Retaining and exploring online remains on YouTube

Demosthenes Akoumianakis, Ionannis Kafousis, Nikolas Karadimitriou, Manolis Tsiknakis
Department of Applied Informatics & Multimedia
Technological Education Institution of Crete, Heraklion, Greece
da@epp.teicrete.gr, g.kafousis@gmail.com, karadimnik@gmail.com, tsiknakis@ics.forth.gr

Abstract — The paper presents a method and a collection of techniques for conducting virtual excavations in online social networking services. YouTube and its Data API are used as a case study of a virtual settlement. The objective is to assess not only what is retained by YouTube but also what sense can be made of a designated set of YouTube online remains. The research focuses on defining, capturing and transforming digital trace data into interactive visualizations that unlock crucial dynamics of online activity.

Keywords — Virtual excavation, Youtube, YouTube API; digital traces; social visualization; information discovery

I. INTRODUCTION

Archaeological excavation is an established method for uncovering remains within a settlement, thus gaining insights to (or even re-creating) a past culture [1]. Accordingly, archaeological inquiries commit to an analysis of artifacts in situ and in relation to other artifacts so as to evoke particular understandings of the culture these artifacts exist within. Recent scholarship attempts to extend the premises of traditional archaeology so as to facilitate virtual excavations of cyber-structures residing on virtual settlements [2]. The basic concept is grounded on the assumption that social media and in particular social web sites and social networking services, are increasingly transformed into virtual settlements hosting a wealth of cultural information about past and / or ongoing online communities [3]. Key quality attributes driving such transformations are increased abstraction, connectivity and interoperability. These are typically inscribed into open Application Programming Interfaces (APIs), which together with crawling, form the basis for accessing what is retained by a virtual settlement. An API specifies a set of routines, protocols and tools for building software applications. Respectively, a web API offers the means for third-party applications to access data retained within a web-based service following a collection of technological standards and protocols. Such data can then be processed (i.e., filtered, annotated, enhanced and transformed) to facilitate new understandings and making of sense of online activities. To this end, advances in information visualization [4, 5] have brought about a variety of techniques and toolkits which ease the task of uncovering hidden details and patterns in large data sets.

From the above, it follows that the increasing availability of public APIs coupled with appropriate visualization methods and techniques can provide the grounds for a kind of virtual excavation conducted on large scale social networking services. The present research seeks to justify this claim by considering the case of a video-sharing service, namely YouTube. The focus is on using (exclusively) the YouTube Data API and a collection of exploratory animation-based visualization techniques designed to re-construct historical digital traces of online activities. This translates to the sub-goals of (a) assessing the strengths and weaknesses of public APIs and (b) devising techniques that enable and facilitate making sense of large volumes of social data or digital traces retained by public APIs. Such digital traces are online remains of what users leave behind when interacting in a virtual settlement. Accordingly, there are implications on how digital traces are collected, structured and re-constructed to facilitate information discovery using social visualizations.

The paper is organized as follows. The next section discusses related works aiming to qualify excavation-based approaches and discuss methods that have been found to be useful in extracting and making sense of digital trace data on YouTube. Based on the analysis, certain conditions are defined to anchor virtual settlements and excavation-based inquiries. Then, we discuss briefly YouTube and its provisions that enable or constrain virtual excavations. This entails a more precise insight into what constitute digital traces in YouTube and how they are generated and stored. Finally, a case study is presented to illustrate the concepts and provide insights to deep excavations of YouTube using a variety of visualization techniques. The paper is wrapped up with a discussion on opportunities and challenges and reflections on ongoing and promising research directions.

II. RELATED WORK AND RESEARCH FOCUS

Assessment of online user activities in YouTube is a subject that has recently attracted research interest from different angles and perspectives. Nevertheless, available scholarship is not uniform, in terms of intention and methods, as it reports on both non-content and content specific techniques. Thus, not all of the available research can be qualified as virtual excavation despite the appropriation of computer-based techniques. Consequently, this section will first review representative works and then highlight basic requirements for virtual excavations by extending earlier proposals (i.e., [7,8, 25]).

A. YouTube data mining

Starting with non-content methods, several researchers have studied YouTube data to detect spammers and content polluters. Sureka [8] describes a non-content method to automatically detect comment spammers. The approach makes use of a rule-based method relying on four special indicators to identify users’ spam intentions. Benevenuto
and colleagues [9] focus on understanding user interactions with videos in order to show common user behavioral patterns and samples of anti-social behavior such as self-promotion and other types of content pollution. In a subsequent effort [10], the authors’ focus shifts on detecting video spammers and promoters. They describe a method based on mining user profile data together with video responses to identify polluters. Their method is able to correctly detect most of the promoters but not all spammers because it is harder to find the differences between them and the regular users. The identification of spam campaigns is also addressed in [11] where motifs for user profiling methods are investigated in order to detect different spam strategies. The case study deals with tracking two active campaigns, making use of two different spam strategies. Results show that both campaigns are managed by a single spammer who controls a number of spam bot user accounts.

Other researchers focus on combinatorial analysis of user profiles and digital trace data. Rotman et al., [12] examined more than 30 videos, associated comments and user profiles of commentators to indicate whether YouTube enables formation of online communities. The results show that the relationships in the friendships and subscriptions are almost random. Moreover, users’ sense of community is not necessarily correlated to the structure of the YouTube network, but it also has to do with other factors. Yo-Sub Han proposes an algorithm that computes user reputation on the grounds of subscriptions and the number of the user uploads [13]. Subscriptions and the differences with the network of friends is the subject of Biel’s paper [14]. He found that some properties do differ from friends network and those resemble the web. He also noticed that the usage of subscriptions is constant over time. In a similar vein, Biel used a sample of 270 thousand users to study user behavior from the perspective of their categories [15]. The research shows that people who interact and participate mostly on YouTube are actually a small group of users who follow recognizable behavioral patterns. He also found that getting simple behavioral data from a user’s profile can reveal the category the user belongs to with accuracy rates up to 73%. In a more recent paper the same authors examine automatic analysis of conversional vlogs (video blogs) [16]. The case presented focuses on the automatic characterization of vloggers based on audiovisual and non-verbal behavior. That would help characterizing social aspects of human communication beyond the spoken words. The research revealed vloggers’ common practices for video creation and editing, concluding that as long as this type of videos is driven by actual intention to communicate, it is reasonable to be accompanied by non-conversational snippets.

There is also a wide range of efforts concerned explicitly with content-specific digital trace data of various types such as user posts, comments and social interactions. Mining topical trends is the theme studied by Colorado Reed and colleagues [17]. They present a system for detecting trends in user posts that contain textual data. In their case study they demonstrate the use of their system with a dataset of 2 million video posts. On such grounds they propose a methodology for characterizing user behavior [17]. Another research effort focuses on capturing information about friends, subscriptions, favorites and related videos in order to discover hate videos and understand extremism on YouTube [18]. The approach succeeds in finding the hate videos, making this work potentially valuable for security analysts. Susarla et al., [19] explore how the commenting actions early in the life of a video can affect word-of-mouth communication which actually influences the popularity of the video. They examined a group of users that were previously correlated with a focal channel on YouTube and all of their relationships. The results show that a video can actually be turned into a “hit”, but that depends on the social influence created by users and their relationships within the network.

Some researchers examine the video or textual responses of videos. Benevenuto and colleagues deal with video responses – a video interaction that YouTube offers to users [20]. They try to characterize these interactions either based on the video response view or the interaction network view. Their study uncovers typical user behavioral patterns and provides evidence of opportunistic behavior on YouTube. It also comes to the conclusion that the characteristics of those video interactions are fairly different from traditional because of the change from textual to video-based communication. Finally, YouTube has been investigated as a potential means for reinforcing public health [21]. The work is concerned with mining data together with relationships to provide complementary information to public health researchers. This will help people to get informed about public health practices. In a similar vein, the American Medical Association provided a research that shows how YouTube can act as a source of information on immunization [22]. Specifically, YouTube was crawled to compile an amount of videos that contain information about the risks and the benefits of immunization. Then, videos were classified into three categories, positive, negative and ambiguous. Eventually, they came to some very interesting outcomes which showed how YouTube can play a very important role on informing people about immunization.

B. Consolidation and research focus

All papers mentioned above deal with mining some sort of YouTube data for studying different aspects of individual behavior, online groups or social networks. The techniques reported utilize a broad variety of methods to obtain YouTube online remains and conduct their analysis. Respectively, there have been proposals relying on both non-content and content-specific methods. In some of the content-specific methods, data are translated into measures of theoretically interesting constructs. In such cases, the findings depend solely on the availability of measures and offline analysis to determine their validity. Other researchers rely on crawling mechanisms to compile reliable
data sets to support further analysis. Finally, other works appropriate open APIs to extract parts of what is retained by YouTube.

It follows therefore that digital traces and online remains vary substantially in type, sort and format, raising implications on reliability, information-processing capacity as well as affordances for revealing new knowledge. Due to such variations, it is hard to qualify all available scholarship as excavation-based inquiries. On the other hand, and to the best of our knowledge, available literature offers very little insights into what conditions need to be satisfied by research efforts claiming to support virtual excavation of online tells and remains. For our purposes, a virtual excavation is confined to content-specific inquiries that rely upon digital trace data and satisfy four pre-conditions:

(a) assume a designated virtual settlement in the sense reported in [2, 6, 7, 25];
(b) qualify the settlement in terms of one or more boundaries – thematic or otherwise;
(c) support a clearly specified data access strategy declaring what is deemed as digital traces and how digital trace data are compiled, assembled, filtered and transformed;
(d) provide a set of techniques that enable making sense of the designated data set.

Phrased differently, virtual excavations are intended not so much to test a measure, as to uncover elements of culture and practices based on digital trace data retained in virtual settlements and capable of being transformed to useful knowledge without the need for offline processing.

III. EXCAVATING YOUTUBE

Following our earlier definition, the first consideration is to assess whether or not YouTube qualifies as a virtual settlement. To this end, Jones theory of virtual settlements [7] is a useful starting point. Once this criterion is satisfied, it is then possible to assess what artifacts reside within the settlement, what use of these is retained in the form of digital trace data and how such data can be appropriated.

A. YouTube as virtual settlement

Drawing upon Jones theory [7], virtual settlements are conceived as computer-mediated social spaces that make provisions for (a) interactivity (b) multiple communicators (c) a common public place where members can meet and interact and (d) sustained membership over time. Given these criteria, it is actually straight-forward to conclude that YouTube meets all four of them and therefore can be safely qualified as virtual settlement (first condition confining virtual excavations). In terms of settlement boundaries (second condition), YouTube implements inscriptions that serve as rigid technical boundaries (i.e., registration policies, API constraints about what is retained and how, etc.), but also soft thematic boundaries defined by cultural artifacts such as video channels and user profiles. As for data access strategies (third condition), YouTube offers APIs that allow programmatic control to different types of digital traces. One popular API as already mentioned is the YouTube Data API. Additionally, YouTube offers two player APIs that allow third-party applications to control the YouTube Player using JavaScript or ActionScript. The weakest part of YouTube is currently deemed to be the provisions made for making sense of digital trace data (fourth condition). For this purpose very little is available other than third party applications.

B. Digital traces through the YouTube Data API

A digital trace is the evidence that something occurred in the past – a piece of retained information which is event-based and longitudinal. In YouTube such data are stored in public feeds that can be accessed using the API. At present, there are two versions of the API with the main differences being related to authentication. In terms of specification, the YouTube Data API is based upon the Google Data Protocol (GDP) which provides the developer a secure means to access any information retained by YouTube. GDP is simple protocol for reading and writing data on the web which combines common XML-based syndication formats (atom or rss) with a feed publishing system based on the Atom publishing protocol. Information is sent either using this syndication formats to represent data together with HTTP to handle the connection, or as JSON objects that mirror the Atom representation. The API also supports JSON-C format, a variant of JSON which is not yet enabled for some types of feeds. In YouTube each type of public feed is bound to contain a maximum of 25 entries. Subsequent entries can be accessed using the tag or JSONObject referring to the next feed link. Sometimes it is recommended or necessary to include the developer’s key (i.e., value obtained from API Developer Dashboard Webpage that uniquely identifies an application). Popular types of feeds include video feeds, comment feeds, channel feeds, event feeds, etc. A more detailed description of these is widely available, and thus, it is not further elaborated in the present work.

C. Manipulating digital traces

YouTube digital traces of particular interest to our current investigation comprise any piece of information related to a user’s activity i.e., interaction with a video or with another user. Accordingly, unitary digital traces are created when a user submits a comment, rates a video, shares a video, posts a video respond, uploads a video, marks a video as favorite, creates a playlist, adds songs in a playlist, subscribes to a channel or adds a friend. For purposes of illustration, it is worth examining an example of how comments of a specific video can be turned into digital traces by ascending the JSON file that YouTube API provides. To this end, we will refer to an existing video named “Crete - Greece” whose id is “scTM3T41-YE”. At first, the API URL for this video is specified by using specific parameters, such as the link followed by a
designation of the version of the API to be used for handling the request and the format of the feed to be returned. It is also possible (although not necessary here), to specify the developer’s key. The response of the API would be a video entry holding data about the requested video id (Figure 1).

Among all the amount of information given in the video entry there is a JSONObject as we call it named “gd$comments”. This object holds information about the comments of this video. Inside this object there is another JSONObject called “gd$feedLink” that contains the link to the Comment feed which is the value of the “href” attribute. This returns all the comments made for this video. The “rel” attribute that has a value of “http://gdata.youtube.com/schemas/2007#comments” is used to identify that the URL value of the “href” attribute stands for retrieving comments for that video entry. It also contains the “counthint” attribute which indicates that the number of comments made for this video is 97. Using that URL to retrieve the comments made for that video returns the comments but in atom format. To continue viewing the comments in json format the parameter “&alt=json” should be added at the end of the URL address.

The comment feeds have an amount of comment entries and each of them provide information about every user comment activity for this video (Figure 2). It is that piece of information which is considered to be a digital trace since it indicates user interaction with a video on YouTube. However, since a comment feed contains a maximum of 25 comment entries and the specific video has 97, the JSONObject can be consulted again to establish the next feed link so as to access subsequent comments.

### IV. CASE STUDY

This case study sets out to demonstrate the value of an excavation-based approach to the analysis of digital remains on YouTube. The intention is to focus on a subset of online traces retained by YouTube and reveal how they may be turned into useful knowledge by articulating suitable information visualization techniques. The subsequent discussion is structured around the four conditions for qualifying virtual excavations, namely (a) defining the virtual settlement, (b) specifying the settlement’s boundaries (i.e., thematic or otherwise), (c) devising a suitable strategy for compiling digital ‘remains’ and (d) making sense of digital remains and digital trace data.

#### A. Virtual settlement

As already stated YouTube meets Jones’s criteria for virtual settlements since it enables users to interact with other users and to contribute various sorts of user-generated contents, including videos, comments, posts, etc. By accessing YouTube, it is straightforward to establish not only records of multiple different users submitting their contribution, but also to confirm that there is recurrent engagement. Specifically, online activity is public and all users have access to it. Consequently, YouTube acts as the meeting point for these users.

#### B. Settlement’s boundaries

For the purposes of the present study, the virtual excavation is limited by thematic boundaries. Specifically, we have chosen to study music videos of different genres. As described below the initial data sample was screened through filters to establish the final data set that meets designated quality criteria. Accordingly, several research questions were devised and addressed through excavating the specific virtual settlement. Following these steps, 10 popular music genres and for each of them the 10 leading videos were selected, leading to a data sample of 100 videos.

#### C. Data access strategy

To compile digital trace data for the video sample, the present work relies solely on YouTube online ‘tells’ and remains accessible through the YouTube Data API (i.e., public feeds) and the JSON representation. In order to obtain the data we composed a query, following YouTube’s “grammar”.

### TABLE 1: QUERY STRUCTURE

```plaintext
https://gdata.youtube.com/feeds/api/videos/yuFI5K5PAt4/comments?=2.1&client=IstLab+Application&key=AI39si5-WAMOVJtR1Sk8-
HRvp13Mmwgy7yt0IPXv_bCBMdkwogkJ85WEeAL
Au560PGGQcderkNw9BbW14yVJL979Nn_-pq6iediA
```

The query (see Table 1) consists of three parts, one of which is variable. The first part is a reference to the video object from the YouTube API designated by extract ‘https://gdata.youtube.com/feeds/api/videos/yuFI5K5PAt4/’. The second part (videos/ yuFI5K5PAt4/) designates the video id and variable. The last part consists of
the object returning the comments (/comments), the API version (v=2.1), client name (client=IstLab+Application) and the researcher’s key (i.e., remaining part of the query). The query was issued for every one of the designated videos comprising our data sample.

For each video entry, the information retrieved includes the video title, the unique video id, the full text of each comment on the video, the comments’ unique id and date of creation, followed by the id and username of the respective user. For purposes of simplicity, we do not describe the technicalities of bypassing constraints imposed by YouTube e.g., limitation in the number of comments returned in each step. The result of the query is a CommentFeed type object, which is manipulated as a JSONObject. Every CommentFeed object contains at most 25 entries which are actually the comments made for the requested video. CommentFeeds also may contain feed links which indicate if there are more comments for a designated video. From each data element in the JSONObject we retained only the relevant subset corresponding to the fields of interest mentioned above. The data are stored in a relational schema using MySQL.

Our initial effort was constrained by limitations in the API which allows access to the 1000 most recent comments of a video. To relax this constrain and establish a larger set of relevant data, the data extraction exercise was carried out repetitively over a period of seven days, adding new comments each day. Table 2 summarizes the results indicating both totals and counts per day.

<table>
<thead>
<tr>
<th>Table 2: New Comments per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
</tr>
<tr>
<td>Disco</td>
</tr>
<tr>
<td>Electronic</td>
</tr>
<tr>
<td>Hip Hop</td>
</tr>
<tr>
<td>Jazz</td>
</tr>
<tr>
<td>Latin</td>
</tr>
<tr>
<td>Metal</td>
</tr>
<tr>
<td>Pop</td>
</tr>
<tr>
<td>RuB</td>
</tr>
<tr>
<td>Rock</td>
</tr>
</tbody>
</table>

D. Making sense of digital remains

Having established the relevant data set, the final step entails the use of suitable visualization techniques so as to make sense of the data. A key concern has been to ‘unlock’ online ‘tells’ about the prominent users as well as cumulative practices. Obviously, such a focus is only illustrative and non-exhaustive of the range of potentially relevant issues to be targeted. Respectively, different visualizations were devised as exploratory dynamic displays capable of qualifying hypothesis of different scale and leading to useful insights regarding the entire data set as well as specific questions about i.e., the most active users, type of activity performed and analysis of what is actually being done online. In terms implementation, all visualizations have been constructed using Prefuse – a java-based toolkit for building interactive information visualization applications [23]. To this end, most of our efforts have been devoted to extending or creating new layout management policies as well as integrating dynamic querying mechanisms. In the reminder of this section, we provide a representative but non-exhaustive account of some of the techniques and their application.

In order to obtain structured and summative accounts of our data sample, an established and proven visualization method, namely tree map, was recruited to provide a tentative classification of online remains. Tree maps were introduced by Ben Shneiderman during the 1990s and since then they have evolved in various directions [24]. Figure 3 assembles our data set in a searchable hierarchical display using nested rectangles to classify user comments by music video and music genres. Outer rectangles (bright blue color) represent the 10 music genres. Sub-rectangles (strong orange color) are used to assemble music videos by music genre and comments count. Thus, the most commented videos within a music genre are represented with bigger rectangles in a ‘left-to-right’ sort. It is also possible to search for comments made by specific users. The display highlights the respective comments as shown in Figure 3. Comment contents can be accessed by rolling over a specified area and leaving the mouse over an entry for one second. Alternatively, individual user comments can be displayed by clicking once over a comment rectangle. This turns out to be useful as it reveals repetitions of comments made by users across different boundaries.

A different visualization was used to qualify the data set using different scales. For instance, Figure 4 implements the Fibonacci sequence pattern to anchor the data set by volume of comments per video. Similarly, Figure 5 applies the same pattern to classify the users’ online activity. Accordingly, nodes are clustered in a specific manner indicating most commented videos (Figure 4) or a user’s total online activity (Figure 5). In both cases, nodes placed close to and around the center represent higher volumes of activity compared to nodes in the graph’s periphery.

Equally interesting findings are established by assessing the kind of activity undertaken by different users. For this purpose, a custom visualization was devised to analyze textual comments using tags of positive and / or negative connotation. Our working hypothesis is that there are words that confine users’ intentions and qualify their contributions. For instance, words such as ‘Attention’, ‘com’, or specific pages such as ‘swagFriends’ are most likely to exist in comments of users seeking to promote a site or their own channel. An illustrative display is depicted in Figure 6 where this form of textual analysis is used to create social zones of a user’s comments to videos in four music genres i.e., rock, pop, metal and hip-hop groups.
Figure 3: The use of the tree map

Figure 4: Fibonacci sequence pattern to anchor videos by total number of comments

Figure 5: Fibonacci sequence pattern to anchor users by total count of comments
The word-based analysis entails filtering and isolation of designated words in all video comments. The visualization is compiled incrementally and in an animation-based fashion by processing data items qualified by the specific word, the time the associated comment was made on YouTube as well as information about the video and the respective user. Word size is continuously updated to depict each word’s relative popularity per music genre. As this can be repeatedly performed for different sets of words and different users, it is easy to assess the kind of contributions made by users across music genres. It is worth noticing that the results can also be confirmed by conducting searches using the tree map visualization. In terms of explanatory value, this visualization can lead to useful insights as to what the users’ primary intentions are. For instance, for the case depicted in Figure 6, it becomes evident that the user’s activities spread over specific music genres, while the user’s primary intention is to promote a specific site.

Animation-based visualizations with social zones have also been used to assess settlement-wide issues. This time, the objective was to gain insights to how user comments differ by music videos in different genres. Using the previous technique, selected words were filtered and isolated in all available comments and ranked in popularity within each social zone. The results, for the whole period, are shown in Figure 7. As shown, the “cover” word is far more popular in metal group than in hip hop group where it is barely visible. Phrased differently, the size of each word is used as a proxy to the number of entries in the database that contain this word and as a result it shows the frequency that the specified word is displayed along the comments of that genre. This analysis can also be conducted for a specific time interval or across time periods in an animated fashion so as to depict gradually how the designated words and their relative properties emerged over time.

V. CONCLUDING REMARKS AND FUTURE WORK

The research described in this paper is a step in the direction of understanding the type, range and scope of online remains retained in virtual settlements and how these may be turned into evidence for cyber-structures emerging in virtual settings.

In exploring this issue our working definition of digital remains is that they comprise online traces of co-engagements capable of justifying different configurations of people, artifacts and social relations in a virtual settlement. Thus, a virtual excavation amounts to re-surfacing such data sets and transforming them into useful insights about a past event, activity or culture. There are two key aspects of such a cyber-archaeology of virtual settlements that distinguish it from contemporary archaeology. Firstly, digital traces remain bytes of code until a point that specialized software brings them to light; thus interpretive capacity is bound by the type of tools used to extract, analyze and transform digital remains to a meaningful language. Secondly, digital traces and their processing raises issues about privacy and security and the way these are inscribed into tools or platforms. In other words and in most of the cases, what is retained within a virtual settlement in the form of digital remains, is not always what is released and made available for excavation through public APIs. Consequently, this line of research requires methodological considerations that lie beyond the boundaries of contemporary archaeology.

Our current work deals with the above by capitalizing on YouTube Data API and a collection of visualizations devised to convey structural and behavioral patterns hidden in a representative sample of digital traces. The results confirm that video-sharing services such as YouTube qualify as virtual settlements. This is consistent with other research that explores the case of social media sites (such as Times online magazine) and social networking platforms such as Facebook [25]. However, our experience with YouTube also reveals limitations of the API that demand special considerations. Firstly, latency issues emerge for data updates as the API retrieves search results from a specially optimized search index. The index is designed to include new videos as quickly as possible while ensuring high performance even under heavy API server loads. However, in our investigation we have encountered delays between the time a video is uploaded or updated and the time new information is included in the video feeds. Obviously, this bares implications for time-critical inquiries. Secondly, the API limits the results of a query to the 1000 most recent entries rather than the total set. Attempting to
On-going work addresses a variety of issues ranging from settlement-specific analysis to boundary spanning across settlements. Specifically, with regards to YouTube, current research concentrates on excavations of semantics-oriented properties. This effort, combines social visualizations with text, video and image processing techniques to foster excavations based on features such as mood, music instrument and audio properties. An equally important set of challenges relate to combining online digital traces with offline activities so as to analyze whether or not online ties are maintained offline and vice versa. As for boundary spanning, our interest is in tracing user activities across virtual settlements to assess intertwining of networking tactics and practices. This would help us analyze, amongst other things, user interactions across virtual places and with different media types, virtual settlement interoperability as well as enacted forms of social connectivity and plasticity of cultural artifacts of practice.

REFERENCES