

# A character social network relationship map tool to facilitate digital humanities research

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## Abstract

**Purpose** – Digital humanities aim to use a digital-based revolutionary new way to carry out enhanced forms of humanities research more effectively and efficiently. This study develops a character social network relationship map tool (CSNRMT) that can semi-automatically assist digital humanists through human-computer interaction to more efficiently and accurately explore the character social network relationships from Chinese ancient texts for useful research findings.

**Design/methodology/approach** – With a counterbalanced design, semi-structured in-depth interview, and lag sequential analysis, a total of 21 research subjects participated in an experiment to examine the system effectiveness and technology acceptance of adopting the ancient book digital humanities research platform with and without the CSNRMT to interpret the characters and character social network relationships.

**Findings** – The experimental results reveal that the experimental group with the CSNRMT support appears higher system effectiveness on the interpretation of characters and character social network relationships than the control group without the CSNRMT, but does not achieve a statistically significant difference. Encouragingly, the experimental group with the CSNRMT support presents remarkably higher technology acceptance than the control group without the CSNRMT. Furthermore, use behaviors analyzed by lag sequential analysis reveal that the CSNRMT could assist digital humanists in the interpretation of character social network relationships. The results of the interview present positive opinions on the integration of system interface, smoothness of operation, and external search function.

**Research limitations/implications** – Currently, the system effectiveness of exploring the character social network relationships from texts for useful research findings by using the CSNRMT developed in this study will be significantly affected by the accuracy of recognizing character names and character social network relationships from Chinese ancient texts. The developed CSNRMT will be more practical when the offered information about character names and character social network relationships is more accurate and broad.

**Practical implications** – This study develops an ancient book digital humanities research platform with an emerging CSNRMT that provides an easy-to-use real-time interaction interface to semi-automatically support digital humanists to perform digital humanities research with the need of exploring character social network relationships.

**Originality/value** – At present, a real-time social network analysis tool to provide a friendly interaction interface and effectively assist digital humanists in the digital humanities research with character social networks analysis is still lacked. This study thus presents the CSNRMT that can semi-automatically identify character names from Chinese ancient texts and provide an easy-to-use real-time interaction interface for supporting digital humanities research so that digital humanists could more efficiently and accurately



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establish character social network relationships from the analyzed texts to explore complicated character social networks relationship and find out useful research findings.

**Keywords** Digital humanities, Chinese ancient book, Human-computer interaction, Character name recognition, Social networks analysis, Information visualization

**Paper type** Research paper

## 1. Introduction

Traditionally, humanists are used to studying paper-based texts for their research tasks. In recent years, a lot of research institutions, such as libraries and digital humanities research centers, digitize history files and text data by using information technology to establish digital archives databases and develop digital tools to support digital humanities research so that the humanities research environment and knowledge acquisition appear great changes. The emerging research on digital humanities (DH) in past years helps digital humanists, through the assistance of full-text digital data and digital tools, observe the phenomena which are not easily observed by interpreting traditional paper-based texts (Schreibman *et al.*, 2008). DH that includes the systematic use of digital contents and tools in the humanities disciplines and makes possible new kinds of research is work at the intersection of digital technology and humanities disciplines (Drucker, 2013). Namely, digital humanities research involves the analysis, comprehension, production, and sharing of a huge amount of digital sources with the support of digital tools. Digital humanists in the digital humanities field heavily relied on using information technologies, such as text mining (Widlöcher *et al.*, 2015), annotation (Chen and Tsay, 2017; Sato *et al.*, 2016), social networks analysis (Jackson, 2017; Uboldi *et al.*, 2013), geographic information system (GIS) (Kallaher and Gamble, 2017), and natural language processing (NLP) (Brooke *et al.*, 2015) to analyze data from digital sources to extract useful information and generate new knowledge. Many previous studies (Chen *et al.*, 2019; Luczak-Roesch *et al.*, 2018; Uboldi *et al.*, 2013) have proved that applying digital tools could help digital humanists solve research problems more efficiently than performing manually. For example, Chen *et al.* (2019) developed an automatic text annotation system (ATAS) that can collect resources from different databases through Linked Data (LD) for automatically annotating Chinese ancient texts to support digital humanities research. It allows the digital humanists to refer to resources from diverse databases when interpreting ancient texts as well as provides a friendly text annotation reader for digital humanists interpreting Chinese ancient text through digital reading. The experimental results reveal that the ATAS has higher reading effectiveness than the MARKUS semi-automatic text annotation system. Luczak-Roesch *et al.* (2018) presented a novel tool that leverages temporal data mining, network science, and visual analytics for digital humanities research. Their analytical results show that this approach facilitates a new collaborative methodological practice that is a hybrid of close and distant reading. Moreover, information technology could assist digital humanists in finding out complicated character social network relationships hidden in large historical texts. For example, Uboldi *et al.* (2013) designed the Knot, which is a digital tool for exploring historical social networks, to provide digital humanists with an environment for exploring multi-dimensional and heterogeneous data, allowing them to discover and create explicit and implicit relationships between people, places, and events.

Although a lot of digital tools have already been developed for supporting digital humanities research; however, a real-time social network analysis tool to provide a friendly interaction interface and effectively assist digital humanists in the digital humanities research with character social networks analysis is still lacked. For this reason, the CSNRMT that can semi-automatically identify character names from texts based on a character names lexicon supported with China Biographical Database (CBDB) and provide easy-to-use real-time interaction interface for supporting digital humanities research was developed on an ancient book digital humanities research platform so that digital

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humanists could more efficiently and accurately establish character social network relationships in the analyzed texts to explore complicated character social networks supporting digital humanities research, this study intends to evaluate the system effectiveness in promoting the number of interpreting characters and the number of interpreting character social relationships, technology acceptance, user behavior, and opinions of digital humanists using such a tool to explore character social network relationships for supporting digital humanities research and propose the further development directions, according to the research results, to improve the system. This study provides contributions on the development of a novel CSNRMT that can semi-automatically assist digital humanists through human-computer interaction to more efficiently and accurately explore the character social network relationships from Chinese ancient texts for useful research findings.

## 2. Literature review

### 2.1 *Digital humanities research with information technology support*

Traditional humanities research is performed by humanists through interpreting and analyzing a large amount of paper-based literature to find out useful research clues from texts. Along with the advance of information technology, digital technology allows humanists to collect, analyze, and explore text contents more efficiently than interpreting and analyzing a large amount of paper-based literatures to gradually form an emerging research field, "digital humanities." [Berry \(2012\)](#) defined digital humanities as applying information technology to assist humanity's research that it was the application of information technology to humanities. [Martin-Rodilla and Gonzalez-Perez \(2016\)](#) classified the existing works that already developed digital tools to support digital humanities research contain manual approaches, semi-automatic approaches, and automatic approaches. In the manual approaches, digital humanists performed a manual data analysis by using digital tools. In the semi-automatic approaches, digital tools offered suggestions based on data analysis results for digital humanists to further perform data analysis procedures. In the automatic approaches, digital tools automatically performed data analysis based on the computer algorithms for digital humanists to explore new knowledge.

Currently, in the manual approaches, there are some existing systems for manually annotating historical documents that have functions to append information to historical iconographic or text documents to support digital humanities research. For example, [Chen and Tsay \(2017\)](#) proposed a novel collaborative annotation system (CAS) with four types of multimedia annotations including text annotation, picture annotation, voice annotation, and video annotation which can be embedded into any HTML web pages to enable digital humanists to collaboratively add and manage annotations on these pages and provide a shared mechanism for discussing the shared annotations among digital humanists. Their study indicated that the proposed CAS has high potential in the applications of digital humanities research, including discovering the useful knowledge from a large number of annotations on the historical texts based on data mining technologies, exploring a lot of interactive data generated in the collaborative annotation process based on social networks analysis, and recording the operation processes of humanities scholars on the CAS to evaluate humanities scholars' research behaviors. Moreover, [Sato et al. \(2016\)](#) also presented a prototype Web-based system for collaboratively making annotations on historical documents by humanities researchers who are distant from each other. The proposed system can support users to make annotations to the same document simultaneously. Also, [Haslhofer et al. \(2013\)](#) indicated that semantic tagging is a collaborative process in which a user selects and associates Web resources drawn from a knowledge context. Their study

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applied the semantic tagging technique in the specific context of online historical maps and allowed digital humanists to annotate and tag them. Compared to the label-based tagging technique, the semantic tagging technique not only does not affect tag type and category distributions but also leads to higher user satisfaction.

In the semi-automatic approaches, [Picca and Egloff \(2017\)](#) presented a new Python library, The Digital Humanities ToolKit (DHTK), to provide a fast and intuitive tool to exploit the semantic knowledge resources available in the Linked Open Data (LOD). The key features of the DHTK include ease of use, modularity, efficiency, extensibility, and documentation. Also, [Brooke et al. \(2015\)](#) introduced a software tool, GutenTag, which is aimed at giving literary researchers direct access to natural language processing techniques for the analysis of texts in the Project Gutenberg corpus. [Harris et al. \(2014\)](#) presented the anatomy of Samtla, which is an online integrated research environment designed in collaboration with historians and linguists, to facilitate the study of digitized texts written in any language. Samtla is fundamentally different from standard text search/mining systems which rely on the bag-of-words representation of text. In contrast, Samtla emphasizes the retrieval and discovery of fuzzy text patterns/motifs which are of critical importance to digital humanities research. Furthermore, [Pastorelli \(2017\)](#) applied a hierarchical ascendant clustering algorithm to group the manuscripts of the Old Latin witnesses of the Gospel of John into clusters presented with the calculation of distances between readings, then between witnesses to enable the construction of trees illustrating the textual taxonomy obtained.

In the automatic approaches, [Yohan et al. \(2014\)](#) proposed a rule-based name entity recognition and classification system which can automatically recognize name entities in text and assign them with the appropriate categories for Telugu language. Additionally, [Kestemont and Gussem \(2017\)](#) applied a layered neural network architecture from the field of deep learning to automatically solve two sequence tagging tasks including part-of-speech tagging and lemmatization. Their research result shows acceptable performance, which is on par with previously reported studies. Although there have been a lot of digital tools to be successfully developed to support digital humanities research, [Harris et al. \(2014\)](#) argued that there is still a huge gap between what researchers want and the available digital tools in terms of their functionality and usability based on assessing the experience of historians using digital tools for digital humanities research. Moreover, there has not been a digital humanities tool being able to assist digital humanists in extracting character social network relationships from historical word patterns and effectively precede research on character social network relationships. The CSNRMT for supporting digital humanists to interpret character social network relationships in texts was therefore developed on an ancient book digital humanities research platform in this study, expecting to enhance the effectiveness of digital humanists' digital humanities research.

In recent years, increasing effort has been made not only to make digital texts and tools available but also to create complete virtual research environments (VREs) that provide interpretative frameworks for making sense of cultural artifacts ([Steiner et al., 2014](#); [Chen and Chang, 2019](#)). Such VREs support conceptualizing, visualizing, and analyzing information, as well as digital humanists can collaboratively work on it. VREs usually do not consist of one monolithic technology, but cover a collection of tools assembled in one place to assist research tasks and processes ([Steiner et al., 2014](#); [Chen and Chang, 2019](#)). Among the developed digital humanities platforms, [Steiner et al. \(2014\)](#) presented the CULTURA system that included personalized search tools, faceted search tools, annotators, social network visualization tools, and recommenders to support digital humanities research. Additionally, the TextGrid is a virtual research environment that provides services for supporting researchers in the analysis of text data and the curation of research data through grid technology ([Neuroth et al., 2011](#)). The Taiwan Historical Digital Library (THDL) covers about 80% of all primary Chinese historical materials about Taiwan before 1895. The primary functions of THDL for

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supporting digital humanities research include full-text search, techniques, and interfaces for classifying and exploring a query result as a sub-collection, term frequency analysis, and referential tools (Chen *et al.*, 2007). However, digital humanities platforms developed around the world that have provided character social networks analysis tools to support digital humanities research are still lacked. This study thus develops an ancient book digital humanities research platform with an emerging CSNRMT to semi-automatically support digital humanists to perform digital humanities research.

### *2.2 Applications of social networks analysis in digital humanities research*

Social networks originated from Barnes' (1954) Human Relations aim to represent the social relationship concepts of social scientists or the general public to systematically present the relationship model by using graphs with actors, relationships, and linkages. Wasserman and Faust (1994) defined social network analysis as a method in sociology, mainly searching for potential social network structure from the interaction model between the social actors, relationships, and linkages. Namely, social networks are composed of actors, relationships, and linkages (Hanneman and Riddle, 2005). Actors are the nodes in a social network. A node, as the basic unit of a social network, represents an individual, an organization, or a company; meanwhile, it is the body of the social network. A relationship refers to a certain type of attribute and is represented by linkage among actors due to message exchange or interaction. In social networks, a line stands for the linkage (i.e. relationship) among nodes. Relationships could also be divided into directed and undirected; different social networks would be constructed along with various relationship types.

Moretti (2011) applied social networks theory to the plot analysis of texts. Social networks analysis was utilized for transferring space and time structure, and core roles in narrative texts into a network structure map. Sides and nodes were used for forming the social networks in plots. The network map would change with the development of plots, allowing researchers easily to understand the relationship and plot changes in the text for deeper exploration. Moretti (2011) found out the key character, Horatio, through the social networks of Shakespeare's *Hamlet*, and discussed the context from the social networks of Horatio. Zhao (2016) also studied the character social networks in Li Wei's *Big Wave* and the changes of story plots with such an idea. Moreover, Jackson (2017) used social networks analysis to identify an additional role played by Duncan II, Earl of Fife and applied the social network density model to identify opinion leaders in medieval Scotland based on the People of Medieval Scotland database.

Using social networks analysis to combine multi-source texts can present the life or migration process of characters as well as the time and space context in the entire environment. For example, So and Hoyt (2013) analyzed trans-Pacific literature clubs and literature activities and organized the paths of modernism poetry in 1920 being globally communicated. Liu (2012) analyzed the overseas left publications of Taiwan and presented some overseas Taiwanese people's political thoughts with the map of the social networks. Jin *et al.* (2016) studied the changes of crowds' concepts in *La Jeunesse*, analyzed the change of keywords, and utilized concept network maps for presenting the process of *La Jeunesse* turning from liberalism to Marxism-Leninism. The "Mapping the Republic of Letters" website of Stanford University presented the social networks formed by enlightenment intellectuals through letter exchange (Mapping the Republic of Letters, 2008). CBDB (China Biographical Database) provided open versions of the database for researchers' download so that researchers could input the data, from the aspect of prosopography, into the social networks analysis software for analyses to understand the social relationships among characters. With prosopography, Yeh (2017) also analyzed Kuomintang publication, *Women's Resonance*, and a commercial publication, *Women's Magazine*, with social networks analysis to explain the differentiation and cooperation in Kuomintang.

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The above literature review revealed the importance of social networks analysis to digital humanities research. The CSNRMT on the ancient books digital humanities research platform for supporting digital humanities research was therefore developed in this study. The CSNRMT generated by identifying the character names and relationships from the texts could be observed via human-computer interaction of clicking on a character node to assist digital humanists in exploring character social network relationships. The effectiveness of the system to the support of digital humanities research was examined through actual experiments.

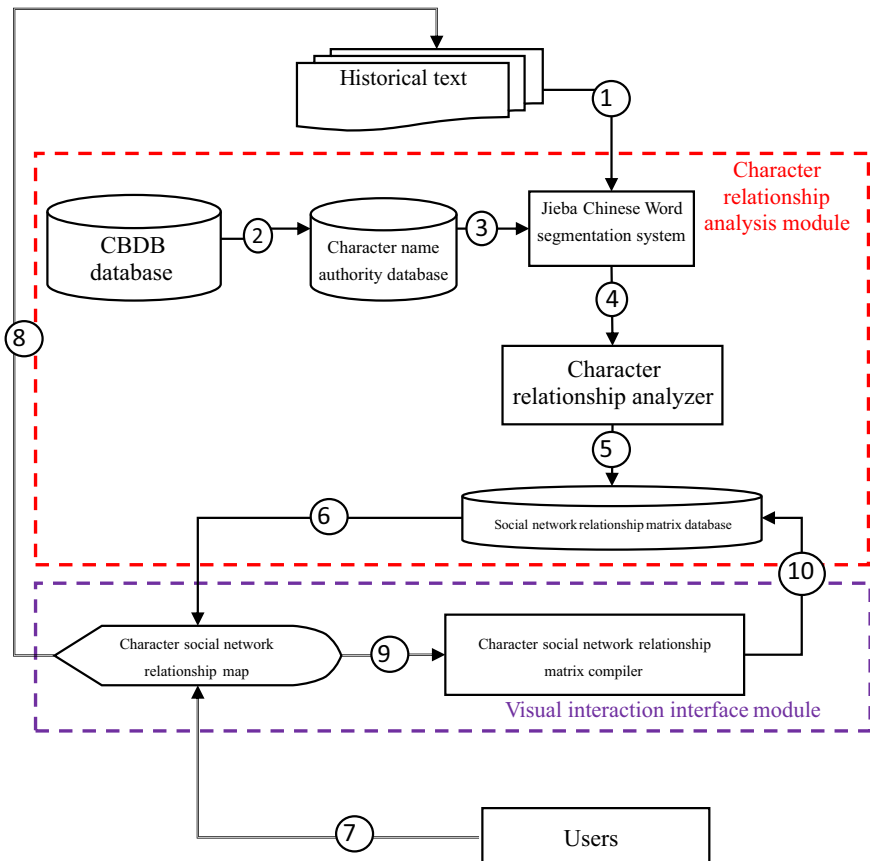
### *2.3 Evaluation of digital humanities research tool in terms of system effectiveness and technology acceptance*

Although a lot of DH tools have already been developed for supporting DH research, many of these tools do not properly fit the needs of the digital humanists due to technical difficulties or scientific objectives (Picca and Egloff, 2017). Furthermore, digital humanists of different domains have considerable differences in their knowledge of the collections, requiring varying levels of support, and every individual humanist has their particular interests and priorities (Chen and Chang, 2019). Therefore, the evaluation of digital humanities research tool in terms of system effectiveness based on user study plays a very important role in the function and user interface improvement of DH tools. However, relatively few studies have paid attention to the evaluation of digital humanities research tools based on a user study. Based on a quasi-experimental design, Chen *et al.*'s study (2019) evaluated the difference between the developed automatic text annotation system (ATAS) and MARKUS semi-ATAS in the system effectiveness of the reading effectiveness and technology acceptance while supporting digital humanists to interpret the ancient text of the Ming dynasty's collections. Additionally, a lag sequential analysis was also used to analyze users' operation behaviors on the ATAS. Moreover, to understand the research participants' perception when interpreting the historical texts and characters' social network relationships with the support of a Chinese ancient books digital humanities research platform (CABDHRP), semi-structured interviews with 21 research participants were conducted by Chen and Chang's study (2019).

Technology Acceptance Model (TAM) proposed by Davis (1986) according to Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975) aims to examine users' use attitude and behavior intention of using information systems. In rational behavior, it was argued that users would determine the usage behavior of an information system according to the behavior intention, user attitude, and subjective norm. Davis (1986) indicated that user attitude, in the use of information systems, presented larger effects on users' behavior intention than the subjective norm. In this case, TAM mainly focused on the effect of user attitude on users' behavior intentions. In TAM, users' use attitude would be affected by "perceived usefulness" and "perceived ease of use." The former refers to a user subjectively regarding that the use of specific products would enhance his/her work performance. When technology products were easier to use, users could complete more tasks with higher work performance. Perceived ease of use refers to subjective consideration of the operation difficulty of specific technology products. The combination of the two was considered as users' internal beliefs (Davis *et al.*, 1989) as well as the major factor in users' information technology acceptance. Furthermore, perceived usefulness and perceived ease of use would generally be affected by external factors of system characteristics and personal traits. In sum, the overall TAM could be divided into an external variable, internal belief, attitude, behavior intention, and actual use of technology.

A lot of past research evaluated information systems with TAM to understand users' information technology acceptance and use attitude (Adams *et al.*, 1992; Ha and Stoel, 2009; Hu *et al.*, 1999; Vijayasarathy, 2004). TAM used in digital humanities was mainly regarded as

an evaluation tool to evaluate the perceived usefulness and perceived ease of use of a database or digital tool. For example, [Kemell \(2016\)](#) discussed historians' use attitude towards a historical database, with TAM and semi-structured interviews, and concluded 15 factors in historians' perceived usefulness and perceived ease of use about the use of a historical database. [Hong \(2011\)](#) used TAM for evaluating Taiwan e-Learning and Archives System and found out the major factors affecting the usability of the system user interface. [Chen et al. \(2019\)](#) evaluated the difference in digital humanists' use of the automatic text annotation system for supporting digital humanities research and MARKUS semi-automatic text annotation system by using TAM. Their research results showed that the automatic text annotation system outperformed the MARKUS semi-automatic text annotation system on perceived ease of use, revealing that the automatic annotation system was more easily used than the MARKUS semi-automatic text annotation system. From the dimensions of users' perceived usefulness and perceived ease of use, this study intends to understand digital humanists' attitude and intention towards using the CSNRMT to support digital humanities research through TAM.



**Figure 1.**  
The system  
architecture of  
CSNRMT

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### 3. System design of the proposed CSNRMT

#### 3.1 System architecture

The system architecture of the CSNRMT developed on the ancient book digital humanities research platform in this study is shown in [Figure 1](#). The overall system architecture is divided into two parts including the character relationship analysis module and visual interaction interface module. The character relationship analysis module aims to identify character names in texts based on the character name authority file from China Biographical Database (CBDB) and Jieba Chinese word segmentation to establish the social relationship matrix of character names. The visual interaction interface module aims to visualize character names' social relationships to establish the character social networks relationship map and allows users to proceed character social network relationship edition by referring to the character social networks relationship map and historical texts.

#### 3.2 System components of CSNRMT

The character relationship analysis module composed of Jieba Chinese word segmentation system, CBDB, character relationship analyzer, character name authority database, and social network relationship matrix database between characters can identify the character social network relationship based on historical texts. All the components composed of the character relationship analysis module are explained as below.

(1) The Jieba Chinese word segmentation system

The Jieba Chinese word segmentation system that is an open-source system was used in this study for Chinese word segmentation. The Chinese word segmentation principle used in Jieba is based on a prefix tree structure to generate vocabulary which is possible to become words. Moreover, the Hidden Markov Model is used for judging the probability of vocabulary combination and a dynamic programming algorithm is applied to find out the path for the most probable vocabulary combination. Such a path is the optimal word segmentation based on the lexicon in Jieba Chinese word segmentation system. Character name authority information recorded in CBDB was added to the lexicon in Jieba Chinese word segmentation system in this study to identify character names from the historical texts.

(2) China Biographical Database (CBDB)

CBDB, collaboratively developed by Academia Sinica, Harvard University, and Peking University, mainly collects the important character biographic data in Chinese history. The database contents are free and open for academic use of biography reference, statistical analysis, and space analysis. It currently collects the character biographic information within the 7th – 19th century in China, about 370,000 characters.

(3) The character name authority database

The character name authority database is established with the characters recorded in CBDB to support character name recognition in texts by using the Jieba Chinese word segmentation system.

(4) Character relationship analyzer

The historical text, after the Chinese word segmentation, is analyzed the social network relationships between characters. In this component, the system automatically establishes a rule to judge the characters' social network relationships. Namely, a linkage between two character names simultaneously appearing in a certain number of words of a historical text is first established as an unknown relationship for digital humanists' further confirmation. The number of words is currently set within 20 words in the system.

## (5) Social network relationship matrix database between characters

The social network relationship matrix database between characters is determined by the character relationship analyzer to show the corresponding character social network relationship map.

The visual interaction interface module composed of the character social network relationship matrix compiler and character social network relationship map can visualize the character social network relationships appearing in texts so that digital humanists could observe them for research findings. All the components composed of the visual interaction interface module are explained as below.

## (1) Character social network relationship map

The character social network relationship map could provide a social network relationship map with character names to help digital humanists view the social network relationships between characters and refer to the text contents of the historical text to determine the relationships. When a user clicks on a character name in the character social network relationship map, the texts with the character name are displayed on the historical text reading interface.

## (2) Character social network relationship matrix compiler

The character social network relationship matrix compiler is mainly used for editing or revising character social network relationships. Digital humanists could revise questioned character social network relationships according to their knowledge or after reading the text, which would be synchronically displayed on the user interface of the character social network relationship map.

### 3.3 System operation processes of CSNRMT

The system operation processes of the CSNRMT are explained as follows.

- (1) The historical texts have to be processed with Chinese word segmentation so that the vocabularies appearing in the analyzed texts can be identified for further analyses of character names and social network relationships because there are no obvious separation signs or space between Chinese words.
- (2) Character names collected in CBDB are used for identifying characters appearing in texts in this study. Information about character, such as ID, autonym, alias, official title, and posthumous is extracted from the CBDB to establish the character name authority database.
- (3) During performing Chinese word segmentation, vocabulary and its corresponding part of speech recorded in the lexicon of the Jieba Chinese word segmentation system are the references for identifying vocabularies in texts. The character authority database established at the previous stage is added to the lexicon of the Jieba Chinese word segmentation system and given an exclusive part of speech code to enhance the character names identification accuracy and authority in the analyzed texts.
- (4) Character names identified from historical texts, after performing Chinese word segmentation, could be output to the character relationship analyzer for analyzing the character names and social network relationships. Social network relationships in this system are identified as unknown if two character names simultaneously appear within a certain number of words in an analyzed text. The relationship judgment is determined by a digital humanist based on reading the historical texts

- with the two character names and searching for the related information about the two characters through the external search functions provided by the system.
- (5) Character names' social network relationships established in the character relationship analyzer are transformed into the character social network relationship matrix database for storage.
  - (6) The character social network relationship map is drawn according to the character social network relationship matrix database established at the previous stage to visualize the social network relationships among character names in the analyzed texts for the reference of digital humanists.
  - (7) A user could select a collection to observe the character's social network relationship map for interpreting the characters' social network relationships in the analyzed texts.
  - (8) A user could browse the character's social network relationship map and the text showing in the reading interface for accurately interpreting the characters' social network relationships.
  - (9) Digital humanists could append and revise the character social network relationships with the character social relationship matrix compiler to confirm the correct character social network relationships.
  - (10) Information compiled with character social network relationship matrix compiler would update the contents of the character social network relationship matrix database. Meanwhile, the visual interface would re-generate a new character social network relationship map.

### 3.4 System user interface and functions

The CSNRMT developed on the ancient book digital humanities research platform provides a friendly user interface and functions that include the character social network relationship map, reading interface, external search, and notebook to allow digital humanists to interpret characters' social network relationships in the text interpretation process. The overall system interface of the CSNRMT is shown in Figure 2 and each function marked with a number is explained as below.

The screenshot shows the CSNRMT interface. At the top, there is a search bar with a magnifying glass icon and a search button. Below the search bar, there is a navigation menu with options like '通用型人物關係分析工具' and '第二階段(A)'. The main content area is divided into two columns. The left column contains a social network relationship map (1) with nodes and connecting lines, and a notebook (4) with a text input area. The right column contains a search results page (2) with a search bar and a list of results, and a text display area (3) showing a snippet of text from a book.

Figure 2. The overall system interface of the CSNRMT





Figure 5. The editing interface of character social network relationship



Figure 6. The reading interface of text

reading interface for the user to analyze character social network relationships. Marking a searched word with a mouse could link with the external search function for inquiry. Detailed operation mechanisms are explained in the text search and external search.

(3) The user interface of text search and external search

The text search allows users to search for characters or vocabularies in texts and then highlight them on the texts. The external search allows users to search for required information through the external databases for interpreting character social network relationships in texts. It provides various external linkages of character database, online encyclopedia, search engines, and dictionaries, such as CBDB, Moedict, Wikipedia, Baidu Baike, Google, Zdic, dictionary of Chinese Character Variants, and Kangxi Dictionary as shown in Figure 7. A user simply marks a word in the text, and the word is automatically filled in the external search box for searching.

(4) The user interface of the notebook

The user interface of the notebook shown in Figure 8 allows users to record the information found during the process of interpreting a text, expecting that users could reduce the time for switching between windows to efficiently complete the interpretation of character social network relationships under a single interface.

#### 4. Research methodology

##### 4.1 Research design

To examine the effects of the CSNRMT developed on the ancient book digital humanities research platform on assisting digital humanists in digital humanities research, a counterbalanced design was adopted in this study to compare the system effectiveness of the research participants in the experimental group and control group on interpreting character social network relationships in texts by using the ancient book digital humanities



Figure 7.  
The user interface of  
external search

**Figure 8.**  
The user interface of  
the notebook

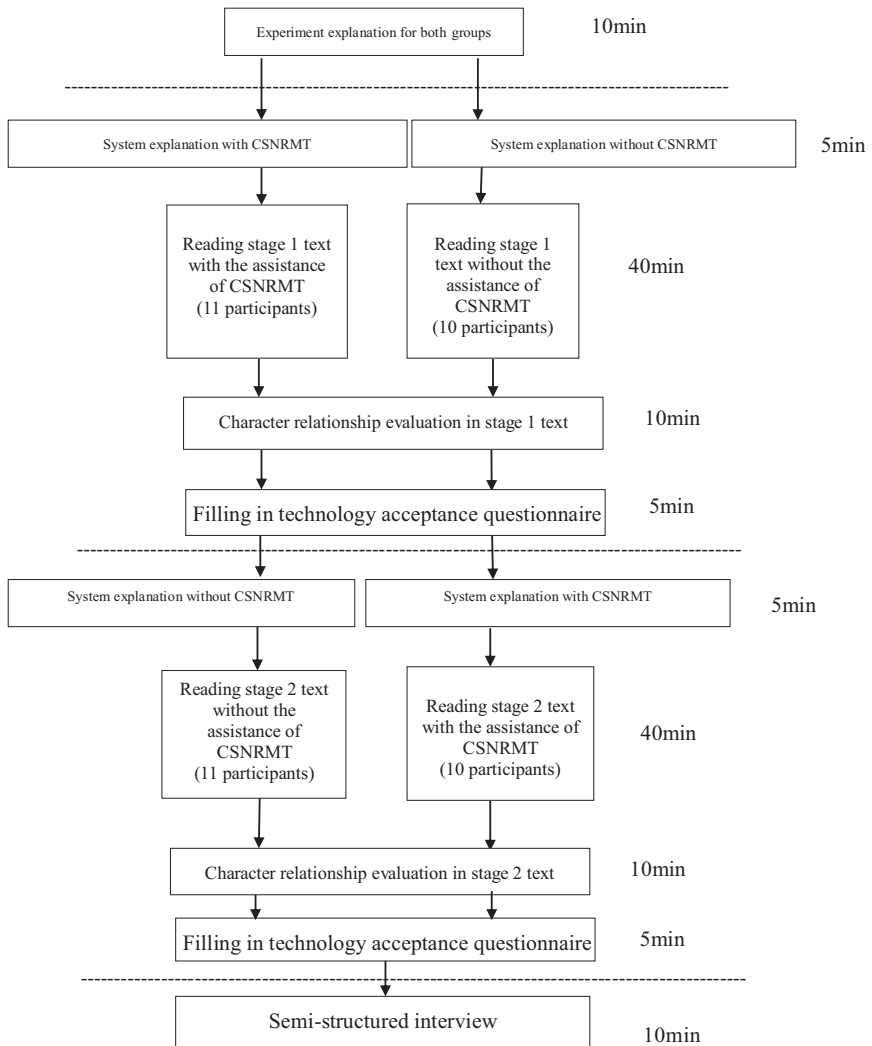
research platform with and without the CSNRMT support. The ancient book digital humanities research platform with the CSNRMT support contains all the functions mentioned in [section 3.4](#), whereas the ancient book digital humanities research platform without the CSNRMT support only has the functions of the reading interface of text, the user interface of external search, and the user interface of the notebook, but lacks the functions of the user interface of the character social network relationship map and editing interface of character social network relationship. Furthermore, the research subjects were also invited to fill in the technology acceptance questionnaire after the experiment to understand the users' technology acceptance of using the CSNRMT developed in this study to explore character social network relationship. It was expected to understand the research subjects' perceived usefulness and perceived ease of use of the system when using the CSNRMT to support digital humanities research. Moreover, to make up for the shortage of quantitative analysis, a semi-structured in-depth interview was preceded to collect qualitative data after the research subjects completed the entire experiment. Finally, to understand the users' behaviors of using the CSNRMT to explore the character social network relationship in texts, the system's operation behaviors of the research participants were encoded with time sequence as a series of behavior sequence samples, according to the system's functions, for lag sequential analysis.

#### 4.2 Experimental process

A total of four texts with a close number of characters, number of character social network relationships, and length of the paragraph were selected by a historical expert from *Correction of Poetry of Mr. Ju Ci* in Ming dynasty collections as the experimental texts. The experiment was divided into two stages, and the character social network relationship was respectively interpreted at each stage. The 21 research participants were divided into two groups respectively with 11 and 10 students to crossly use the ancient book digital humanities research platform with and without the CSNRMT and two texts at stage 1 and stage 2 based on a counterbalanced design. In a normal experiment, the order in which treatments are given can affect the behavior of the subjects or elicit a false response, due to fatigue or outside factors changing the behavior of the subjects. To counteract this, a counterbalanced design that reduces the chances of the order of treatment or other factors adversely influencing the results is often used. In other words, a counterbalanced design allows a study to control the effects of nuisance variables in designs where the same participants are repeatedly subjected to conditions, treatments, or stimuli (Allen, 2017). Therefore, the repeated measure ANOVA was used to perform the statistical analysis in this

study because all the research participants alternately and repeatedly experienced the two different systems.

The experimental process of the study based on a counterbalanced design is shown in Figure 9. At the beginning of the experiment, the research participants in the experimental and control groups were respectively explained the experimental process with 10 min and were taught the system operation with 5 min for the system with and without CSNRMT in the stage 1 experiment. Next, the 11 research participants in the experimental and 10 research participants in control groups respectively read the stage 1 text with and without the assistance of CSNRMT for interpreting character social network relationships in the text within 40 min. They then evaluated the character social network relationships in the first text content and then filled in the technology acceptance questionnaire. To consider research ethics, this study arranged a break time of 30 min before the stage 2 experiment. After that,



**Figure 9.** The experimental process of the study based on a counterbalanced design

the study conducted the stage 2 experiment. The 11 research participants in the experimental and 10 research participants in control groups were respectively taught the system operation with 5 min for the system without and with CSNRMT, and then read the stage 2 text without and with the assistance of CSNRMT for interpreting character social network relationship in the text within 40 min. They then evaluated the character social network relationships in the second text content and filled in the technology acceptance questionnaire. After taking a break time of 10 min, the semi-structured interview was preceded to collect the feelings and use satisfactory of interpreting character social network relationships with and without the assistance of CSNRMT from each research participant. The total experiment time is about 140 min.

#### 4.3 Research subjects

The research participants are the students who can interpret the ancient texts of the Ming dynasty and explore character social network relationships. In consideration of cost, time, and location, a total of 21 students of Departments of Chinese Literature and History in a national university in Taipei City, Taiwan, who were willing to participate in the experiment, were sampled. The 21 students contain 3 undergraduate students (male 1; female 2) aged from 21 to 22, 14 graduate students (male 7; female 7) aged from 23 to 26, and 4 doctoral students (male 3; female 1) aged from 30 to 38.

#### 4.4 Research tools

*4.4.1 The CSNRMT in the ancient book digital humanities research platform.* The CSNRMT developed on the ancient book digital humanities research platform could identify character names in texts, preliminarily establish character social network relationships, and provide character social network relationship matrix compiler to help humanists revise and confirm character social network relationships in texts. The effectiveness of humanists using such a tool for interpreting character social network relationships through texts is examined in this study.

*4.4.2 Technology acceptance questionnaire.* Referring to the technology acceptance questionnaire compiled by [Hwang et al. \(2013\)](#) and revising the sentences to conform to the needs of this research, Likert's 6-point scale was utilized. The questionnaire contains two major dimensions of "perceived usefulness of system", a total of 6 questions, and "perceived ease of system use", a total of 7 questions. Regarding the reliability of the questionnaire, [Hwang et al. \(2013\)](#) confirmed that the Cronbach's  $\alpha$  values are respectively 0.95 and 0.94 in the dimensions of "perceived usefulness of system" and "perceived ease of system use." Both dimensions present favorable reliability. After the experiment, the research subjects were invited to fill in the questionnaire to realize the technology acceptance of using the ancient book digital humanities research platform with and without the CSNRMT support for digital humanities research.

*4.4.3 Google Analytics.* Google Analytics, a website analysis platform developed by Google, could be embedded with specific programming codes written by JavaScript into a webpage to record the use processes from users. Google Analytics was applied in this study to record the micro-behaviors of the research subjects interpreting character social network relationship with the CSNRMT support in the ancient book digital humanities research platform and output the records for lag sequence analysis at the data analysis stage. The format of each micro-behavior includes actor, verb, and object and has a corresponding timestamp. Each micro-behavior that contains an actor, verb, and object is called as a statement. The actor is the executor of behaviors and could be an individual or a group, for example, a user. The verb is the type of action performed by the actor, for example, clicked on or logged in. The object interacts with a actor, with activity as the unit, for example, a certain

system's function. Google Analytics based on Cloud BigTable was used as the user micro-behavior database in this study. The technology presents the advantage of high-efficacy NoSQL macro-database service and is free. The users' micro-behaviors stored in the user micro-behavior database were extracted to perform the user behavior analysis based on lag sequential analysis herein.

#### 4.5 Interview procedure

Aside from examining the effectiveness and technology acceptance of adopting the ancient book digital humanities research platform with and without the CSNRMT to explore the characters and character social network relationships, semi-structured interviews were conducted for all the research participants in the experimental and control groups to help collect some additional feedback about the system performance that might not have been collected with the quantitative study. With the flexibility inherent in a semi-structured interview, the interviewer reused or repurposed questions to obtain in-depth information on the perspectives and personal experiences of each interviewee. The interview questions contained the explanations of the difference between using the ancient book digital humanities research platform with and without the CSNRMT to explore the characters and character social network relationships. The interview questions were designed by this study by referring to [Chen et al.'s study \(2019\)](#). The interview questions include "Is the CSNRMT helpful in assisting you to explore character social network relationships", "Is there any difficulties or questions when using the functions in the system", "Is the overall system function design clear and understandable", "Is the user interface designed in the system perceived usefulness and ease of use", and "Are there any opinions or suggestions for the continuous development of the system", and so on.

## 5. Experimental result and analysis

### 5.1 Effectiveness comparison analysis of the number of interpreting characters between both groups

[Table 1](#) shows the repeated measure ANOVA result of the number of interpreting characters in both groups. Analytical results show there is no significant difference in the number of interpreting characters between both groups ( $F = 1.52, p = 0.231 > 0.05$ ). However, the mean of the number of interpreting characters in the experimental group with CSNRMT support is higher than the control group without CSNRMT support.

### 5.2 Effectiveness comparison analysis of the number of interpreting character social relationships between both groups

[Table 2](#) presents the repeated measure ANOVA result of the number of interpreting character social relationships in both groups. Analytical results show there is no remarkable difference

**Table 1.**  
Repeated measure ANOVA result of interpreting the number of characters in both groups

Group	Number	Mean	Standard deviation	<i>F</i>	Significance (two-tailed)
Experimental group	21	11.80	11.28	1.52	0.231
Control group	21	9.19	7.53		

**Table 2.**  
Repeated measure ANOVA result of interpreting the number of character social relationships in both groups

Group	Number	Mean	Standard deviation	<i>F</i>	Significance (two-tailed)
Experimental group	21	3.14	2.65	0.06	0.806
Control group	21	3.00	1.73		

between both groups ( $F = 0.06, p = 0.806 > 0.05$ ). Nonetheless, the mean of the number of interpreting character social relationships in the experimental group with CSNRMT support is higher than the control group without CSNRMT support.

5.3 Difference analysis of technology acceptance between both groups

Table 3 reveals the repeated measure ANOVA result of the technology acceptance of both groups, where the technology acceptance in the experimental group with CSNRMT support notably outperforms the control group without CSNRMT support ( $F = 10.57, p = 0.004 < 0.05$ ). Such a result shows that the research participants present a significantly higher acceptance attitude on interpreting characters or character social relationships in the text with CSNRMT support. Table 4 shows the repeated measure ANOVA result of perceived usefulness in technology acceptance, where the perceived usefulness of technology acceptance of both groups achieves significant difference ( $F = 9.28, p = 0.006 < 0.05$ ). The experimental group with CSNRMT support remarkably outperforms the control group without CSNRMT support. Table 5 shows the repeated measure ANOVA result of perceived ease of use in technology acceptance of both groups, where the perceived ease of use in technology acceptance of both groups reaches the notable difference ( $F = 4.99, p = 0.037 < 0.05$ ). The experimental group with CSNRMT support significantly outperforms the control group without CSNRMT support.

5.4 The user behavior statistics of the research participants in the experimental group

The importance of understanding the users' behaviors is to examine what functions designed in the CSNRMT were frequently used in assisting the research subjects to interpret character social network relationships. The user behavior statistics of the research participants in the experimental group is shown in Table 6, in which the top three functions are examining text with a character name, clicking on character node in the character social network relationship map, and editing note; and, the top three external search linkages appear Google, Wiki, and CBDB.

Group	Number	Mean	Standard deviation	F	Significance (two-tailed)
Experimental group	21	4.66	0.75	10.57**	0.004
Control group	21	4.00	0.79		

**Note(s):** \*\*indicates  $p < 0.01$

**Table 3.** Repeated measure ANOVA result of technology acceptance of both groups

Group	Number	Mean	Standard deviation	F	Significance (two-tailed)
Experimental group	21	4.03	0.99	9.28**	0.006
Control group	21	3.04	0.94		

**Note(s):** \*\*indicates  $p < 0.01$

**Table 4.** Repeated measure ANOVA result of perceived usefulness of technology acceptance of both groups

Group	Number	Mean	Standard deviation	F	Significance (two-tailed)
Experimental group	21	5.20	0.75	4.99*	0.037
Control group	21	4.81	0.89		

**Note(s):** \*indicates  $p < 0.05$

**Table 5.** Repeated measure ANOVA result of perceived ease of use of technology acceptance of both groups

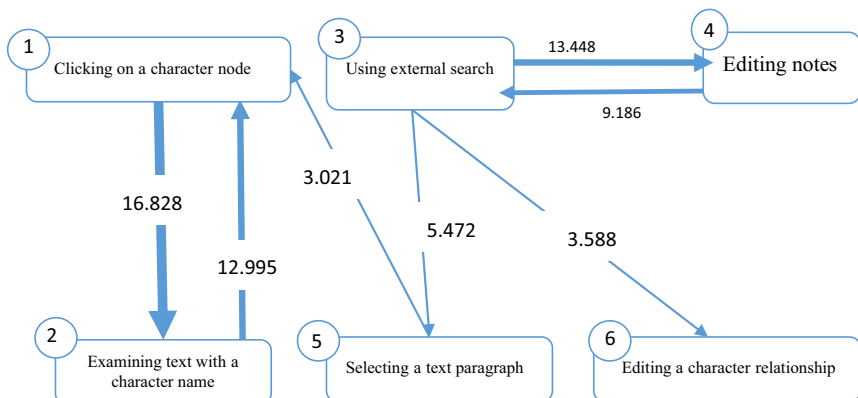
**Table 6.**

The user behavior statistics of the research participants in the experimental group

Event coding	Number of appearances	Appearance percentage
Examining text with a character name	917	35.7%
Clicking on a character node in the character social network relationship map	888	34.5%
Editing notes	266	10.3%
Google search	194	7.5%
Selecting a text paragraph	115	4.5%
Wiki search	60	2.3%
Editing a character relationship	36	1.4%
CBDB search	35	1.4%
Moedict search	23	0.9%
Baidu search	14	0.5%
Zdic search	14	0.5%
Dictionary of Chinese Character Variants search	6	0.2%
Kangxi Dictionary search	4	0.2%
Total	2,572	100.0%

### 5.5 The user behavior sequential analysis of the research participants in the experimental group

The lag sequential analysis enables one to explore and summarize cross-dependencies occurring in complex interactive sequences of behavior (Bakeman, 1986). This method has become an important tool for exploring users' behaviors of operating an information system. To analyze the behavioral transfer of the research participants who used the CSNRMT to interpret character social network relationship, the system's operation micro-behaviors of the research participants in the experimental group were encoded with time sequence for a series of behavior sequence samples, according to the system's functions, for lag sequential analysis. To perform the lag sequential analysis, the number of samples in sequential analyses was calculated by the frequency of the neighboring pairs of behaviors. The zero-order model proposed by Bakeman (1986) was used to calculate the  $Z$  score. The calculation is suitable for samples with a non-normal distribution when the probability of sequence is equal. A  $Z$  score that is higher than 1.96 indicates that the sequence presents remarkable coding transfer. That is, the research participants with an obvious behavioral transfer in the system's operation could be observed, and a high  $Z$  score indicates a larger behavioral transfer compared to a low  $Z$  score. Figure 10 shows the users' behavior transfer map of the



**Figure 10.** Users' behavior transfer map of the research participants using CSNRMT to interpret historical character social network relationship based on lag sequential analysis

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research participants using CSNRMT to interpret historical character social network relationships based on the lag sequential analysis.

Numbers 1–6 in Figure 10 show various system operation behaviors in the CSNRMT, where the arrows stand for the transfer between behaviors, the line would be wider when behavior transfer is more obvious, the value on the arrow line is  $Z$  score, which shows the behavior transfer achieving the significance when a  $Z$  score is larger than 1.96. The sequential behavior transfer results are explained as below.

(1) Clicking on a character node in the character social network relationship map

The behavior transfer of from examining text with a character name to clicking on a character node in the CSNRMT achieves the significance ( $z = 12.995 > 1.96$ ), revealing that a lot of participants would use the character social network relationship map in the CSNRMT after examining text with a character name. Besides, the behavior transfer of from selecting a text paragraph to clicking on characters in the character social network relationship map reaches the significance ( $z = 3.021 > 1.96$ ), showing that lots of participants would click on the character node in the character social network relationship map after selecting a text paragraph.

(2) Examining text with a character name

The behavior transfer of from clicking on a character node in the character social network relationship map to examining text with a character name achieves the significance ( $z = 16.828 > 1.96$ ), presenting that many participants would search for the locations of characters in the text paragraph with full-text search function after clicking on a character node in the character social network relationship map. Combining with the previous first point, it was discovered that most participants would transfer back and forth examining text with a character name and clicking on a character node in the character social network relationship map. The result shows that most of the participants knew determining character relationships should refer to the text with a character name.

(3) Using the external search

The behavior transfer of from editing note function to using the external search reaches the significance ( $z = 9.186 > 1.96$ ), showing that a lot of participants would interpret the text or questions with an external search after recording notes.

(4) Editing notes

The behavior transfer of from using external search to editing notes achieves the significance ( $z = 13.448 > 1.96$ ), revealing that lots of participants would use the note function to record the conclusion or answer after using the external search function. The result shows that the function of editing notes is helpful in the processes of interpreting character relationships. By analyzing with the previous third point, it was discovered that most participants would alternatively use the external search and edit note function for recording useful information during the analysis of character social network relationships.

(5) Selecting text paragraph

The behavior transfer of from using the external search to selecting a text paragraph reaches the significance ( $z = 5.472 > 1.96$ ), presenting that many participants would switch a text paragraph after using the external search.

(6) Editing a character relationship

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The behavior transfer of from using external search to editing a character relationship in the character social network relationship map achieves the significance ( $z = 3.588 > 1.96$ ), revealing that a lot of participants would edit character relationships in the character social network relationship map after using the external search. Namely, the key behavior of editing a character relationship in the character social network relationship map is using external search, not examining text with a character name. The result reveals the importance of using the external search to assist users to determine character relationships.

### *5.6 Interview analysis*

To understand the participants' perception when interpreting the historical character social network relationships with the support of CSNRMT, the semi-structured interviews were preceded with the 21 research participants. First, most interviewees expressed that the CSNRMT developed in this study presents an understandable system interface, clear marks among function blocks, and mutual reference among functions so that they could proceed with text reading, character social network relationship interpretation, external search, and note on the same page without leaving from the page. This study thus concluded that the research participants agreed that the entire interface of CSNRMT is clear to understand, the functions are clearly marked, and the operation process is instinct and user-friendly. Second, compared to without the CSNRMT support, most interviewees agreed that the CSNRMT could present possible characters and the relationships in the text to help them explore the historical characters' relationships before interpreting the text so as to understand the possible relationships mentioned in the text and allow users to not miss characters and the relationships in the text interpretation process. This study thus concluded that the research participants agreed that the information provided by the CSNRMT could help users interpret characters and their relationships in the text. Third, many interviewees expressed that some characters in other dynasties would be identified as the characters in the Ming dynasty in the character social network relationship map. For instance, the first founder of a dynasty in a text paragraph refers to the first founder of the Song dynasty, rather than one of the Ming dynasty, that it would seriously affect the effectiveness of interpreting character social network relationships in the text. In short, the research participants thought that the cross-dynasty difference in the names of people should be solved. Fourth, some interviewees indicated that characters named Hsiung sir and Chang sir in the text, which could not be presented their character social network relationships in the currently developed character social network relationship map because they are the short forms of two-character names; however, such characters might play critical roles in the character social network relationship map. Namely, the research participants thought that substitutions and alternatives of character names in the text should be identified. Fifth, lots of interviewees indicated that the system could search characters through various external search functions, including Wikipedia and CBDB, to largely assist in interpreting characters or character social network relationships in the text. In other words, the research participants thought that the external search function could help better understand character information and character social network relationships during interpreting character social network relationships. Sixth, the text search function provided by the system allows users to click on characters in the character social network relationship map to rapidly mark the location of characters in the text. It also allows users to find out vocabularies in the text for interpreting character social network relationships. Restated, the text search function allows users to rapidly find out the required characters or vocabularies. Seventh, the note function and the reading interface developed in the CSNRMT are presented on the same interface, allowing users to read texts and make notes at the same time to reduce the switch back and

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forth the reading text and note interface. They therefore could pay more attention to interpreting character social network relationships in the text. In other words, the note function provided by the system could enhance the speed of text interpretation.

## 6. Discussion

With the repeated measure ANOVA to analyze the difference between the ancient book digital humanities research platform with and without the CSNRMT support in the effectiveness of the number of interpreting characters and character social network relationships in the text, the ancient book digital humanities research platform with the CSNRMT support presents higher system effectiveness than the one without the CSNRMT support but does not reach the statistical significance. The result shows that the development of the CSNRMT in assisting digital humanists to interpret historical character social network relationships still needs to be enhanced in the future. Additionally, the repeated measure ANOVA was applied to analyze participants' technology acceptance in interpreting the character social network relationship with and without CSNRMT support. The results reveal remarkable differences in technology acceptance, where the technology acceptance of the ancient book digital humanities research platform with CSNRMT is significantly higher than the one without CSNRMT. More importantly, "perceived usefulness" and "perceived ease of use" in technology acceptance with CSNRMT appear significantly higher than those without CSNRMT. Such a result is consistent with many participants' interview that the CSNRMT could help interpret character social network relationships in the text, the system interface is user-friendly and easy to use, and there are definite marks among function blocks.

Currently, the character information and relationship provided in the CSNRMT focus on characters in the Ming dynasty collected in CBDB, and character names are identified with lexicon comparison. Some participants indicated that the names of characters would be wrongly interpreted to appear interference. Moreover, some other participants indicated that some characters before the Ming dynasty are not displayed in the system, while such characters might be critical characters in the text or present primary character social network relationships. Also, the problem of cross-dynasty same names might result in mistakes. For instance, an interviewee mentioned that the first emperor of the Song dynasty was identified as the first emperor of the Ming dynasty due to the same posthumous name. Furthermore, the characters in the Ming dynasty collected in CBDB are mainly Jinshi in imperial exams or officials, while collections in the Ming dynasty are broad and diversified that some characters in Ming dynasty collections are not recorded in CBDB. Such a point is proven in the interview and user behavior process records. Several interviewees expressed that if characters cannot be searched in CBDB, then they could use Google or Wikipedia for assistance. The most number of linkages of external search in the behavior process recorder show that Google and Wikipedia are ranked at the top two positions, and CBDB is ranked at the third position. The above problems might be the possible reasons that the ancient book digital humanities research platform with CSNRMT support does not remarkably outperform the one without CSNRMT in interpreting character social network relationships. It also highlights that character social network relationships provided by the CSNRMT should be more accurate and broad to conform to the text characteristics, types, and digital humanists' needs.

Lag sequence analysis was used in this study for analyzing participants' behavior process in the CSNRMT. It was discovered that the behavior transfer between clicking on a character node in the character social network relationship map and selecting a text paragraph achieves the statistical significance, showing that the participants would use this function for searching the locations of characters in a text paragraph. The behavior transfers of from using the external search to editing notes and character relationships in the CSNRMT also

reach the significance statistical, revealing that the participants would record the searched information or edit character social network relationships in the character social network relationship map with the notebook after using the external search. The research subjects also indicated, in the interview, that they need to inspect the information searched from text contents and external linkages to assist in the interpretation of character social network relationships.

Many interviewees mentioned that the user interface of the CSNRMT developed in this study is easy to use, the functions are clearly marked, and the integration among system functions is good. Moreover, “perceived ease of use” in the technology acceptance questionnaire also receives a high score. It particularly receives high satisfactory that clicking on a character node in the character social network relationship map could find out the locations of characters in texts. Furthermore, the micro-process analysis that uses the user behaviors stored in the micro-process behavior recorder also shows the high significance of the behavior transfer that it is commonly used by users.

Several interviewees indicated that the external search being designed on the same page is convenient for use, without leaving from the text page for a search. Furthermore, they could directly make notes or edit character social network relationships in the character social network relationship map with the notebook. The micro-process behavior analysis also presents a remarkable behavior transfer between editing notes and using the external search; and, the behavior transfer of from using the external search to editing a character social network relationship in the character social network relationship map also achieves the statistical significance. Some interviewees regarded that the character social network relationship map is similar to a mind map as well as the visual character social network relationship map allows digital humanists to rapidly grasp the entire historical characters or character social network relationships. The micro-process behavior analysis also shows the notable behavior transfer of clicking on the character social network relationship map after switching the text.

Despite its important contributions, this study has some limitations. First, a total of 21 students of Departments of Chinese Literature and History recruited from a national university in Taipei City, Taiwan, who were willing to participate in the experiment, were sampled to examine the effects of CSNRMT on exploring the character social network relationships from texts in this study. Whether or not the experimental results can be transferred readily to other aged groups or academic background users needs to be further investigated. Therefore, expanding to accommodate a greater diversity of potential system users has been considered as future work. Second, the character name recognition technology used in this study is based on the Jieba Chinese word segmentation system with a character’s lexicon built from CBDB. The effectiveness and technology acceptance of exploring character social network relationships from texts were thus affected by the limited accuracy of recognizing the character names.

## 7. Conclusions and future works

This study develops a novel CSNRMT in an ancient book digital humanities research platform to semi-automatically assist digital humanists through human-computer interaction in more efficiently and accurately exploring the character social network relationships from texts for useful humanities research findings. Analytical results show that the ancient book digital humanities research platform with the CSNRMT support presents higher effectiveness in exploring the character social network relationships from texts than the one without the CSNRMT support, but does not reach the statistical significance. Moreover, it is encouraging that the technology acceptance of using the ancient book digital humanities research platform with CSNRMT to explore the character’s social network relationships from

texts is significantly higher than the one without CSNRMT regardless of the “perceived usefulness” or “perceived ease of use” in technology acceptance. Importantly, the behavior transfer of from using external search to editing character relationship reaches the statistical significance, revealing that using external search is the key step of determining the relationship between characters. Namely, using only texts in the digital humanities research platform sometimes cannot directly provide sufficient information to determine both characters’ relationships. Therefore, seeking more rich databases or text resources related to the solving target problem to enhance external search is needed in the developed CSNRMT. More importantly, to make the developed CSNRMT more practicably, improving the accuracy of recognizing character names from Chinese ancient texts based on natural language processing technologies is the most important issue.

According to the above research conclusions, this study proposed several future works to improve the proposed CSNRMT. Firstly, the development of the CSNRMT should contain social network measure analyses of centrality, structure hole, and the most influential nodes and be able to randomly match different collections for the analysis of character social network relationship to more effectively assist users in finding out character social network relationship or context hidden in the text. Secondly, the character name recognition technology of Ming dynasty collections should be further improved to find out the rules for correctly recognizing character names by using machine learning technology, such as Hidden Markov Model (Bikel *et al.*, 1997) or Conditional Random Field (Gu *et al.*, 2015). Particularly, human-machine collaboration based on active learning (Settles, 2012) could help improve the accuracy of the established character name recognition technology of Ming dynasty collections. Besides, the context correlation between collections is also worth of discussions. Using bibliometrics for analyzing the reference between texts might be able to acquire the character’s social network relationships which cannot be easily discovered in text contents.

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