were stored in a structured narrative database. The narratives were indexed manually in terms of country, sector, theme, positive or negative experience, etc. Further analyses on the diversity of the themes or distribution of positive and negative experience were conducted (Skyrme, 2011). People can access, retrieve, reuse and analyze the wisdom of practitioners and pioneers after tagging and indexing the collected organizational

narratives in the narrative database.

The narrative database provides not only the best practices or successful cases in organizations, but also retains real stories with bad experience. Individuals can learn from both the successful and failed stories so as to facilitate future success (Snowden 2002; Cheuk, 2007). When building a narrative database, stories are shared among workers. However, the narrative database only allows abstract searches of the narratives in the narrative database and workers need to assimilate the meanings of the narratives by themselves (Snowden 2002). It shows limited support to facilitate readers to understand and learn from the narratives.

Also, current approaches related to storytelling or narrative databases focus on retaining, sharing or applying existing organizational narratives or personal narratives and shows limited power in knowledge creation. Narratives in the organizations or individuals' minds are limited and costly, especially in a high risk industry. Generating new plausible semi-fiction narratives from existing narratives can provide an alternative narrative source to facilitate individuals to learn lessons.

Venkitachalam and Busch (2012) highlighted that perceiving tacit knowledge is one of the main areas in future research especially in organization learning (OL), narration and storytelling, and Information and Communication Technology (ICT). Current KM approaches are inadequate to support future research. This study attempts to investigate a new approach using existing narrative sources to generate new semi-fiction narratives to facilitate learning in organizations. The new approach can computationally propose suitable narrative gaps and fragments for the generation of new semi-fiction narratives. Apart from producing more plausible semi-fiction narratives for learning, the new approach can reduce the dependence on the capability and expertise of the storytellers.

2.2 Narrative fiction, semi-fiction and non-fiction

Table 1 shows a review of definitions of narrative fiction, semi-fiction and non-fiction. It can be summarized that fiction is a narrative which is not real and mainly created by authors based on their imagination. Non-fiction is a narrative which is written based on factual events. Semi-fiction is a mixture of fiction and non-fiction. A semi-fiction narrative is developed based on factual events. Some actions or consequences in semi-fiction which are different from the facts are rewritten by the authors.

Table 2 shows a comparison between main types of narratives including fiction, semi-fiction and non-fiction. Basically, fiction is the creation from an author based on imagination (Emelda, 2011). The characters, events and places in fiction are not factual. Hence, fiction is generally created for entertainment purposes. Novels, fables, fairy tales and films are examples of fiction. Fiction can be divided into two groups: realistic fiction and non-realistic fiction. Although the content of fiction is imaginary, some events, people and places in realistic fiction can be supported by historical facts or may be even real, such as fiction regarding space travel. The imagined events in realistic fiction may possibly happen in the future. In contrast, events in non-realistic fiction are impossible and supernatural. As a result, the events cannot really happen. Several examples of non-realistic fiction are Alice in Wonderland by Lewis Carroll and Harry Potter by Rowling (Variados, 2014).

Table 1 here.

Non-fiction is the narrative which is constructed based on factual events and people. It aims to inform readers of facts, in a simple, direct and clear way. Natural history, journals, handbooks and biographies are examples of non-fiction. Bruner (1990) argued that fiction and non-fiction narratives have the same power to transfer narrative knowledge to readers, no matter whether the narrative is non-factual or factual. Semi-fiction has the features of both fiction and non-fiction. It is constructed based on a true story or a factual incident. Authors make use of their imagination to make additions or subtractions from the original story to create semi-fiction. Although the content of semi-fiction is not completely true, authors agree that the events in semi-fiction could happen in real life (Emelda, 2011).

Table 2 here.

Narrative fiction and semi-fiction have been used in social science (Whiteman and Phillip, 2008). Apart from teaching, narrative fiction and semi-fiction were used as a means to present plausible scenarios which were constructed based on non-fictional events (Vickers, 2010). Phillips (1995) and Vickers (2010) indicated that the constructed narrative fiction or semi-fiction can provide alternative perspectives for a particular situation. They emphasize particular ironies, conflicts or dilemmas by creating narrative fiction or semi-fiction in order to observe the responses from participants (Coffee and Atkinson, 1996). By narrative fiction and semi-fiction, researchers not only gain access to a particular kind of truth, but can also validate their claims through different experiments (Rolfe, 2002).

2.3 Narrative Generation

Narrative generation is widely used to facilitate knowledge retention and learning (Balen et al., 2010). Traditionally, people play a critical role in narrative generation. Sharples (1999) indicated that there is no infallible guide to good writing. Humans can only learn to write by practice. A critical writing cycle of humans proposed by Sharples (1999) is shown in Figure 1. Firstly, a variety of data and concepts are collected by the writer. Then, critical ideas are selected and organized in the writer's mind. After producing narrative texts in an explicit form, the writer further reviews and refines the narrative texts in order to generate a piece of good writing.

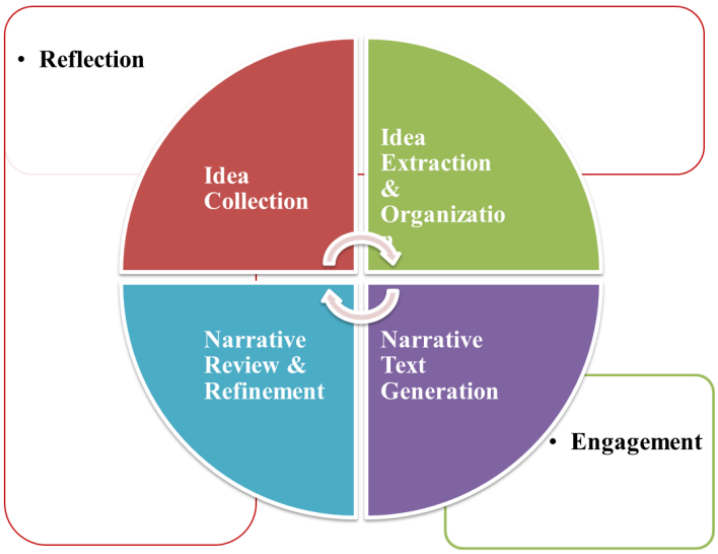

Figure 1 The human writing cycle
(Adapted from Sharples, 1999)

Sharples (1999) classified the narrative generation cycle into two main areas: engagement and reflection. The narrative text generation process, which requires conscious attention to conduct, is under an engagement status. The idea collection, idea extraction and organization, and narrative review and refinement, which greatly involve mental processes in information association and planning, are defined as a reflection status. The narrative generated by the human writing cycle is not limited to children's tales. It also includes academic writing and technical reports. Preparing an incident report during an incident investigation is an example. A narrative is formed from the incident investigation report after a real incident occurs. Investigators are responsible for gathering information, extracting critical information and organizing them in order to prepare an incident investigation report. Narrative authors require

effort and domain knowledge to produce a coherent narrative without conflict events in the traditional narrative generation approach (Riedl and Young, 2006).

Several narrative generation programs such as Script applier mechanism (SAM), plan applier mechanism (PAM) and TALE-SPIN were built (Schank and Riesbeck, 1981). Yeung et al. (2011) summarized the performance of the three programs. Although the first generation of narrative generation programs can only understand structured texts and produce simple and coherent narratives with few structured sentences, it has been proven that computers are applicable to generate narratives. The second generation of narrative generation systems includes MINSTREL, BRUTUS and MEXICA. The narrative generated by MINSTREL is regarded as an understandable and consistent narrative by readers. However, readers indicated that the use of English generated by MINSTREL is not as polished as that of a human author (Turner, 2014). Pérez and Sharples (2004) also pointed out that MINSTREL relies heavily on past problems. If there are mistakes in the past situations, MINSTREL will use item to form an invalid narrative. MINSTREL may generate creative narratives with errors. BRUTUS is capable of writing short stories about pre-defined themes in English. (Bringsjord and Ferrucci, 1999). Sousa (2000) indicated that BRUTUS can help generate narratives in correct English. Narrative elements in the theme have to be reviewed and grouped together in order to support the association of narrative content and rule construction for the narrative development process of BRUTUS (Pérez and Sharples, 2004). Sousa (2000) pointed out that narratives produced by BRUTUS are not so interesting. The creativity of BRUTUS is not as good as a human. MEXICA adopts human cognitive approaches to produce frameworks for short-stories generation. Differing from TALE-SPIN, MINSTREL and BRUTUS, MEXICA produces narrative materials guided by content and rhetorical constraints rather than using explicit goals or canned frameworks to generate narratives (Pérez and Sharples, 2004).

The use of artificial intelligence (AI) in narrative generation has been advocated. New possibilities have been opened up in narrative generation especially in the area of storytelling (Mateas, 2010). Whittaker (2010) indicated that interactive storytelling has been prevalent in digital entertainment media and game design and development. The interactive story system which integrates multimedia tools is regarded as the third generation of narrative generation systems. Multiplayer Interactive Storytelling (MIST) is an example of an interactive storytelling system in the game industry. It adopts an agent-based approach and interaction with players to facilitate the generation of narratives (Paul et al., 2010). The agent-based approach helps create a readable and reasonable game context under a dynamic approach. It can generate a 2D

or 3D presentation by using the latest multimedia tools. Figure 2 shows a snapshot of MIST. The narrative content may be limited for entertainment and is inadequate for learning or decision support. Four major narrative generation approaches are summarized in Table 3. The current narrative generation approaches have limited power in understanding and analyzing narrative texts. Authors are required to review the narratives in the relevant domains to extract information and define constraints. The information regarding indication of the potential areas for further narrative generation is limited. The narratives generated from the current approaches are mainly suitable for entertainment. They show limited support to facilitate readers to understand and learn from the narratives.

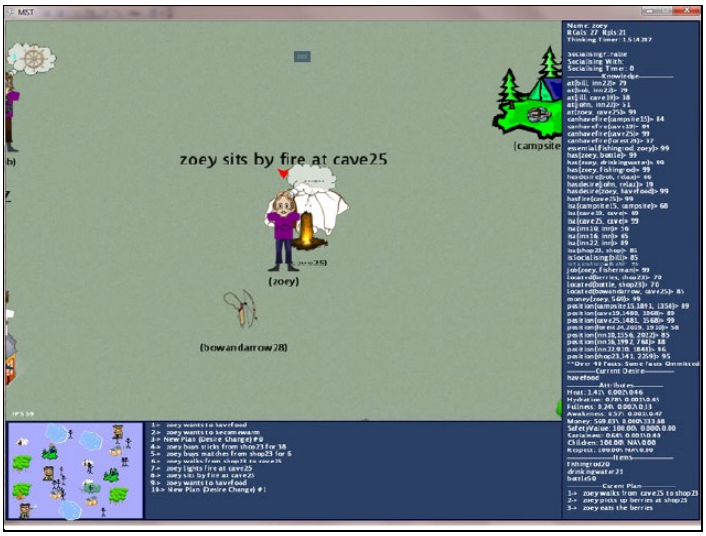

Figure 2 A snapshot of multiplayer interactive storytelling
(Source: Paul et al., 2010)

A review of traditional human-based and computational-based narrative generation approaches was conducted. Traditional human-based approaches such as narrative writing or storytelling are widely used by organizations to disseminate knowledge and facilitate novices to learn lessons from predecessors (Balen et al., 2010; Harvey, 2012; Ofri, 2015). For the computational approaches, researchers concentrate on producing programs to generate narratives. Experiments or evaluations are limited to measuring the learning performance gained by participants through reading the new narratives. Narratives for lessons learnt are limited in some high-risk industries. A new approach to generate semi-fiction narratives form existing narrative sources to facilitate lessons learnt in organizations is much needed. Apart from facilitating readers to understand and learn from the narratives, it is also important to generate narratives which can aid readers to gain lessons learnt and learn how to make decisions in a complex environment.

Table 3 here.

3. Methodology

This study attempts to present a novel systematic and semi-automatic approach to facilitate the narrative generation process which aims to generate new plausible narratives from existing narratives and narrative fragments. Figure 3 shows the framework of the computational narrative semi-fiction generation (CNSG) approach. It includes narrative gap identification, narrative fragment recommendation and user construction. A computational narrative semi-fiction generation (CNSG) system is built, that is capable of automatically identifying narrative gaps from the raw narrative texts and suitable narrative fragments are then proposed for generating new semi-fiction-based narratives. The narrative fragments are collected from previous narrative texts, domain regulations and instructions. Suitable narrative fragments are proposed by the CNSG system based on the identified narrative gaps. Users can then select suitable narrative fragments to construct narratives. They may add, delete, and replace the original narrative contents to generate new narratives.

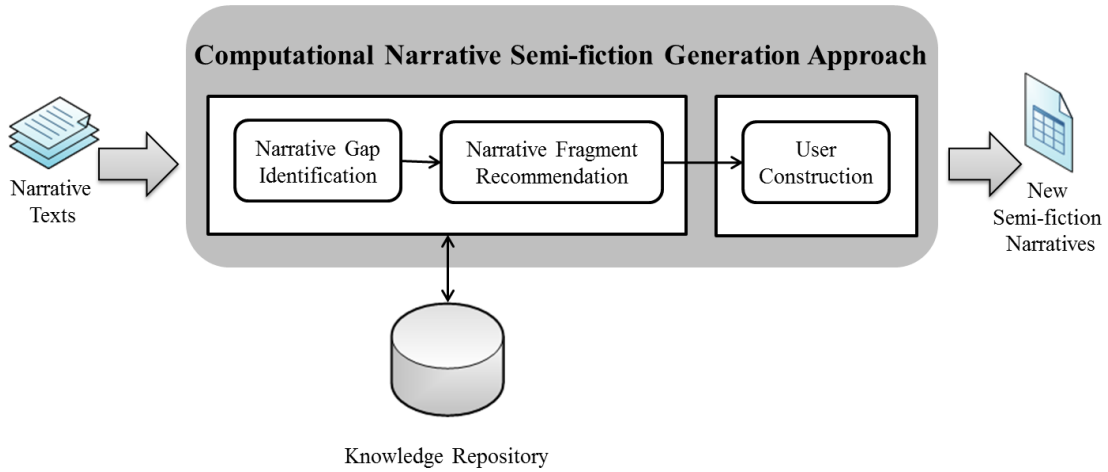

Figure 3 Framework of computational narrative semi-fiction generation approach

3.1 Narrative Gap Identification

To facilitate the generation of new plausible narratives, narrative gap identification (NGI) is firstly conducted by the computational narrative semi-fiction generation (CNSG) system to indicate the potential areas for generating new narratives. As mentioned by McKee (1997), the gap in the narrative is the difference between the

subjective expectation of the protagonist and the objective result. In narratives, the gaps can be found in areas that have unexpected changes in the present situations, or areas that the authors would like to highlight, such as the reasons that cause particular events to happen or the things that trigger the occurrence of particular consequences.

Table 4 shows a list of conjunctions and keywords that indicate narrative gaps in narratives and their corresponding synonyms. According to The Free Dictionary (http://www.thefreedictionary.com), conjunctions such as "but, however, nonetheless, nevertheless and yet" are commonly used to show an unexpected contrast in a sentence. Keywords such as suddenly, unexpectedly and accidentally are also used to indicate the occurrence of an unexpected situation. Conjunctions such as "because" and "since" or keywords such as "because of" and "due to" can indicate the sentences in the narratives that authors would like to address. These sentences show the reasons that cause particular events in the narrative to happen. If someone or something which is important to a narrative is missing or absent, the author would also like to highlight it so as to let readers pay attention to it. These narrative gaps can be found in the sentences with keywords such as lack of or sentences with a negative expression, i.e. a sentence with no, not or neither…nor.

The workflow for the narrative gap identification (NGI) is shown in Figure 4. Each sentence in the narrative texts is analyzed by the CNSG system. If a sentence contains texts in the word list as shown in Table 4, it is classified as a sentence containing a narrative gap in the narrative. If a narrative gap is found in the sentence, the sentence value is marked as "1" by the CNSG system. Otherwise the sentence value is indicated as "0". After checking all the sentences in the narrative texts, the $\sum_{j=1}^{n} X$ is then calculated by summing up all the marks in the narrative. Figure 5 shows an example of narrative gap identification. Each sentence in the narrative texts is checked by the CNSG system. If the sentence contains conjunctions or keywords, the sentence is marked as "1". Other sentences are then indicated as "0". According to Figure 5, two sentences are recognized as sentences with narrative gaps. The total number of sentences in the narrative text is 10. The narrative gap value is calculated by Equation 1. In this example, the narrative gap value of the narrative is 2/10 = 0.2. Figure 6 shows a snapshot of the CNSG system for NGI. After clicking the button Get Narrative Gap Value, the CNSG system checks the inputted narrative text with the word list as shown in Table 4. Apart from identifying sentences with a narrative gap, the number of sentences with a narrative gap, the total number of sentences in the narrative and the narrative gap value are calculated.

Table 4 here.

$$Narrative\ Gap\ Value\ = \frac{\sum_{j=1}^{n} X}{\mathrm{n}} \quad (1)$$

where n is the total number of sentences, X is the sentence value of the narrative.

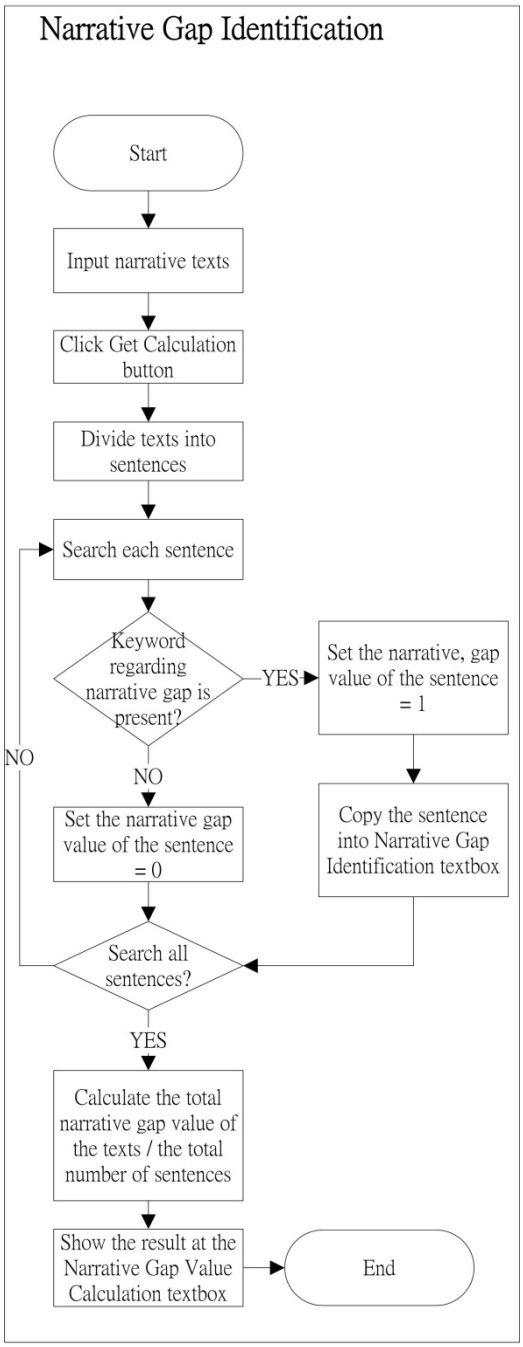

Figure 4 A workflow diagram of narrative gap identification

A sub-contractor had a contract with the main contractor to undertake site clearing in a construction site. [0]
The lift shaft involved in the accident was about 5 metres in length and 3.5 metres in width. [0]
A wooden platform was erected inside the lift shaft on the third floor and its height was about 18,3 metres. [0]
The platform served no specific purpose and was merely left there to catch debris, concrete fragments and timber pieces. [1]
As a matter of fact, it was planned to be removed soon. [0]

At the time of the mishap, two workers of the sub-contractor were clearing the debris on the platform. [0]
Suddenly part of the platform structure failed. [1]
One worker lost his foothold and fell to the bottom of the lift shaft. [0]
The other worker, though managed to escape the fall in the first collapse, fell subsequently when the entire platform collapsed at the end. [0]
As a result, the two workers sustained fatal injuries in the fall. [0]

Narrative gap value : ∑Sentence value/ Total number of sentence: = 2 /10 = 0.2

Figure 5 An example of narrative gap identification

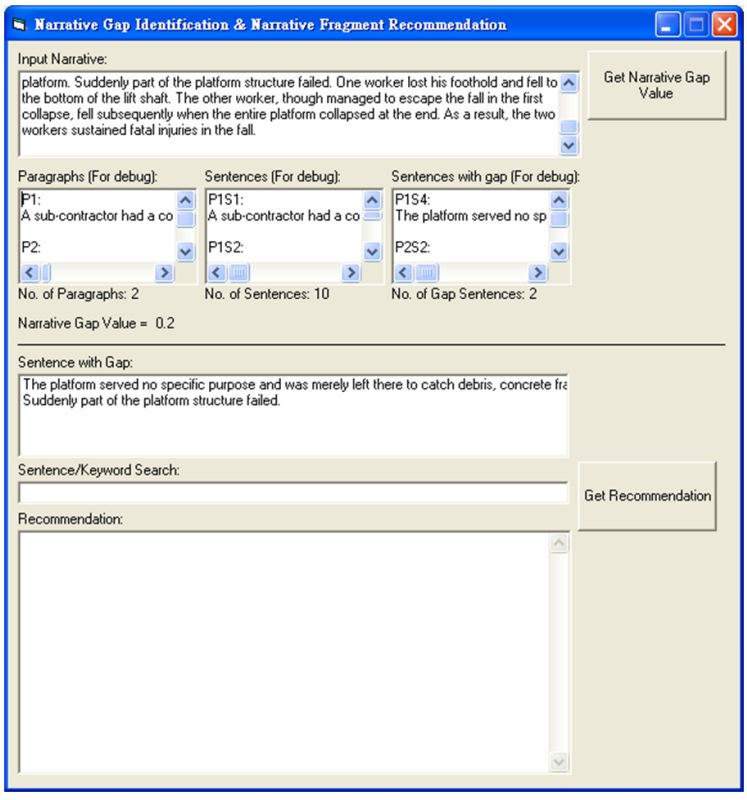

Figure 6 A snapshot of computational narrative generation system for narrative gap identification

3.2 Narrative Fragment Recommendation

Narrative fragment recommendation (NFR) attempts to computationally recommend appropriate narrative fragments so as to facilitate authors to generate new narratives

from existing narratives. The recommendation process is conducted after identifying the narrative gaps in the input of the narrative texts, as discussed in Section 3.1. The narrative gaps are recognized by the CNSG system in the narrative texts and the potential narrative fragments are proposed from the knowledge repository. To facilitate the NFR process, domain literature such as narratives, instructions or recommendations are collected and reviewed. Figure 7 indicates a schematic diagram of narrative fragment construction.

To extract narrative fragments from narratives, the narrative texts are preprocessed by a modified fuzzy association concept mapping (MFACM) method developed by the authors (Yeung et al., 2014). Apart from identification of the narrative texts at the beginning section and the middle section, narrative elements and narrative flows are identified and extracted by the MFACM. It is also capable of extracting narrative elements and their attributes in the beginning section. The extracted narrative elements are further matched with the narrative flows. If the subject of the narrative flow is related to the extracted element, they are linked together and form a narrative fragment pair. The narrative fragment pair includes a narrative element and its narrative attribute or narrative element and its related narrative flow. For the narrative fragments related to instructions and recommendations, they are mainly extracted by domain workers who review the existing literature and extract suitable narrative fragments. Each narrative fragment is analyzed and matched with possible trigger keywords. The narrative fragment pair is formed by trigger keywords and instructions or recommendations related to narrative fragments.

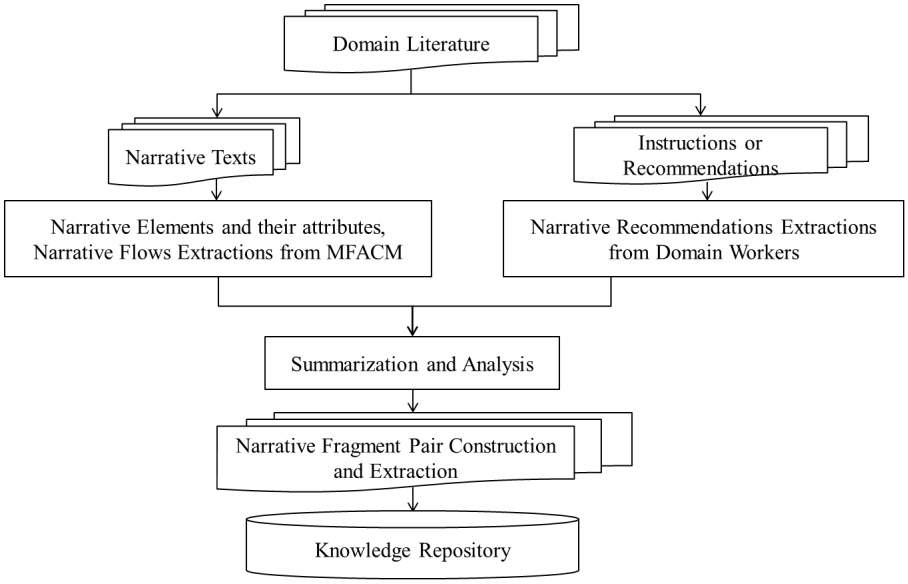

Figure 7 A schematic diagram of narrative fragment construction

The structures of narrative fragment pairs are shown in Table 5. Take “wooden platform” as an example. In a narrative, “wooden platform” and all its attributes in the beginning section are extracted by the modified fuzzy association concept mapping (MFACM) method. The narrative fragment pair of “wooden platform” and its attributes is {wooden platform: served as no specific purpose; was merely left there to catch debris; was merely left there to catch concrete fragments; was merely left there to catch timber pieces; was planned to be removed soon}. As the narrative element “wooden platform” is related to a narrative flow “part of the wooden structure failed”. They are linked and form a narrative fragment pair: {wooden platform: failed}.

Table 5 here.

Domain workers are responsible for extracting narrative fragments from instructions and recommendations in existing domain literature. Domain workers review the related literature and extract suitable narrative fragments. Then, possible trigger keywords are extracted from the texts of the narrative fragments computationally. One of the examples of a narrative fragment pair related to instructions or recommendations is {wooden platform: the wooden platform should be properly designed, constructed, inspected and regularly maintained to ensure its structural stability before any person is allowed to work on it and to carry out cleaning operation}. “wooden platform” is extracted as a trigger keyword. The trigger keyword which can be extracted by the texts in the narrative fragments is related to the actor, thing, location or action mentioned in the narrative fragments.

Domain workers can further propose other proper trigger keywords if needed. Another example of a narrative fragment pair is {suitable safety harness, fall: suitable safety harness with a fall arresting system attached to an independent life-line were provided and are used by workers when workers are required to work at height}. “suitable safety harness” is the trigger keyword extracted from the narrative fragment texts while “fall” is the trigger keyword proposed by domain workers. The extracted narrative fragment pairs are retained in the knowledge repository to facilitate the narrative fragment recommendation. To ensure that new narratives are not generated from original narrative fragments, the narratives which generate the narrative fragment pairs are recorded and retained in the knowledge repository.

The workflow diagram of NFR is shown in Figure 8. The CNSG system firstly identifies narrative gaps in the inputted narrative texts, as mentioned in Section 3.1.

Hence, the narrative elements or trigger keywords in the narrative fragment pairs are matched with the texts in each sentence with a narrative gap, in order to propose suitable narrative fragments. If the narrative elements or trigger keywords are absent from the knowledge repository, the CNSG system also allows domain workers to search for potential narrative fragments or add new narrative fragments during narrative generation.

Figure 9 shows a snapshot of the CNSG system for NFR. When a sentence with a narrative gap is selected and the Get Recommendation button is clicked, the CNSG system matches the texts in the sentence with narrative elements or trigger keywords in narrative fragment pairs, based on similarity. Equations 2 to 4 which are adapted from Yeung et al. (2014) are used to measure similarity. The similarity index is the number of matched texts between the selected sentence with a narrative gap and the narrative elements or trigger keywords in the narrative fragment pairs. The similarity index increases 1 when one text in the sentence in the narrative gap matches with a text in retrieved narrative elements or trigger keywords. The narrative fragments are ranked based on their similarity index in descending order.

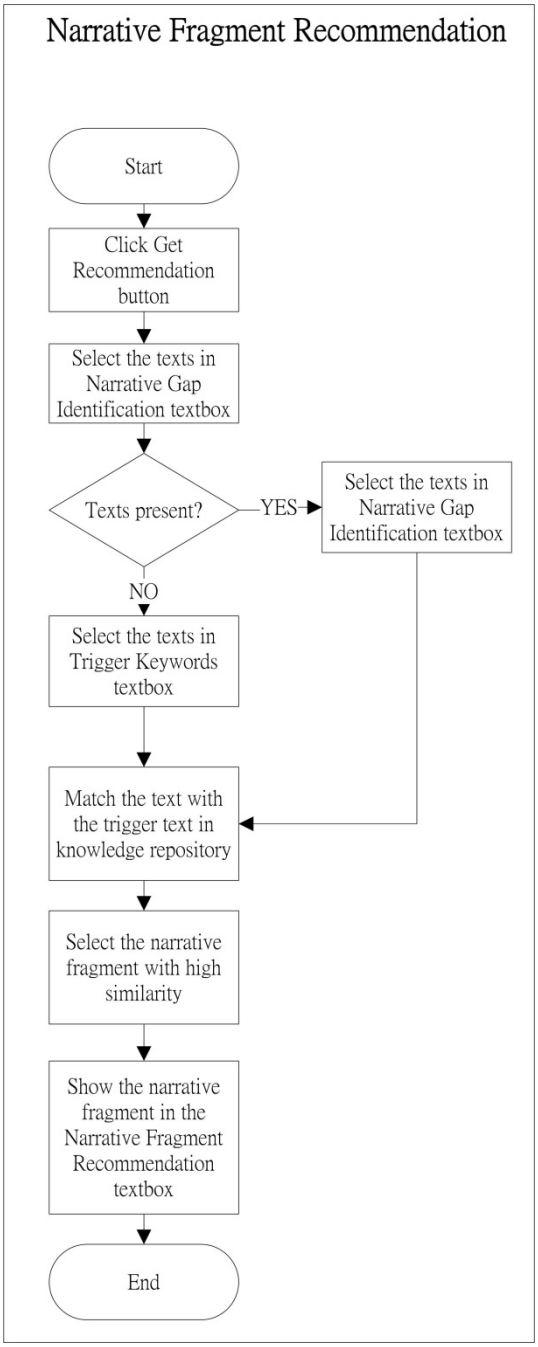

Figure 8 A workflow diagram of narrative fragment recommendation

$$\text{Similarity} = \frac{\sum_{j=1}^{m} w_j \, \text{sim}(v_j^0, v_j^r)}{\sum_{j=1}^{m} w_j} \tag{2}$$

where m is the number of inputs, w_j is the weighting of the j th text, v_j^0 and v_j^r are types of the j th text of the input sentence and that of the retrieved text in narrative elements or trigger keywords, $\text{sim}(v_j^0, v_j^r)$ is the similarity function for the j th text as follows:

$$\text{sim}(v_j^0, v_j^r) = 1 \quad if\ v_j^0 = v_j^r \tag{3}$$

$$\text{sim}(v_j^0, v_j^r) = 0 \quad if\ v_j^0 \neq v_j^r \tag{4}$$

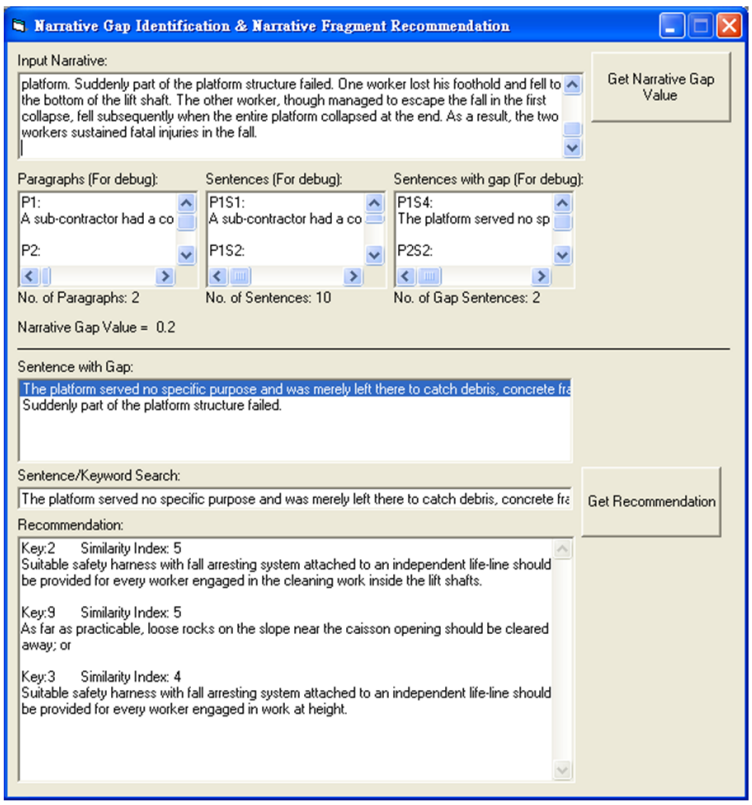

Figure 9 A snapshot of computational narrative semi-fiction generation system for narrative fragment recommendation

3.3 User Construction

The CNSG system is capable of identifying potential narrative gaps in the narrative and recommending narrative fragments for narrative generation. Domain workers can select suitable narrative fragments to construct new semi-fiction narratives. Figure 10 shows an example of a new semi-fiction narrative. The new narrative fragments "suitable safety harness with a fall arresting system attached to an independent life-line were provided and are used by workers when workers are required to work at height" is suggested by the CNSG system. "But the workers did not wear any safety harness when they were working" is suggested by the domain worker so as to construct a new narrative to facilitate novices to benefit from lessons learnt.

A sub-contractor had a contract with the main contractor to undertake site clearing in a construction site.
The lift shaft involved in the accident was about 5 metres in length and 3.5 metres in width.
A wooden platform was erected inside the lift shaft on the third floor and its height was about 18,3 metres.
The platform served no specific purpose and was merely left there to catch debris, concrete fragments and timber pieces.
As a matter of fact, it was planned to be removed soon.

Suitable safety harness with fall arresting system attached to an independent life-line should be provided for every worker engaged in work at height.
But the workers did not wear any safety harness when they are working.

At the time of the mishap, two workers of the sub-contractor were clearing the debris on the platform.
Suddenly part of the platform structure failed.
One worker lost his foothold and fell to the bottom of the lift shaft.
The other worker, though managed to escape the fall in the first collapse, fell subsequently when the entire platform collapsed at the end.
As a result, the two workers sustained fatal injuries in the fall.

Figure 10 An example of a new narrative

4. Findings

The computational narrative semi-fiction generation (CNSG) approach was developed and its prototype, the CNSG system, has been built. To evaluate the performance of the CNSG approach in real life, a high-risk industry in Hong Kong was selected as a reference site. The construction industry is regarded as one of the highest-risk industries in the world as realized by its high number of fatalities and accident rate (Yeung et al. 2014; Al-Humaidi and Tan, 2010). The Labour Department in Hong Kong (2014) also reported the highest number of fatalities and accident rate were recorded in the construction industry based on the latest statistics.

To improve the situation and support novices to benefit from lessons learnt through narratives, the CNSGS has been trial implemented in a statutory body in the construction industry in Hong Kong. Falling of a person from height is a one of the main accidents in the construction industry (Chan et al., 2008). The scope of this study is focused on narratives related to the falling of a person from height. A total of eight narrative sources regarding the falling of a person from height have been used for narrative generation. The narrative sources which were collected from the Construction Industry Council (CIC) represent typical incidents regarding falling of a person from height in the construction industry in Hong Kong. Twenty-six narratives

have been generated. In order to evaluate the twenty-six narratives, two experiments were conducted. Domain experts were invited to evaluate the content in experiment 1. Experiment 2 was designed to measure the learning outcome gained by the participants through reading the narratives generated by CNSG.

Four construction experts were invited to participate in the evaluation experiment of the CNSG approach. They were required to read the new narrative semi-fiction generated by the CNSG approach and then they were asked to fill in an evaluation questionnaire for each of the new narratives in order to obtain their feedback. In this evaluation experiment, the eight narrative texts collected were regarded as the narrative sources for producing new narrative semi-fiction. Computational identification of the narrative gaps and narrative fragment recommendation were conducted by CNGS for each narrative in order to produce the new narrative semi-fictions.

An evaluation questionnaire of the narratives generated by the CNSG approach was purposely designed, and is shown in the Appendix. The questionnaire included personal information and evaluation questions. Six questions related to respondents' profile were included in part one. Nine questions (Q1 to Q9) regarding performance of the CNSG approach while eight questions (Q10 to Q17) about the new narratives outputted by the CNSG approach were included in part two, respectively. Each construction expert was responsible for providing the information in part one in the questionnaire once and each was required to answer the questions in part two for each new narrative.

In order to design the performance evaluation, the questionnaires regarding narrative content evaluation were reviewed. The narrative content should be veracious and useful as the narrative content is used to facilitate individuals to learn the decision making process from predecessors' experience. It also provides information to individuals and facilitates individuals to associate with their thinking processes. This evaluation adapted the questionnaire proposed by McCrary and Mazur (1999). The narrative content was evaluated in terms of veracity, informative, usability and cognitive. Table 6 shows the evaluation questions in part two and the short form of questions. The short forms of the evaluation questions were used to represent each evaluation question from Table 7 to Table 9, respectively.

The questionnaire made use of the 5-point Likert scale (5 = strongly agree; 4 = agree; 3 = neutral; 2 = disagree; 1 = strongly agree) for Q1 to Q16 of the evaluation process.

Q17 was a polar question (with two choices: Agree or Disagree). Four construction safety experts in the organization participated in the evaluation process. They came from Hong Kong and have prior knowledge of the construction industry. Apart from having a master's degree, they have an advanced English level. Since each construction expert was required to answer the questions in part two for each new narrative, one hundred and four questionnaires were collected for twenty-six new narratives. Table 7 to Table 9 show the overall feedback scores for Q1 to Q17 for the twenty-six new narrative outputs. As shown in Table 7 and Table 9, the mean feedback scores for Q1 to Q9 range from 3.00 to 4.00. The standard deviations are between 0 and 1. The average scores of all twenty-six outputs are between 3.3 and 3.9. Over 88% of the evaluation statements obtained average scores of more than 3.5 for all twenty-six outputs.

Figure 11 shows the distribution of the feedback of Q1 to Q17 of the CNSG approach. The responses of twenty-six outputs based on the four construction experts in terms of each evaluation statement are shown. The majority of the responses (75% or above) indicated that the experts agree or strongly agree with the following evaluation statements: "Q1. The approach generates a narrative with appropriate length", "Q2. The narrative texts generated by the approach are properly written", "Q3. The approach can properly link the events in the narrative", "Q6. The content of a narrative generated by the approach is informative", "Q9. The content of a narrative generated by the approach is realistic and authentic", "Q10. Students can relate personally to this narrative", "Q12. The information learned from the narrative will help students respond to a situation" "Q14. The narrative helps students remember important things", "Q15. T The narrative can transfer the defined learning points to students", "Q16. The narrative can be used to provide training to students" and "Q17. The narrative can be classified as a new narrative for training and learning".

Table 6 here.

Table 7 here.

Table 8 here.

Table 9 here.

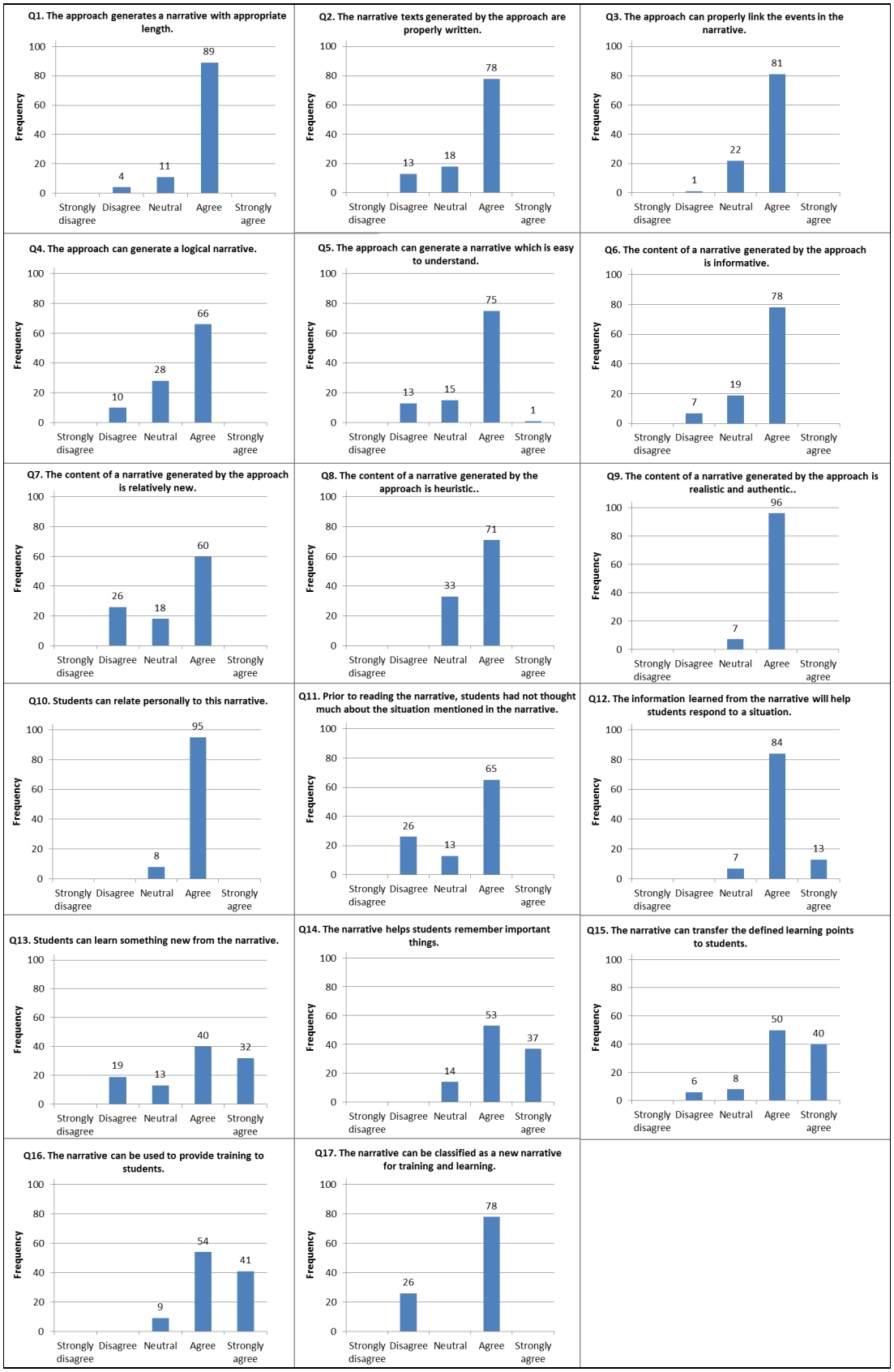

Figure 11 Distribution of feedback of Q1 to Q17 of the CNSG approach

For Q5, around 74% of the responses from the experts indicated that “The approach can generate a narrative which is easy to understand”. For the questions related to “Q4. The approach can generate a logical narrative”, “Q8. The content of a narrative generated by the approach is heuristic”, “Q11. Prior to reading the narrative, students had not thought much about the situation mentioned in the narrative” and “Q13. Students can learn something new from the narrative”, the percentages of responses indicating that the experts agree or strongly agree with the evaluation statements are between 62% and 70%. For Q7, around 58% of the responses from the experts indicated that “The content of narrative is relatively new”. Further analysis will be mentioned in the discussion section.

Experiment 2 was designed to measure the learning outcome gained by the participants through reading the narratives generated by CNSG. A total of 20 participants were invited to join experiment 2. Due to the increasing demand for construction manpower, good remuneration packages and promotion prospects, many graduates in tertiary education tend to develop their careers in the construction industry. As a result, participants with a tertiary education background were invited to join this experiment.

The profiles of the participants in experiment 2 are shown in Table 10. The ratio between the male and female participants was 2 to 3, i.e. 2:3. They mainly came from the age group between age 20 and age 24. Most of them came from Hong Kong while the rest were from China. Most of them were currently studying a degree or were degree holders in Hong Kong. The remaining participants were currently studying a master or doctorate degree in Hong Kong. In terms of the English level of the participants, 10% of the respondents thought that they had an elementary level while 75% of them thought that they were in the middle level; 15% of them thought that they were of an advanced level. The medium of instruction in universities in Hong Kong is English. As the respondents were current university students in Hong Kong, their level of English was adequate for the evaluation. With regard to working experience, most of them had less than one year or one to three years of working experience. Lastly, all of them did not have any prior knowledge regarding the construction industry.

In experiment 2, the participants were firstly invited to read the narratives generated by the CNSG system. Each participant was required to read four narratives regarding the falling of a person from height of a length, ranging from 220 to 440 words, before conducting a test exercise. The test exercise included eight multiple choice questions

and one case study. The case study included two questions. The questions in the test exercise were developed from the test materials in the construction industry. Apart from answering the eight multiple choice questions, the participants were required to read a scenario in the case study and then select the most appropriate method to handle the situation. The results of the test exercise are shown in Table 11. The average score of the participants was 75 out of 100. The averaged accuracy of each question ranges 25% to 100%. Further analysis is mentioned in the discussion section.

Table 10 here.

Table 11 here.

5. Discussion

Domain experts were invited to evaluate the content of each new semi-fiction narrative in experiment 1. The findings of experiment 1 are shown in Table 7 to Table 9. Figure 11 shows the distribution of the feedback of Q1 to Q17 of the CNSG approach. Based on the findings of experiment 1, the majority of the respondents agreed that the CNSG approach can generate narratives with appropriate length. The narrative content generated by the CNSG approach was informative, realistic and authentic. The narrative texts generated by the CNSG approach were properly written. The CNSG approach could properly link the events in the narrative. As the new semi-fiction narratives were constructed based on existing narratives or incidents in the construction industry in Hong Kong, the contents of the narratives were veracious and organized with suitable information.

Almost all the respondents agreed that the narratives generated by the CNSG approach can facilitate students' learning. The narratives generated by the CNSG approach can help students to relate with their personal experience, remember important things, and learn learning points. The respondents also agreed that the information in the narratives can help students to respond to a situation and they will use the narratives in training. The new semi-fiction narratives contain information such as person, location, time, etc. People can immerse themselves in the situation so as to understand and remember the situation. Around 74% of the responses from the experts indicated that "Q5. The approach can generate a narrative which is easy to understand". As the new narratives include information regarding some actual situations and domain knowledge in the construction industry, some of the respondents think that the content of some narratives are a bit complicated but are still applicable for novices.

For “Q8. The content of a narrative generated by the approach is heuristic” and “Q13. Students can learn something new from the narrative”, more than two-thirds of the responses agreed that CNSG approach can generate narratives which facilitate students to think and learn something new. The new semi-fiction narratives were generated from existing narratives with a moderate change of narrative content. These situations described in the new narratives are plausible but involve something different from the existing narratives. The new narratives can foster students to consider situations in different viewpoints and learn how to handle different situations.

For “Q4. The approach can generate a logical narrative” and “Q11. Prior to reading the narrative, students had not thought much about the situation mentioned in the narrative”, more than three-fifths of the responses agreed that CNSG approach can produce logical narratives in new situations. The semi-fiction narratives include some new content adapted from other existing narratives. Most of the respondents think the narratives are logical but 27% of the responses are neutral to this statement. As the new semi-fiction narratives were generated from existing narratives with a moderate change of narrative content, some respondents thought that students may have read a similar situation before. For “Q7. The content of a narrative generated by the approach is relatively new”, more than half of the responses agreed that the CNSG approach can generate narratives with relatively new content. It may also be due to the fact that the narratives were generated from existing narratives with a moderate change of narrative content. The portion of new content in the semi-fiction narratives is relatively small.

On the whole, the majority of the respondents agreed that the CNSG approach, which generates new narrative semi-fiction from existing narratives, can produce narratives with appropriate length and properly written texts. Apart from linking the events in the narrative, the CNSG approach can generate narrative content which is informative, realistic and authentic. Almost all the respondents agreed that the new narratives generated by the CNSG approach can help students to relate their personal experience to the narratives, learn and remember important things, and learning points from the narratives. The respondents also agreed that the information in the narratives can help students to respond to the situation and they will use the narratives in training. More than half of the respondents agreed that the contents of the narratives are heuristic and logical. The new plausible situations mentioned in the new semi-fiction narratives can facilitate students to learn something new. Three quarters of the respondents agreed

that the new narratives generated by the CNSG approach can be classified as a new narrative for training and learning. The performance of the CNSG approach was considered good for facilitating the human narrative generation process.

Experiment 2 was designed to measure the learning outcome gained by the participants through reading the narratives generated by CNSG. Apart from multiple choice questions, the evaluation included case study questions for participants to select the most appropriate method to handle the situation. The average score of the participants was 75 out of 100. For 60% of questions attempted by the participants, they obtained an average accuracy of more than 57%. It indicates that the narratives generated by the CNSG can help participants to understand and remember the narratives, and also assist them in learning how to make decisions.

There are several challenges in this study. Eight data sets were collected from the Construction Industry Council (CIC), which is a statutory body in the construction industry in Hong Kong. The data sets represent typical incidents regarding falling of a person from height in the construction industry. As a result, the data sets are representative and adequate to act as a data source for the investigation in this area. The other challenge is to validate new semi-fiction narratives. Since domain knowledge is needed for ensuring the quality of the narratives, domain experts are required to participate in the validation process of the new narratives. For future research, crowdsourcing is suggested to be used which allows the recruitment of domain experts in the crowdsourcing community to support the undertaking of the validation process through the online platform. More responses would be acquired through crowdsourcing to support further analysis.

Moreover, it is difficult to ensure individuals learn how to make decisions as they have different capabilities. In this study, a test exercise was used to evaluate individual performance. For future research, it is suggested to establish a virtual environment with sensing devices and multimedia, so as to facilitate knowledge workers to be immersed in the simulated environment. It can help to better reflect individual performance. A drill in the actual environment will also be considered to further evaluate individuals' responses in real situation.

6. Conclusion

This study presents a review of the narrative generation approach and system. Narratives generated by most of the tools are mainly fiction used for entertainment.

Limited numbers of them are developed for learning or teaching novices to make decisions. In order to develop a cost-effective approach to retain organizational knowledge and generate new narratives to support individuals to gain lessons learnt and learn how to make decisions, this study presents a novel methodology to generate narratives. A computational narrative semi-fiction generation (CNSG) approach and its prototype, the CNSG system, were developed and successfully implemented in a statutory body in the construction industry in Hong Kong. The performance of the CNSG approach is found to be effective in facilitating new narrative generation from existing narrative sources and generates synthetic semi-fiction narratives to support and educate individuals in learning how to make decisions. Domain experts in the construction industry agreed that the new narratives generated by the CNSG approach can help students learn and remember important things and learning points from the narratives. 75% of the respondents agreed that the new narratives generated by the CNSG approach can be classified as a new narrative for training and learning.

The strength and weakness of the proposed CNSG approach is discussed in this section. The CNSG approach provides an alternative method to computationally generate narratives for lessons learnt rather than from the occurrence of accidents. It is capable of identifying potential areas from narrative texts and proposing narrative fragments for new narrative generation. This approach can facilitate less experienced domain workers to carry out narrative generation processes. The semi-fiction narratives constructed from factual accidents can help provide a realistic experience for individuals to gain lessons learnt. For the existing CNSG approach, the narrative gap is found through matching the identified word list. The word-based technique is restricted on the identified word.

For future study, the integration of multimedia such as graphics, animation and sound effects to the proposed approach can be considered. Visual and audio narratives in the form of graphics, animation, and sounds can attract new learners' attention and foster learners to generate images of the narratives in their minds in an appropriate way in order to understand the concepts of the narrative background. The integration of sensing devices such as Microsoft Kinect, can also help detect and monitor users' actions and responses during their learning. The integration of existing multimedia and sensing technologies can help create a virtual learning environment with realistic and historical-based narratives to enable users to learn how to make decisions.

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Appendix Narrative Evaluation Questionnaires

QUESTIONNAIRE

Narrative Evaluation Questionnaire

The aim of the questionnaire is to gather information for the purpose of continuous improvement of the designed narrative. It is composed of two parts which are personal information and narrative evaluation. It would be appreciated if you could spend a few minutes to complete this questionnaire. All information provided is confidential and strictly for the above purpose.

Part I - Personal Information

Please insert "√" in the box or fill in the following information.

1.	What is your gender?	Male ☐	Female ☐	
2.	How old are you?	20-24 ☐	25-29 ☐	
		30-34 ☐	35-39 ☐	
		40-44 ☐	45-49 ☐	
		50-54 ☐	55-59 ☐	
		Other ☐ Please specific: _____		
3.	Where do you come from?	Hong Kong ☐	China ☐	
		Other ☐ Please specific: _____		
4.	What is your educational level?	Certificate ☐	Diploma ☐	
		Higher Diploma ☐	Bachelor ☐	
		Master ☐	Doctor ☐	
		Other ☐ Please specific: _____		
5.	What is your level of English?	Elementary ☐	Middle ☐	
		Advanced ☐		
6.	Do you have any prior knowledge about construction industry?	Yes ☐	No ☐	

Part II – Narrative Evaluation

In this part, you are required to read the narratives and fill in some information.

Narrative No.: _____ Date: _____

Please tick "√" the most appropriate one.

	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
1. The approach generates a narrative with appropriate length.	☐	☐	☐	☐	☐
2. The narrative texts generated by the approach are properly written.	☐	☐	☐	☐	☐
3. The approach can properly link the events in the narrative.	☐	☐	☐	☐	☐
4. The approach can generate a logical narrative.	☐	☐	☐	☐	☐
5. The approach can generate a narrative which is easy to understand.	☐	☐	☐	☐	☐
6. The content of a narrative generated by the approach is informative.	☐	☐	☐	☐	☐
7. The content of a narrative generated by the approach is relatively new.	☐	☐	☐	☐	☐
8. The content of a narrative generated by the approach is heuristic.	☐	☐	☐	☐	☐
9. The content of a narrative generated by the system is realistic and authentic.	☐	☐	☐	☐	☐
10. Students can relate personally to this narrative.	☐	☐	☐	☐	☐
11. Prior to reading the narrative, students had not thought much about the situation mentioned in the narrative.	☐	☐	☐	☐	☐

1

12. The information learned from the narrative will help students respond to a situation.	☐	☐	☐	☐	☐
13. Students can learn something new from the narrative.	☐	☐	☐	☐	☐
14. The narrative helps students remember important things.	☐	☐	☐	☐	☐
15. The narrative can transfer the defined learning points to students.	☐	☐	☐	☐	☐
16. The narrative can be used to provide training to students.	☐	☐	☐	☐	☐

	Agree (2)	Disagree (1)
17. The narrative can be classified as a new narrative for training and learning.	☐	☐

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12. The information learned from the narrative will help students respond to a situation.	☐	☐	☐	☐	☐
13. Students can learn something new from the narrative.	☐	☐	☐	☐	☐
14. The narrative helps students remember important things.	☐	☐	☐	☐	☐
15. The narrative can transfer the defined learning points to students.	☐	☐	☐	☐	☐
16. The narrative can be used to provide training to students.	☐	☐	☐	☐	☐

	Agree (2)	Disagree (1)
17. The narrative can be classified as a new narrative for training and learning.	☐	☐

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