Content Summarisation of Conversation in the Context of Virtual Meetings: An enhanced TextRank Approach

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***Abstract*— Organisations now frequently rely on virtual collaboration through the use of computer technology. After a sequence of meetings, participants may only need to refer to the most important points rather than the whole meeting proceedings. This paper addresses the need for automated meeting summarisation in virtual meeting systems. An extraction approach to summarisation is adopted and a new algorithm is proposed by extending the TextRank algorithm to include constructs representing the structure of the meeting. This helps extract the most relevant sentences from the meeting transcript. The proposed method was evaluated in the context of student-tutor meetings. Results show that harnessing and utilising the structure of a virtual meeting can lead to more relevant automated summaries.**

Keywords*— virtual meeting summarisation; cscw; structured meeting; TextRank

I. INTRODUCTION

Organisations now frequently rely on virtual collaboration through the use of computer technology. Various collaborative media exist from simple email through to sophisticated telepresence systems [1]. However current systems do not offer sophisticated facilities for structuring and recording meetings in a way that makes for easy recall, minute taking and archiving. A chat-based virtual meeting system has been developed called VRoom [2, 3]. VRoom enables the structure of the meeting to be specified as well as the roles of participants. Constructs to represent structure include: *Agenda*, which lists the items to be discussed; *Role*, which represents the assigned task domain of an actor in the meeting; and *Item*, which represents a topic on the agenda. *Roles* include: *Facilitator*; *Chair*; and *Participant*. *Roles* can also be defined to suit particular meeting protocols such as *Tutor* and *Student* in the case of a tutorial meeting. Such structure serves to provide more direction to the meeting and can subsequently be used to ascribe more meaning to its content. One of the tasks investigated during the development of VRoom has been that of automatic summarisation. The relevance of summarisation is the ability to be able to make a shortened record of the meeting that can be used to recall proceedings at a later date or to offer a digestible account of the proceedings to non-participants. It has been noted previously that the form of a summary may vary according to its purpose [4]. Thus, in VRoom, various policies can be used to create different types of summary. The VRoom summarisation process takes as input the text of the contributions made in the meeting together with information about who said what and when. This information combined with the meeting structure information can be used to support the generation of relevant summaries according to the policies used. One method that has been explored is that of the use of TextRank [5], which exploits the structure of the text to determine key phrases which are central to the text. We combined TextRank with structural information held by the VRoom system in an attempt to produce improved meeting summaries. Our preliminary results show that the use of meeting structure in combination with TextRank produces improves summaries.

The paper is organised as follows. Section II describes related work in virtual meetings and summarisation. Section III describes the VRoom approach to summarisation, while section IV presents the experiment used to evaluate our approach. Section V provides results and discussion. Some some difficulties are discussed in section VI and finally section VII offers some concluding remarks and directions for future work.

II. RELATED WORK

There is relevant related work in two areas: structured support for virtual collaboration; and automated summarisation.

A. Structured support for virtual collaboration

Virtual collaboration is a now frequent activity in many fields of human enterprise. Our previous work found that Skype was the most popular form of virtual meeting interaction in the business world [2]. Skype is a powerful, quick and easy method for conducting meetings but is limited as it does not offer facilities for supporting meeting structure. The same is true for other commercial systems. VRoom was developed to fill the lack of automated support for meeting structure. However some other researchers have also addressed the issue of software support for structure in meetings. We have categorised the efforts into: pre-meeting support; in-meeting support; and post-meeting support. Table 1 summarises the various approaches to structured support for virtual collaboration, also showing the unique features of VRoom. The main innovation of VRoom compared to other systems is the extended development of meeting structure and

the introduction of a summarisation component at the post-meeting stage.

Pre-meeting support

In the area of pre-meeting support, standard computer-supported features are the specification of the date and time of a meeting as well as invitation to specified participants. At a more ambitious level, researchers have investigated the use of technology to support discussion and argumentation in order to help participants understand their stance and that of others on agenda items before the decision-making meeting [6, 7, 8], often using an extension of the IBIS argumentation model [9]. In that research the emphasis was on using a discussion database as a communication channel and agenda items, objectives, tasks, remarks, proposals and constraints were incorporated for use in the ensuing structured discussion. MeetingManager [10] developed at the MIT Artificial Intelligence Laboratory, provided a meeting planner which could be used to create the agenda of the meeting. Later this agenda was used to support the meeting and post-meeting facilities. In terms of pre-meeting support, VRoom allows an agenda to be set with items and item timings. It also allows participants to be allocated as leaders for items as well allowing specification of the chair and the facilitator of the meeting. Extended roles can also be specified to match various meeting protocols. It differs from other research in the extent of the roles provided and the provision for extensibility with regard to meeting protocols.

In-meeting Support

In-meeting support has been considered by Thompson, James and Stanciu [11]. A software agent was developed to assist the human facilitator of the meeting. A graph database was used to create a meeting ontology with an underlying triples data store. This was used to link terminology used in the meeting environment to supportive processes and relevant digital objects. Another system, I-Room, which has been used to support synchronous meetings, is a virtual world system that supports collaborative activity using agents and avatars [12]. Its underlying structure is based on the I-N-C-A (Issue-Node-Constraint-Annotation) model [13]. SLMeetingRoom [14] is another virtual world meeting facility. The SLMeetingRoom model features include whiteboard, personal schedule, task-tracking schedule, information repository and model of argumentation. Some systems additionally capture specific business and management methodologies. PowerMeeting [15] is a system that also supports groupware settings. It supports decision making, brainstorming, some roles, agenda items and voting with a multi-criteria decision support tool. In addition, the system's extensibility is granted by allowing users to develop and integrate tools that they wish to use. It also includes a Chat and Skype facility. In MeetingManager [10], during the meeting, the facilitator service displays each agenda item according to its duration, and videotapes the discussions. Issues and commitments are marked as they occur. In VRoom, support is provided in-meeting through the display of timed agenda items, polls, and document upload and download. It also allows for the mark-up of conversational components that may later aid summarisation. It differs from other research in the richness of the underlying meeting model for in-meeting support, and in particular the use of roles.

Post-meeting support

At a post-meeting level, VRoom supports the archiving of meeting transcripts as well as automated summarisation to make minutes which might vary according to the summarisation policy used. Summarised minutes can be linked back to original transcripts in case of further detail being required. MeetingManager [10] provided summarisation and browsing of structured meetings. The tags made during the in-meeting activity and linked to agenda items were used to enable appropriate post-meeting browsing and summary viewing of recorded parts of the meeting. The summarisation method of VRoom differs from this in that, in Vroom, a textual summary based on conversational contributions is provided.

B. Automated Summarisation

Typical activities in summarisation include topic: identification though word frequency counts and the use of ontologies [16]; sentiment analysis through emotion-bearing word analysis [17]; and the exploitation of recognised conversational structure [18, 19, 20, 21]. Characteristics of summarisation include: single vs. multiple object summarisation; extractive vs. abstractive summary; generic vs. query-based summaries; and indicative vs. informative summarisation [22]. Single vs. multiple objects refers to whether a summarisation is done on the basis of a single object or whether the summarisation is carried out in the context of multiple objects. Extractive vs. abstractive summarisation refers to whether whole sentences or phrases are extracted unaltered from the transcripts or whether some post-extraction processing is carried out on these to improve the summary. Indicative vs. informative summarisation refers to the amount of detail presented in the summary, indicative providing just heading-type information and informative providing more detail. Other characteristics include: domain-specific vs. general-purpose; and textual vs. multi-media output. The approach adopted in VRoom is textual sentence extraction with meta-information added in the form of who made the contributions and the context of the discussion. Since both headline and more detailed content is provided we consider our summarisation to be both indicative and informative. Our approach is general-purpose since it can be applied to various domains. We use lexical analysis to find relevant sentences in the context of a topic under discussion.

Table 1: Various approaches to structured support for virtual collaboration

Research Project	Pre-meeting	In-Meeting	Post-meeting
SISCO [6, 7]	Discussion and Argumentation facilities	n/a	n/a
MeetingManager [10]	Meeting Planner to create agenda	Facilitator component displays each agenda item according to its duration, and videotapes the discussions	Archiving of video recordings; summarisation and browsing of recordings
PRIME [8]	Discussion and Argumentation facilities	n/a	n/a
I-Room [12, 13]	Agenda setting	Virtual world; Meeting progress support; process and issue based argumentation	
SLMeeting Room[14]	Personal schedule	White board; information repository; model of argumentation	Task tracking schedule
PowerMeeting [15]	Agenda setting	Decision making; brainstorming; some roles; agenda items; and a voting tool with a multi-criteria decision support tool	n/a
VRoom	Agenda setting; items with times; item leaders; other roles.	Timed agenda items; polls; document upload and download; discussion component marking	Archiving of meeting transcripts; automated summarisation according to policy

III. THE VROOM APPROACH TO SUMMARISATION

A. General VRoom meeting representation

VRoom uses an underlying model to categorise the types of utterances that typically form part of a meeting structure. At the top level the concept of meeting for summarisation purposes is broken down into three main objects: *Agenda*; *Role*; and *Transcript* [23]. These objects are further broken down. An *Agenda* is made up of *Items* which have characteristics such as *Title*, *Start-time*, *End-time* and *Leader*. The *Title* of the item serves as a heading in the generated minutes. The objects mentioned are set at the pre-meeting stage. *Role* can have various instances such as *Chair*; *Facilitator*; *Item Leader* and *Participant*, which are identified at pre-meeting stage. At the post-meeting summarisation stage other characteristics of items are identified, such as *Transcript*, *Issue* and *Outcome*. The transcript for an item is the part of the complete transcript of the meeting that relates to the particular item. An item can have many *Issues* which represent topics brought up in the meeting under that item heading and will also typically have an *Outcome* which could be an *Acknowledgement* or a *Decision Summary* for example. Each issue belonging to an item can be further categorised to be made up *Description*, *Proposition*, *Outcome* and *Transcript*, representing the common situation of a proposition being made regarding an issue and that the proposition will have an *Outcome*. Outcomes can be of various types. As well as those already mentioned, outcome type includes *Acceptance*; *Dismissal*; and *Action*. Actions can be further broken down to show description, time frame, and person responsible. Fig. 2 and Fig. 3 shows the meeting model adopted in VRoom as hierarchical object diagrams.

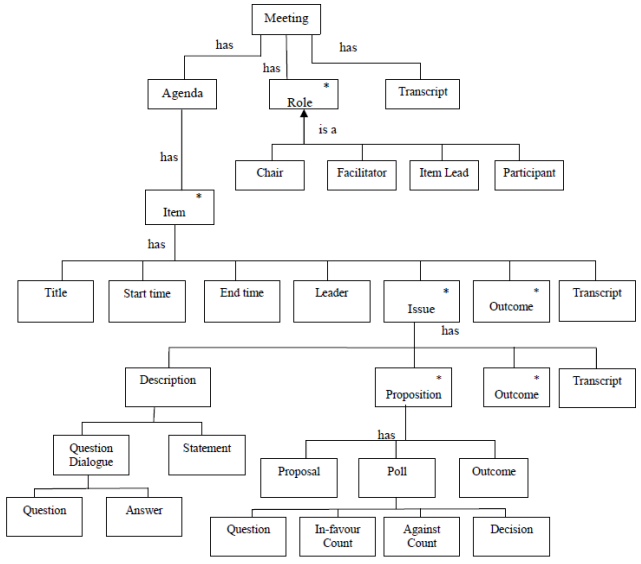

Fig. 2. The VRoom meeting model

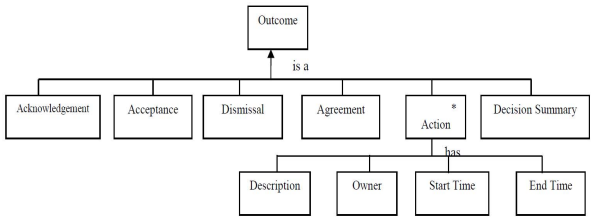

Fig. 3. The Outcome object structure Vroom summarisation process

B. *Summarisation stages*

The VRoom summarisation process has three stages: pre-processor; summariser; post-processor. The transcript is read into a pre-processor which adjusts spelling, grammar and improves term consistency. Next the summariser extracts the most relevant sentences according to a method and policy selected from a number available. Finally the post-processor adds meta-data to make the meeting minutes which includes the summary of each item. The process is illustrated in Fig. 4.

Various methods and policies can be used for the summarisation, all of which are based on sentence extraction but they vary in that the structure of the meeting can be used in different ways to select the sentences to extract. TextRank is an example of a method. An example of a policy is to give all contributions equal weight as opposed to, for instance, giving longer sentences more weight than shorter. The user can select which summarisation method and policy to use. In fact the user can try alternative policies and methods to assess which summary suits the business context best. This paper compares two methods: the use of the TextRank method alone; and the use of a TextRank method together with item title information.

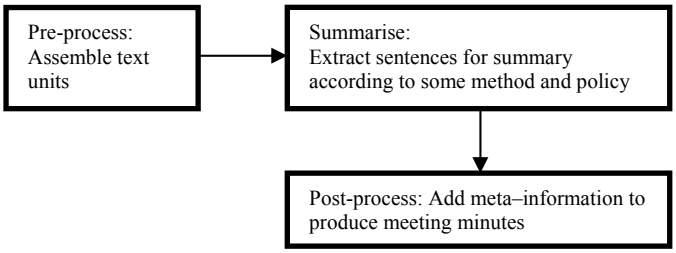

Fig. 4. Overview of V-ROOM summarisation process

Generally the procedure for summarisation is as follows. First assemble the text units into item topics. Each topic represents the conversation about a particular item. For each topic the following steps occur. Pre-process the topic text to improve spelling, grammar and term consistency. Decide on an arbitrary value for N, where N represents the cut-off in the ranking beyond which extracted sentences will not form part of the topic summary. Submit the topic text collection to the summarisation method. Receive the results. Collect the top N closest sentences and present in chronological order to maintain the correct sequence of the meeting proceedings. The collection of sentences represents the topic summary. Add the summary to the output. After all summaries have been added, post-process the results by adding meta information, such as sentence contributor and context (i.e. which item was under discussion when the contribution was made) as well as higher level meta information about the meeting, for instance time and place and who attended and whatever other meta information is required according to the required style of the minutes.

C. *TextRank as used in VRoom Summarisation*

TextRank is a graph-based algorithm [5] which is based on PageRank [24], an algorithm used in Google to rank pages. The PageRank algorithm works by giving a page a score based on those of its input link pages, moderated by the number of other pages linked to by each of its input link pages and by a damping factor which models the probably of a user clinking on a link randomly [25]. The formula for PageRank is as follows. Let G= (V,E) be a directed graph with the set of vertices V and a set of edges E, where E is a subset of V x V. For a given vertex V_i, let $In(V_i)$ be the set of vertices that point to it (predecessors), and let $Out(V_i)$ be the set of vertices that vertex V_i points to (successors). The score of vertex V_i is defined as [25, 5]:

$$S(V_i) = 1 - d + d * \sum_{j \in In(V_i)} \frac{1}{|Out(V_j)|} S(V_j)$$

TextRank modifies the above formula. Instead of pages TextRank works on natural language text where a unit of text is represented by a vertex and a link between two units of text is represented by an edge. A link may be formed between two text units if the same word or phrase is used in both text units. Links between natural language text units may be multiple (more than one word or phrase connection occurs) or partial (part of a phrase connects but not the whole phrase). For this reason the formula in TextRank has been modified from that of PageRank to associate weights with the edges where weights are in the interval 0-1 depending on the strength of connection. The TextRank formula is provided below [4] where $WS(V_i)$ is the weighted score for vertex V_i.

$$WS(V_i) = (1 - d) * d \sum_{V_j \in In(V_i)} \frac{w_{ji}}{\sum_{V_k \in Out(V_j)} w_{jk}} WS(V_j)$$

An overview of the TextRank algorithm given in Algorithm1. At Step 2 of the algorithm varying types of lexical analysis could be used [5].

Algorithm1: TextRank Algorithm Overview

Step1: Assemble units of text from the meeting transcript
Step2: Find connections between each pair of units
Step3: Weight each connection
Step4: Apply the TextRank formula to obtain ranking

For our TextRank-ItemTitle (TRIT) method we have introduced the use of agenda item titles by introducing the title as a text item into the collection of assembled text units. Our assembly of text units consists of sentences contributed by participants at the meeting and the agenda item titles. The algorithm for the TRIT method is shown in overview in Algorithm 2.

Algorithm 2: TRIT Algorithm Overview

Step1: Assemble units of text from the meeting transcript
Step2: Add item title as an additional text unit
Step3: Find connections between each pair of units
Step4: Extract only the text units connected to the title text
Step5: Weight each connection
Step6: Apply TextRank formula on the extracted sentences to obtain ranking

IV. Designing and running the Experiment

The experiment explores the use of TRIT to summarise meeting transcripts. In particular we were interested to see the difference between TRIT and Text Rank used without the benefit of including any meeting structure inclusion. We call the latter method Text Rank no Item Title (TRnIT).

A. Context of the experiment

A virtual meeting carried out in an educational setting was used. The meeting was between academic staff and students on a group project module. The subject of the group project was to test a virtual learning environment and to evaluate VRoom. The transcript used in the experiment was from an early meeting, when the tasks were being discussed. Before each meeting the chairman designed the agenda and the facilitator invited the students. The items of the agenda were assigned to particular students and each knew what to prepare in order to brief the rest of the participants. During the meeting, the discussion was focused on the items of the agenda and deviations were not encouraged. In addition, the meeting included upload and real-time consideration of shared documents.

B. Source data

The transcript used is part of a virtual meeting carried out in VRoom with 11 participants. The agenda was as follows: *Introduction*; *VRoom Use*; *VRoom Evaluation*; *Types of Testing*; *Project Roles*; *Report Structure*; *Questions*. From those items, two sub-transcripts have been chosen for the experiment: *VRoom Evaluation;* and *Types of Testing.*

C. Experiment

The transcripts for each item were extracted from the complete meeting transcript on the basis of data item timings and signpost phrases such as "Let's move to next item – VRoom evaluation". Then the summariser was used on the transcripts according to two approaches: without using the item title (ie. TextRank only with no item title – TRnIT); and using the item title (TextRank with item title – TRIT). The value of N is this experiment was 6, i.e. the top six sentences were selected for the summary and then presented in chronological order. The *Types of Testing* item had 36 text units to start with and the *VRoom Evaluation* item had 31.

D. Evaluation

After the meeting, participants were asked to manually rate the importance of each sentence in the transcript. The 6 most highly rated sentences were taken to form a Human Judgement (HJ) summary. This HJ summary was compared to the summaries produced by the summarisation algorithms, TRnIT and TRIT, in terms of the number of sentences in common.

V. Results and discussion

The results of the experiment are presented in Table 2. The first column represents the summary without taking in account the structure of the meeting (TRnIT). The second column illustrates the results when the item title is under consideration (TRIT). The score shows the number of sentences in the automatically produced summary which are in common with the HJ summary.

For the first item, *Types of Testing* the results were considered valuable in both cases (see Table 2). The scores showed that the TRIT method produced the most representative summary, when compared to the HJ summary. The purpose of the *Types of Testing* item had been to describe what participants had found out about the types of testing and to come to some decision about what might be best to use in the project. Although the TRIT method scored best in the evaluation, it could be argued that the TRnIT method produced a summary that was more indicative of the emerging decision whereas the TRIT method gave more information about the discussion.

For the second item, *VRoom Evaluation*, the TRIT method was considered to have produced a summary which was meaningful in contrast to the TRnIT approach where the summary is meaningless and does not provide adequate information for future reference. The TRIT summary scored highly compared to TRnIT in the HJ evaluation.

Results indicate that in some contexts the TRnIT method provides reasonable results (e.g. for the *Types of Testing* item) but in other contexts it does not (e.g. for the *VRoom Evaluation* item). On the other hand the TRIT method produced a valuable summary for both items. Therefore we conclude from our experiment that supplementing the TextRank algorithm with item titles and keywords may be useful because in the cases tested it produces a better summary. However we note that further testing is needed and that in different contexts different results may occur.

Our experiment has provided us with interesting results regarding how we can further enhance the VRoom summariser. We consider that it would be useful to add a context for the agenda items, which means that as well as the title, a short explanation of the purpose of the item could be given when the meeting is set up. This description can be used by the summariser algorithm in order to produce richer summaries. For instance, it would have added useful context in the *Types of Testing* summaries. In the post-processing, a sentence such as "The students were required to discuss what they had learnt about testing and to decide what testing would be best for the task." could be added to the minutes to give useful context. The description will also encourage better participant–to-participant interaction since participants should have clearer prior knowledge of the exact objective of the item.

The summariser algorithm does not yet take into account the file upload feature of the VRoom system. The act of uploading a document adds information regarding the context of the discussion and therefore some reference should be made to this in the summary. Since our approach to summarisation is based around meeting structure, it would be feasible to encourage the uploader to add a brief description of the document in the context of the meeting when uploading. This will add more information and enable a richer summary. The aim of such a feature is to improve cases such as the *VRoom Evaluation* item of our experiment, in which discussion is intended to be stimulated from the content of an uploaded document. Even without such a description, at the very least in the post-processing part of the summariser when the meeting minutes are produced, text such as "X uploaded document Y" can be added to provide more context.

Table 2: Experimental Results

TRnIT	**TRIT**
Item Title: Types of Testing	
'For v-room I think usability testing would be most important. Yes, black box will be but what kind? Yes black box or even grey box as we will have access to both the code and system right? I have found out about white box and black box testing. I also think usability testing would be good as we are trying to develop this system so by using, testing and finding improvement we can develop vroom acceptance testing. Black box is best for this so yes. **Score: 3/6**	For v-room I think usability testing would be most important. I have found out about white box and black box testing. Black is when the internal structure and design of a software is not known and white is when it is known. I also think usability testing would be good as we are trying to develop this system so by using, testing and finding improvement we can develop vroom acceptance testing. Grey box testing is another one involves having knowledge of internal data structures and algorithms for purposes of designing tests. Yes I think anything other than testing v-room for how usable it is would be overcomplicating it. **Score: 5/6**
Item Title: VROOM Evaluation	
TRnIT	**TRIT**
Got it. Got it. In it you will see I have made some observations from last couple of occasions on which I have used vroom. Each one of you has to do a vroom evaluation and I would like you to do it using the same template as in the document. Okay got it. Got it. **Score: 2/6**	The other one is v-room evaluation. In it you will see I have made some observations from last couple of occasions on which I have used vroom. Each one of you has to do a vroom evaluation and I would like you to do it using the same template as in the document. This format is fairly simple, you just make the observation (good or bad), put the date you observed it (because vroom is under development and you might use different versions at different times). As you use vroom you will think of issues and things that can be improved and this is valuable to us as we develop the system. At the end of the project someone - whoever decides to be the v-room leader will collate all the lists of observations to make a final evaluation. **Score: 5/6**

VI. DIFFICULTIES

The richness of the agenda is vital not only for the effectiveness of the meeting but for the summarisation. Thus if the facilitator adds non-specific item titles, the resulting summary may not be good.

Even if the meetings are classified as serious from the beginning, some diversions are often made and the conversation does not follow exactly the agenda items. Participants may even skip an item entirely. This sometimes happens in meetings and the automated summariser needs to take account of this.

Another key issue is the accuracy of pairing the items with the corresponding text in order to identify the boundaries

correctly and feed the algorithm with the appropriate title and text. Possible solutions include: matching the planned timing of the item in the agenda with the timestamp of the text (each item has an expiration time in the agenda, although this is not failsafe because of diversions and timekeeping); utilising lexical signposting but this requires good meeting hygiene such as a facilitator or chair announcing item change and participants observing; or topic clustering via lexical analysis [16]. We are exploring combinations of these approaches.

The transcript content is not always in the best form and as a result pre-processing needs to occur before summarisation to correct grammar and punctuation as far as possible. The text itself sometimes is not meaningful because participants can upload documents to support their contributions and the algorithm does not currently "look" inside them or exploit the connection between a message and an uploaded document.

VII. CONCLUSION AND FUTURE WORK

Utilising the structure of a meeting can lead to improved summarisations especially when the text is not that rich and a lot of noisy data can be found in the text. Various methods are possible for summarisation, each of which may exhibit strengths in different contexts. In future work the improvements to combat issues described in section VI and will be explored and so will the relationship between content characteristics and summarisation method. Furthermore the roles of the meeting participants will be exploited to improve the summaries based on the assumption that the contribution of the chairman or recognised expert may be more valuable than those of other participants. The rationale behind the extra weighting of particular roles is to embody the meaning of real life roles in a virtual meeting system.

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