CemoMemo: Making More Out of Gravestones (With Help From the Crowd)

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Digitizing cemeteries and gravestones aids cultural preservation, genealogical search, dark tourism, and historical analysis. CemoMemo, an app and associated website, enables bottom-up crowd-sourced digitization of cemeteries, categorizing and indexing of gravestone data and metadata, and offering powerful full-text and numerical search. To date, CemoMemo has nearly 5,000 graves from over 130 cemeteries in 10 countries with the majority being Jewish graves in Israel and the USA. We detail CemoMemo's deployment and component models, technical attributes, and user models. CemoMemo went through two design iterations and architectures. We detail its initial architecture and the reasons that led to the change in architecture. To show its utility, we use CemoMemo's data for a historical analysis of two Jewish cemeteries from a similar period, eliciting cultural and ethnological difference between them. We present lessons learned from developing and operating CemoMemo for over 1 year and point to future directions of development.

CCS Concepts: • **Software and its engineering** → **Software architectures**; • **Information systems** → **Crowdsourcing**; *Search interfaces*; • **Human-centered computing** → **Collaborative and social computing systems and tools**; • **Applied computing** → *Anthropology*;

Additional Key Words and Phrases: Cemeteries, gravestones, digitization, history

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1 INTRODUCTION

Cemeteries and gravestones contain a wealth of historical, genealogical, and ethnological information. They are a primary source for preserving and analyzing the cultural heritage of communities, both existing and historical. Gravestones, particularly in European and American cultures, are historical documents, short or long essays carved in stone or engraved in metal that contain a message to the future. Since gravestones are traditionally prepared by the burying family or community, the message is mediated and can have many aspects. Some gravestones are decorated, large, and elaborate, echoing the importance of the deceased person. Some contain epitaphs, quotes, poetry, or sayings from the deceased person to emphasize his spirit or personality. Some are terse, containing just a name, a date, or some other personal detail. Some include sacred attributes, symbols, carvings, statues, or words to connect with a religious or spiritual community. Most stones include a mixture

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Fig. 1. Growth of users and gravestones in CemoMemo.

of the above, so gravestones allow us to analyze the place of the deceased person in the burying community by cultural, social, and community attributes.

Because of the historical and genealogical information contained in cemeteries and gravestones, systems have been recently developed to make them more accessible to a worldwide audience and more appealing to visitors. Digitization offers the advantages of making gravestones in remote areas easier to see; preserving a snapshot of gravestones that might later suffer from weathering, overgrowth of weeds, or vandalism; and enabling computer-aided search and retrieval.

CemoMemo (<https://cemomemo.kinneret.ac.il>) began as a senior capstone project in the Software Engineering and Land of Israel Studies departments in our institution. Our initial vision was to create a system that enables digital preservation, historical research, and *dark tourism* (tours to cemeteries and graves of familial, cultural, or historical interest). Due to the amount of work foreseen for the project (there are thousands of cemeteries and many millions of graves in Israel), we designed the system to be crowd-sourced. We therefore sought to engage community members, schools, and historical societies to use the system to document gravestones and cemeteries of importance to them. We reached out via academic channels and later via a series of interviews and articles in the press. We offered a series of guided tours to historical cemeteries for community members to tell the oral histories of some gravestones and to encourage participants to document the graves around them using CemoMemo. We made connections with historians and Jewish communities in other countries to find documentation partners.

Our efforts led to an initial wave of interest and user registration in July–August 2019 (see Figure 1). Most users from the initial wave documented only a few graves, those of close relatives or of interest to them. We maintained growth in the number of gravestones in the system through the help of partners, historians, historical societies, and schools who took it upon themselves to photograph and document entire cemeteries. To date, the system has graves from over 130 cemeteries, in 10 countries, and with names or epitaphs in 19 languages. The majority of graves are from Jewish cemeteries in Israel and the USA (see Figure 2(a)) from 1900 onward (see Figure 2(b)).

CemoMemo supports research based on information commonly found on Jewish gravestones. Traditions vary, but a significant number of Jewish gravestones include, in addition to basic vital information (i.e., name, date of

Fig. 2. Graves in CemoMemo by country and decade of death.

death), names in multiple languages (the local language and Hebrew), multiple dates (the local dates and the Jewish date), and parental names. Older Jewish gravestones (pre-1900) often include only Hebrew and Jewish dates, regardless of local language and custom. Many gravestones include epitaphs (i.e., quotes, poetry, or personal dedications) or scriptural verses. Modern gravestones include symbols and designs that reflect community (e.g., star of David) and family (e.g., hands for members of the priestly caste). CemoMemo categorizes information on the gravestone as well as metadata about the grave, allowing full search on all fields.

The contribution of this work is twofold. First, as a presentation of CemoMemo as a system and database for research on the cultural heritage of Jewish cemeteries and burial practices. CemoMemo has unique search and analysis capabilities not found in other publicly available cemetery digitization systems. We motivate the usefulness of CemoMemo via an comparative analysis of the burial cultures of two Jewish cemeteries. Second, as a case study of the software engineering design process behind a crowd-sourced collaborative system aimed at historians and non-technical users. We present the development process in detail, including the design decisions, high level, and detailed architecture of the initial beta. After the beta, CemoMemo went through a full redesign. We explain what shortcomings the initial design had and motivate the change to the final system architecture. We also point to remaining technical and user-based challenges.

The rest of this article is organized as follows. Section 2 has related work about cemetery digitization and analysis. Section 3 gives a detailed technical description of the design iterations of CemoMemo. In Section 4, we explore some sociological and ethnological aspects of two cemeteries completely digitized in CemoMemo as an example of what the system enables. Section 5 contains lessons learned from building and operating the system. Section 6 points to future directions of work and concludes.

2 RELATED WORK

As a rich source of history, cemeteries have been studied with respect to their structure, architecture, and use. Studies include maps of how people use cemeteries and ideas for how to modernize memorial experiences.

2.1 Necrogeography and History

Foster and Eckert [13] use burial records and cemetery information to reconstruct the history of a rural African American community in the midwestern USA. They use the cemetery information to augment existing historical information derived from oral histories, diaries, and family records. We took lessons from their work in our exploration of two cemeteries in CemoMemo.

Francaviglia [14] analyzes the geography, layout, and spatial constructs of cemeteries (*necrogeography*) over time. He argues that necrogeography is a microcosm of society and reflects how people view death and communicate with the dead. He analyzes tombstone styles, cemetery layout, and cemetery expansion in cemeteries in southern Oregon, USA. We used ideas from his work in CemoMemo's data fields.

Johnson [25] explores the history of cemetery layout and use in the French and English traditions through the plans of John Claudius Loudon. CemoMemo supports analysis of cemetery layout since graves are associated with GPS coordinates.

Vajta [37] extracts cultural meaning and identity by analyzing the language and terms used on headstones in the region of Alsace, a region that moved from France to Germany and back in recent history. She analyzes the language used in light of community and nationalistic associations. Reimers [31] and Anderson et al. [3] examine the language used on gravestones in different countries to document how immigrant communities preserved ethnicity and how secularization progresses or recedes. CemoMemo will enable such analyses on gravestones due to its rich multilanguage support.

2.2 Next Generation Cemeteries

Ciolfi and Petrelli [8] report on techniques used by volunteers in an English cemetery to engage visitors and enhance visits. They describe augmented reality technologies to give insights into the stories of those buried in the cemetery. Dow et al. [10] report experiences building *The Voices of Oakland*, a mixed reality system for an American historic cemetery. They use a combination of voice narration and drama to guide visitors and enrich experiences. Sabra et al. [34] report on a similar system for a Danish cemetery. CemoMemo does not support augmented reality and is not tailored to specific cemeteries. It may support such features in the future, but that will require partnerships with communities to create and manage content.

Häkikilä et al. [18] report on a prototype app built for navigating a Finnish cemetery. The app lets users search for graves by multiple parameters and offers GPS navigation. Newton et al. [29] report on an app that enriches visitor experiences to a Singaporean cemetery with a high density of graves. They use feature tracking and GPS to let users identify monuments and learn about those buried. We integrated GPS and compass-based navigation for gravestones in CemoMemo, but since the system is crowd-sourced and not tailored to a specific cemetery, we are limited by the accuracy of the location information provided by users.

2.3 Grave Databases and Cemetery Digitization

Online systems that digitize physical cemeteries and allow perusal of cemetery data or images, have seen recent growth.

Digitized cemetery information can be made more useful when presented in a queryable format using ontologies. Eichert [11] presents a series of case studies of digitally mapped cemeteries in Austria and Czechia using the **International Council of Museums' International Committee for Documentation Conceptual Reference Model (CIDOC-CRM)** ontology [23]. Epidat [26] and the **Portal of Epigraphy, Archaeology, Conservation, and Education on Jewish Funerary Culture (PEACE)** [33] are online systems with Jewish epitaphs and gravestone images that use the EpiDoc [12] epigraphy ontology. CemoMemo supports flexible queries on all data fields, but we do not support ontologies and semantic querying yet.

Some online repositories store cemetery information in searchable databases. Internment.net [9] is a repository of worldwide cemetery burial records with an emphasis on genealogical research in the Americas and Europe.

People Legacy [30] contains information about American cemeteries, photos, and genealogical information. Both websites contain official burial records from governments, burial societies, and cemeteries and are not crowd-sourced. A full listing of such systems is beyond the scope of this work.

With respect to the two cemeteries we consider in depth in Section 4, Homestead Hebrews [22] is a web archive of the Homestead, PA, USA Jewish community and contains information about the history of the people and its cemetery. The Ein Harod-Gidona, Israel cemetery’s layout, monument structure, and history were analyzed by Bar Gal [4]. Alon [1] gives a short online tour of the cemetery, including photos and backstories of some notable individuals.

2.3.1 Worldwide Systems. Several commercial worldwide cemetery digitization systems exist, aimed primarily at genealogical research. Billion Graves [5] enables crowd-based documentation of graves; to date it has about 30 million grave photos. Find A Grave [2] enables people to create digital memorials of the dead; photos are optional. To date it has about 180 million memorials. Both are crowd-sourced, support grave geotagging, and help navigate to the location of the grave. Fields on both sites are limited to basic vital information, epitaph, and personal notes. Both systems support search based on names, dates, and cemetery location alone.

CemoMemo is similar in some ways to both systems, but differentiates itself in terms of its search capabilities, its categorization and data fields, and personalization options.

2.3.2 Country Level. Some cemetery digitization systems focus on a single country. Maceva [28] (Hebrew for “gravestone”) is a centrally managed online database of historical Jewish cemeteries in Lithuania. It is a closed system, centrally managed and aimed at non-active Jewish cemeteries in Lithuania. A similar closed, centrally managed system was developed for non-active Jewish cemeteries in Turkey [15]. Like CemoMemo, both document all the text on the gravestone and support geotagging. The Turkish system supports rich search, including physical categorization of the gravestone and level of preservation, properties CemoMemo does not include. Such properties require central management for consistency and accuracy, which are not possible in a crowd-sourced system.

Some militaries keep online records for military burials. Izkor [24] (Hebrew for “remember”) is the Israel Defense Forces’ searchable online system for all Israeli military dead and cemeteries. The US Veterans Administration keeps an online, searchable system of all American military burials [36]. Both systems augment grave data with personal history and directions for visiting the grave, but only allow searching for graves based on vital information, military events, or battles.

2.3.3 Local Systems. Some cities and cemeteries have websites to search based on names or vital information. The Tel Aviv-Yafo, Israel Jewish burial society [7] and the Haifa, Israel Jewish burial society [6] have websites for cemeteries in their jurisdictions. Gravez, an Israeli website, covers 29 Israeli cemeteries with about 1.3 million graves, offering search, navigation, and detailed maps [17]. A full list of such systems is beyond the scope of this work. All such systems we found enable search based on names, burial locations, and vital information alone.

2.4 Crowd-Sourcing

Crowd-sourcing is a popular tool for achieving large-scale projects with minimal expense and central management, but creating and maintaining a successful crowd-sourced project is not trivial. Retelney et al. [32] explore the limitations of crowd-sourcing in the context of the complexity of the tasks to perform, issues we have faced in the context of digitizing cemeteries. Grau et al. [16] explore methods of increasing and preserving participant motivation in a crowd-sourced enterprise using personalized encouragement messages, a technique we use in CemoMemo.

3 CEMOMEMO

CemoMemo began as an effort to digitally preserve gravestones in small northern Israel cemeteries suffering from weathering, erosion, neglect, or subsidence. It began in 2017 with groups of undergraduate students documenting

Basic Info	Personal Details	Dates and Family
First/Given name	Nickname	Civil date of birth
Last/Family name	Date of Immigration to Israel	Civil date of death
Cemetery Name	Place of birth	Hebrew date of birth
Location in cemetery	Circumstances of death	Hebrew date of death
	Profession	Maiden name
	Place of death	Father's name
	Paintings or sculptures	Mother's name
	Epitaph	Age
Gravestone properties	Additional info (not on the stone)	
Grave type (e.g. religious, family, common)	Personal memories	
Symbols (e.g. Star of David, flowers)	Bibliography	
Secondary memorial		
Languages (on the stone)		

Fig. 3. Fields recorded by CemoMemo. All fields are optional.

the historic Rosh Pinna, Israel cemetery. Students photographed the gravestones and filled out a paper form to transcribe the text and categorize physical aspects of the gravestone. The primary goals were the documentation of a decaying cemetery and education of the students about the history of the place and its people.

The effort emphasized the need for a system for historical digital preservation of Jewish cemeteries, something not available then on the market. Historical analysis requires a consideration of many properties of gravestones such as the language used, the terms and information recorded, the date formats used, the symbols and icons present, the location of the grave, and the epitaph. Contextual metadata such as who documented the grave and the date of documentation can also give social insight. Genealogy-oriented cemetery digitization systems we found didn't fully support such details.

To address the gap, we built CemoMemo, a website and associated Android app. CemoMemo went through two major versions: a beta with students and a public version for groups and volunteers. The platform went public in June 2019; we have released several upgrades and bug fixes since.

3.1 Data Fields

The data fields CemoMemo supports are tailored to the style of gravestones used in Jewish cemeteries from the 19th century and onward. A list of the fields included in CemoMemo is in Figure 3, categorized by topic for ease of reference. While many fields are self-explanatory, some require additional explanation since they have special meaning in common Jewish burial practice. Appendix A contains six gravestones from CemoMemo to illustrate the following discussion.

3.1.1 Names. Outside of Israel, many Jews have a given name in the local language in addition to a Hebrew one, so Jewish gravestones often have both names. More religious Jewish communities regularly give only a Hebrew name, while more secular Jewish communities may give only one in the local language. Therefore, examining the languages and kinds of names on the gravestones can show patterns of religiosity and secularness in the community (see also Vajta [37]). For Israeli-born Jews, it is common to have only a Hebrew given name, so the language of the name in Israel is not as indicative of community.

Some gravestones record nicknames. The use of nicknames is uncommon in Jewish gravestones; the most common place they are found in CemoMemo is on Israeli military and secular style gravestones.

Jewish tradition gives importance to patronymics and matronymics. One or both may appear on Jewish gravestones in addition to a family name. Patronymics and matronymics are found almost exclusively in Hebrew, even

on graves with family names in the local language. On gravestones, Jewish communities of European descent tend to only write the patronymic; Jewish communities of Middle Eastern descent tend to write both or only the matronymic. In more recent cemeteries outside of Israel, the use of patronymic and matronymic is less common among secular burials. In Israel, both religious and secular communities regularly write one or both.

3.1.2 Civil and Jewish Dates. Jewish graves outside of Israel often contain dates in two forms: in the local calendar and according to the Jewish calendar. The Jewish date of death has religious significance but the birth date does not, so the death date is more common to find on gravestones than birth date. As with names, outside of Israel the use of only Jewish dates is associated with a more religious style of burial. The use of only local dates is associated with a more secular style. In Israel, older secular gravestones included only Jewish dates, likely out of a sense of Hebrew pride. More recently, secular gravestones often include both Jewish and Gregorian dates. Religious gravestones in Israel tend to have only the Jewish date.

3.1.3 Secondary Memorial. Some gravestones include memorials for individuals not buried in the grave, but which the family or community sought to memorialize. The practice was most common in Israel post-World War II, when Holocaust survivors sought to memorialize family members who were killed and not buried properly. The most common form is a separate epitaph with the names, dates, and places of birth of the ones to memorialize (e.g., Masha Kaplansky's gravestone (Figure 13(b))).

3.2 Technical Attributes and History

3.2.1 Initial Beta. CemoMemo's beta was developed as a capstone project. It had three parts: a MySQL database backend for photos and data, a website coded in PHP, and an Android app. The database and server were hosted on a dedicated server in our college. Users authenticated using OAuth 2.0 [19] via Google or Facebook. Logged in users could upload graves using the app and navigate to graves. The website enabled full text search and allowed creation of personal lists of graves. Media were stored on the server's file system with pointers to the files in the database. The physical architecture (deployment) and logical architecture (component diagram) are shown in Figures 4 and 5, respectively.

Our initial assumption was that users would upload graves to the website using the mobile app, so the component for grave addition was coded in the app and interfaced directly with the MySQL backend. To allow for offline documentation, we included a local storage cache (SQLite) that could later sync with the MySQL server. The website offered search, forums about each grave, and personal lists of favorite graves.

We performed beta testing with students, documenting several local cemeteries. We observed the students and received oral feedback from them immediately after. Both revealed problems with our initial architecture. First, the grave addition process had several steps that could take 2 to 3 minutes total. Many users wanted to photograph quickly and upload later at home, something not possible from the mobile app. Second, students with non-Android devices were left out. Third, non-uniformity of design between the app and website created dissonance and confusion with users who wanted to see their work immediately and be able to update or improve graves already uploaded. Fourth, users complained of slow upload and page loading times.

To solve the first three issues, we concluded that the website and app need to be unified, to allow search and upload from both. Due to budget issues, we needed to avoid duplication of code. We therefore decided to change the architecture, moving the app business logic to the website and leaving only mobile-specific logic on the app. To improve performance, we divided the website into separate Docker containers and increased support for asynchronous interactivity (e.g., upload photos in the background while documenting). To solve the fourth issue, we decided to move media storage from our server to a cloud storage platform. All changes were included in the first public version.

3.2.2 Public Version and Architecture. The public version's physical architecture is documented by a UML deployment diagram in Figure 6. Its components, internal, and external interfaces are documented by a UML

Fig. 4. CemoMemo beta deployment diagram.

logical architecture diagram in Figure 7. Briefly, the server is divided to two Docker containers, frontend and backend. The website is mobile-friendly, displaying properly on large screens and mobile devices. We use multiple frameworks for internal communication and database interactions. The local database stores only user data and grave metadata; media and photos are stored in the Amazon S3 cloud storage service. Grave addition, search, comments, and personal grave lists are managed on the website. The mobile app's primary view is a webview pointing to the website that supports all of its functionality. The app contains native code for mobile-specific features only (i.e., compass navigation).

Since any user can modify grave details or upload new photos and the barrier to login is low, we worried about vandalism and spam. We therefore built the database schema to support unlimited versioning on all fields and media details. Admins receive daily notifications of all new and updated graves and can undo any change or remove any photo.

3.2.3 Location. CemoMemo uses location for navigation to the grave, to find nearby graves, and to automatically detect the cemetery a grave is in. We faced technical challenges in getting accurate GPS readings of gravestone locations.

First, the GPS location given by Android is less accurate when the phone is on "battery saver" mode. Often the location is old or is the location of the nearest cell tower.

Second, the accuracy of the GPS reading varies by phone model. In general, lower cost phones give less accurate readings.

Third, by default the camera does not attach GPS location to photographs taken even when the location sensor is on.

Last, users can upload photos to CemoMemo from a desktop computer that does not have a GPS sensor.

Since CemoMemo needed to support documentation by general users who are not technically savvy, we did not want to dissuade users by blocking uploads of photos with low quality or missing location information. Therefore, to cover as many bases as possible while remaining fully automatic for non-sophisticated users, CemoMemo extracts the location of a gravestone photo using the following methods, taking the first one that works:

Fig. 5. CemoMemo beta logical architecture diagram.

- (1) The GPS location from the mobile device.
- (2) The GPS location from the web browser.
- (3) The location encoded in the EXIF metadata of the photo.

If none of the above work, the upload continues with empty location information. The location can be manually edited after upload.

3.2.4 Search. CemoMemo's search capabilities support cemetery and historical research and offer unparalleled power in finding and categorizing graves.

Regular search works with free-text and performs a cross-cemetery search on all fields CemoMemo stores (see Figure 3). A sample simple search is shown in Figure 8.

Fig. 6. CemoMemo new deployment diagram.

Advanced search works using cumulative field-specific filters. There are two types of fields: text and numerical. Filters on text fields can be added with *equals*, *not equals*, *contains*, *empty*, *not empty*. Filters on numerical fields can be added with *equals*, *not equals*, *greater than*, *less than*, *empty*, *not empty*. A sample advanced search is shown in Figure 8.

Cemetery Search. Cemetery search finds cemeteries based on their name, address, or description. A found cemetery can be opened, showing its cemetery page.

3.2.5 Grave Page. The grave page contains photos, the text on the gravestone categorized by fields, comments left by users, a list of contributors, and nearby graves. A sample grave page is shown in Figure 9. Users can share the grave via social media or email, start navigating to the grave, leave a comment, or enter into edit mode for the grave. Some actions (leaving a comment, editing) require log-in first.

Fig. 7. CemoMemo new logical architecture diagram.

(a) A regular search for "Sidney." Any grave with "Sidney" in it will match.

(b) An advanced search for gravestones with the age at death greater than 15, a father's name, and that contain text in English. All details must be written on the stone (ages are not calculated).

Fig. 8. Searching with CemoMemo. Gravestone photos © Tammy A. Hepps, CemoMemo Project and Contributors.

Fig. 9. Grave page sample. Gravestone photos © Tammy A. Hepps, CemoMemo Project and Contributors.

Navigation. Navigation is handled differently on browsers and mobile. Using the Android app, compass and distance remaining is shown since cemeteries often do not have mapped paths or named roads. Using the browser, Google Maps is opened to navigate to the grave's coordinates. On graves without GPS coordinates, the "navigate to location" button is hidden.

3.3 User Models

In designing CemoMemo's user interface and experience, we identified two primary user models (*casual* users and *documenting* users) and one secondary user model (*admins*).

As with other online crowd-sourced initiatives, we presumed the majority of users would be casual ones who want to search or peruse the system, not contributing or editing. We therefore didn't place any barriers (e.g., log-in) to read or search.

Documenting users must register for the system, authenticating using OAuth 2.0 [19] via Google or Facebook. Registering may be a psychological barrier for some, so we encourage casual users to become and remain active documenters in multiple ways. First, we put the "Upload a grave" button prominently on the top of the home

Table 1. CemoMemo Features and Availability Based on User Model: (Cas)ual, (Doc)umenting, (Adm)in

Feature	Cas	Doc	Adm
Search			
↪ Basic/Advanced: Grave	•	•	•
↪ Cemetery Search	•	•	•
Grave Page			
↪ View details and photos	•	•	•
↪ Share/Email grave	•	•	•
↪ Navigate to grave	•	•	•
↪ View nearby graves	•	•	•
↪ Add comment		•	•
↪ Edit details/Add photo		•	•
↪ Undo edits/Remove photo			•
Grave Management			
↪ Add new grave		•	•
↪ Add grave to favorite list(s)		•	•
↪ Delete grave you created		•	•
↪ Delete any grave			•
Cemetery Management			
↪ Add cemetery		•	•
↪ Update cemetery details			•
↪ Add cemetery photos			•
↪ Remove cemetery			•
Messaging			
↪ Updates on graves edited/created		•	•
↪ Comments on graves edited/created		•	•

page, encouraging users to take an active part in documenting. Second, after a user takes the first step and uploads a new grave, the system shows an “Upload another grave” button, nudging him to continue contributing. Third, inspired by the *legitimate peripheral participation* model of user acclimation [27], we let users make small contributions (e.g., adding a grave with just a photo, editing a single data field) and get immediate credit for their contribution: CemoMemo shows a thank-you message after uploading a new grave, it adds the name of the new contributor on the grave page, and it puts the grave at the top of the home page.

Admins are global managers. For now only our development team and us use it. In the future, we want to create a limited admin role that covers specific cemeteries or countries that can be given to partners or contributors who will take responsibility for them.

Table 1 summarizes the features of the system and categorizes them by user model.

4 USING CEMOMEMO FOR RESEARCH

One goal of CemoMemo is to support sociological and historical research about gravestones. Gravestones are created by family or friends, so they reflect the priorities of the burying community. Indexing and searching all gravestone text and numbers allows research on the social, familial, and religious attitudes of the community. CemoMemo helped us perform historical and ethnological analyses of communities that we will publish in other,

Fig. 10. Summary of epitaphs on Homestead Hebrew Cemetery gravestones by decade.

dedicated work. To give a taste, we use CemoMemo to extract cultural and community differences between two Jewish cemeteries in different countries that cover similar periods of history.

4.1 Epitaphs and Family

Statistical analyses of gravestone text and style show trends within cemeteries likely due to peer expectations, available engravers, and prevalent custom. For example, in **Homestead Hebrew Cemetery** (Homestead, PA, USA) (hereafter **HHC**), the cemetery of a small Orthodox Jewish community near Pittsburgh, a majority (58%, $n = 495$ of 853) of gravestones include the word “beloved” in the epitaph. In **Ein Harod-Gidona Cemetery** (Gidona, Israel) (hereafter **EHG**), the cemetery for a group of small Jewish socialist kibbutzes in northern Israel, a minority (5.5%, $n = 7$ of 126) include the comparable word in Hebrew (“yakar” or its derivations). In HHC, the predominant type of epitaph is family appellations as can be seen in Figure 10, but in EHG, very few graves have family appellations (6.3%, $n = 8$). The difference reflects the kibbutz’s attitude toward breaking bonds with family in the “old country” (many kibbutz members were young European Jewish immigrants who came without parents) and forging new ones within the collective [35].

Notable sample graves from a similar period from HHC and EHG are in Figure 11. Goldman’s grave shows a typical family epitaph emphasizing family bonds and relationships. Rosenfeld’s grave has a patronymic (uncommon in EHG), but emphasizes Rosenfeld’s position, actions, and the circumstances of his death. The latter’s grave is unusually detailed and elaborate for EHG, due to Rosenfeld’s importance in the community and the historical impact of his death.¹

The emphasis on family epitaphs in HHC reveals cultural trends. HHC had 70 to 90 burials per decade during its period of peak usage (1920s–1990s). In the decades after, usage dropped (50 during the 2000s, 36 in the 2010s). Analyzing the trends of family appellations used shows patterns over time.

First, there is an increase in the mentioning of family on epitaphs from the 1920s onward. The trend hints to a communal desire to surround the deceased with family, showing how dear the deceased was to family and emphasize that they are not alone even in death. Non-family epitaphs often include general praises (e.g., “A perfect and straight man”) or military service details.

Second, community cultural norms affect what combinations of family appellations are written (Tables 2 and 3). Gravestones most commonly include parental (father, mother) and spousal appellations (husband, wife). Unsurprisingly, the most common multi-appellation combinations are husband/father and wife/mother. While everyone is somebody’s child, the norm is to not write “son” (“daughter”) when the deceased was also a

¹We conjecture from the epitaph that Rosenfeld’s current gravestone was erected significantly after his death when it became clear that his death was only the first of many Jewish deaths during the multi-year Arab revolt.

(a) Gravestone of Morris Goldman in Homestead, PA, USA. The grave reads, “Here lies/My son and our brother/the young man/Moshe Aharon/son of Meir Haim/Who was plucked away during his choice years/on 11 Elul 5696/In the 44th year of his life/TNZBH” The back of the stone (not shown) reads in English, “My son/Morris A./Goldman/March 21, 1892/August 29, 1936/Rest in peace.”

(b) Gravestone of Moshe Rosenfeld in Gidona, Israel. The grave reads, “The beauty of Israel/upon your high places, dead/how the mighty have fallen/First of the fallen of the Yishuv/In the bloody events/5696/Here lies/Sargeant/Moshe/son of Shlomo Yitzhak/Rosenfeld/Fell dead on Mount Gilboa/while standing watch over the nation/born first of Kislev 5665 in Menahamia/Fell dead 11 Marheshvan 5696/TNZBH” 5696 refers to the 1936–9 Arab revolt in Mandatory Palestine. The birth and death dates correspond to 9 November 1904 and 7 November 1935 respectively.

Fig. 11. Sample graves from HHC and EHG in CemoMemo. Photos © Tammy A. Hepps, CemoMemo Project and Contributors.

father (“mother”). “Grandfather” (“Grandmother”) and “great grandfather” (“great grandmother”) are used only in combination with “father” (“mother,” respectively), preserving the chain of family continuity. Family appellations since the 1970s are consistent enough that one can reasonably guess who died without children or grandchildren based on the epitaph.

Third, the maturity and increased longevity of the community can be traced by analyzing which family appellations are used over time. “Grandfather” and “grandmother” become more common in the 1960s and “great grandfather” and “great grandmother” begin in the 1980s. The Jewish community of Homestead that founded the cemetery began to expand in 1901–2 [21], so this corresponds to the community maturing, with members reaching grandparenthood before death. A detailed breakdown of family appellations by decade can be found in Appendix B.

Table 2. Summary of Male Family Appellation Popularity in Homestead Hebrew Cemetery

	Son	Brother	Uncle	Husband	Father	Grandfather	Great Grandfather
Son	-	21	4	1	3	0	0
Brother	21	-	12	10	7	3	0
Uncle	4	12	-	4	1	1	0
Husband	1	10	4	-	157	42	1
Father	3	7	1	157	-	47	1
Grandfather	0	3	1	42	47	-	1
Great Grandfather	0	0	1	1	1	1	-
Total	48	55	0	186	248	47	1
% of total graves	5.6%	6.4%	2.0%	21.8%	29.0%	5.5%	0.1%

Table 3. Summary of Female Family Appellation Popularity in Homestead Hebrew Cemetery

	Daughter	Sister	Aunt	Wife	Mother	Grandmother	Great Grandmother
Daughter	-	12	2	4	5	3	0
Sister	12	-	9	13	10	4	0
Aunt	2	9	-	4	2	3	1
Wife	4	13	4	-	141	49	5
Mother	5	10	2	141	-	67	5
Grandmother	3	4	2	49	67	-	5
Great Grandmother	0	0	1	5	5	5	-
Total	26	40	15	161	274	67	5
% of total graves	3.0%	4.7%	1.8%	18.9%	32.1%	7.8%	0.6%

4.2 Cause of Death

Another cultural difference between the cemeteries can be found by analyzing causes of death written on the gravestone. In EHG, 13.5% ($n = 17$) of gravestones include the cause of death. The cemetery of Degania A, a small secular kibbutz in northern Israel, shows a similar custom with 13% ($n = 21$ of 159) of graves including the cause of death.² The causes of death given include drowning, violence, murder, and suicide. The kibbutz communities saw no shame in recording the causes of death of their members, even those who ended their own lives.

In HHC, no grave includes a cause of death, even for those whose manner of death was covered by the press. This reflects the community's attempt to save face for its members whose manner of death might be shameful [20].

5 LESSONS LEARNED

Having run CemoMemo for over a year, we collected lessons from operating it, documenting graves, and performing historical research with it.

5.1 Location and Navigation

CemoMemo's initial focus included tourism, so navigation to graves was a central feature. Despite the app and website's multi-step strategy to get location information, about 28% ($n = 1,388$ of 4,886) of gravestones do not

²Degania A's cemetery has a military section in which all graves include the cause of death. Including military graves, the percent is 39% ($n = 90$ of 228).

have location information. This arises either because users uploaded with the GPS sensor off or because the photographs did not have GPS coordinates. For now, we manually add GPS coordinates to graves missing them based on rough estimates. Even when GPS information is recorded, Android may deliver imprecise locations, sometimes kilometers off when the device is on “battery saver.” Better training can mitigate, but not prevent the issue. Including detailed maps of cemeteries and step by step navigation can make physical visitation easier, but that is feasible only with significant on the ground mapping with the help of local partners.

5.2 Crowd-Sourcing

Crowd-sourcing was key to a quick roll out and to reach many cemeteries with minimal effort. Using crowds, however, led to spotty coverage of cemeteries, duplicates of notable graves, waxing and waning interest, and non-uniformity in data and photo quality. Partners have yielded more consistent and comprehensive results, but reaching a critical mass of such partners is a challenge.

Often users add additional details to the documentation that are not written on the gravestone. The most common details added are age, birthday, country of birth, and cause of death. Since we seek to record only what is actually written on the stone, we created the *personal memories* field to allow people to put additional information not written on the stone.

5.3 Search, Indexing, and Language

Search enables us to analyze aspects of gravestones to trace cultural and community priorities. That requires us to accurately transcribe the text on the gravestone without additions. Thus, gravestones in Hebrew are documented in Hebrew and those in Russian are documented in Russian. This allows detailed historical analysis, but may impede search and discovery by people not familiar with the source language. Some gravestones include obvious spelling or date errors in them, which we do not correct.

5.4 Dates

Jewish gravestones often have multiple dates, local and Jewish. When the Jewish date falls on a holiday, often the holiday is given rather than the calendar date (e.g., Rosh Hashana instead of 1 Tishrei). The desire to preserve such details led us to preserve three dates (Jewish, local, free text) for birth and death. Thus, search by date became complicated since someone searching for a local date of death (e.g., 1 May 1950) would not find a grave with only a Jewish burial date (e.g., 14 Iyar 5710).

With Gregorian dates, month names differ by language (e.g., January in English, Enero in Spanish). For uniformity of search, we converted all Gregorian dates to a single template, losing some detail. Some gravestones use Roman numerals for months (e.g., 5 IX 2010 for 5 September 2010), a custom we found among graves from some ethnic communities (primarily Jews of German or Russian descent), a detail we can preserve using the free text date option in addition to the fixed format. Preserving the language and form of the date can thereby reveal cultural and community affiliations.

5.5 Age

A minority of graves (32%, $n = 1,545$ of 4,886) note the age at death, so a gravestone that records age at death underlines its significance (e.g., the tragedy of a young death, having reached what the community considered old age). Although CemoMemo could calculate age at death if not written, it does not do so to avoid obscuring the graves that chose to emphasize the age.

6 CONCLUSION AND FUTURE DIRECTIONS

CemoMemo is a crowd-based platform for digitizing cemeteries and gravestones that enables anyone to document a grave using only a smartphone or a home computer. It categorizes information on the gravestone and

about the gravestone into over 20 categories, enabling powerful full text and numeric search. It has been running for a year now and has nearly 5,000 graves documented by volunteers, students, partners, and research staff.

We built CemoMemo with a hybrid web/mobile architecture to enable quick documentation in the field or at home with minimal user friction. The website automates many simple tasks and enables rich search. The architecture supports a moderate number of users and graves on non-specialized hardware augmented with cloud media storage.

We are currently working to introduce more automation to CemoMemo.

First, we are working on an **optical character recognition (OCR)** algorithm to automatically read text from gravestones, saving typing time. Image quality, lighting, and contrast are issues with outdoor photographs, particularly with older graves or ones that have significant weathering.

Second, we are working on an automated symbol recognition algorithm to detect symbols of importance on graves. Automated detection will reduce data entry time, give more uniformity to symbol descriptions, and make multi-language search by symbol easier. As with OCR, photograph quality, lighting, and weathering will affect the quality of automated detection.

Third, we are working on an algorithm to automatically detect duplicate graves and merge them.

Expansion of CemoMemo is ongoing, with graves added daily. While CemoMemo currently focuses on Jewish graves, we are working to digitize Arab Muslim cemeteries in Israel, expanding our cultural reach to cemeteries that have not received much digitization attention.

We invite you, the reader, to use CemoMemo to document graves near where you live, work, or travel. Doing so connects you to your community's past and can be key to understanding its future.

APPENDICES

A SAMPLE JEWISH GRAVESTONES IN CEMOMEMO

(a) Gravestone of Lena Katz in Marinette, WI, USA. The grave reads, “Lena Meyer Katz/Reva Leah daughter of Haim the Priest/June 21, 1911 Dec. 11, 1982/25 Sivan 5671 25 Kislev 5743.”

(b) Gravestone of Ethel Jacobson in Homestead, PA, USA. The grave reads, “Here lies/the girl/Etil daughter of reb Avraham/David Jacobson/29 Tamuz 5672/TNZBH/Ethel Jacobson/1910–1912/Beloved daughter and sister.” The date corresponds to 14 July 1912.

(c) Gravestone of Allen Smooke in Homestead, PA, USA. The grave reads, “Smooke/Here lies/Abba Baruch son of Yekutiel Yehuda/Allen B./“Smokey”/Loving husband/Father and zeidy/Sept. 18, 1925 - July 27, 2017/4 Av 5777/Always in our hearts/TNZBH.” Zeidy is a Yiddish term for grandfather. The Jewish date refers to the death date.

(d) Military gravestone of Avraham Amikam in Rosh Pinna, Israel. The grave reads, “Avraham Amikam (Shein)/Son of Chaya and Aryeh/Born in Poland immigrated [to Israel] 5693/Died from wounds during his service/7 Tishrei 5738/58 years at his death TNZBH.” The immigration date corresponds to 1932-3. The death date corresponds to 19 September 1977.

Fig. 12. Sample American and Israeli Jewish gravestones from CemoMemo. The acronym TNZBH (“Te-hey nafso/nafsha tzrura bi-tzror ha-chaim”, “may his/her soul be bound up in the bundle of the living”) is a common scriptural phrase associated with death. Photos © Tammy A. Hepps, CemoMemo Project and Contributors.

(a) Gravestone of Bruce Abramson in Maagan, Israel. The grave reads, "Here lies/Tsvi Abramson/Bruce Abramson/son of/Harold and Corin/Died 29 Adar A 5749/6.3.1989/He was 33 at his death/TNZBH/In Israel he chose to live/In its land to come for eternal rest."

(b) Gravestone of Masha Kaplansky in Lochamei Hagetaot, Israel. The grave reads, "Here lies/Masha Kaplansky/Daughter of reb Avraham Shlomo/Died 20 Tamuz 5720/In the 68th year of her life/And in memory of/Her husband Yaakov and her son Avraham/Who perished in the Holocaust/And did not come to Jewish grave/TNZBH." The date corresponds to 15 July 1960.

Fig. 13. Sample Israeli gravestones from Cemomemo. Photos © CemoMemo Project and Contributors.

B GRAPHS OF APPELLATION USE IN HOMESTEAD HEBREW CEMETERY

Fig. 14. Male family appellation usage by decade in Homestead Hebrew Cemetery.

Fig. 15. Female family appellation usage by decade in Homestead Hebrew Cemetery.

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