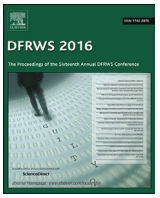
Digital Investigation 18 (2016) S118–S124

Contents lists available at ScienceDirect

Digital Investigation

journal homepage: www.elsevier.com/locate/diin



DFRWS USA 2016 — Proceedings of the 16th Annual USA Digital Forensics Research Conference

Recovery method of deleted records and tables from ESE database

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Keywords:
ESE database analysis
ESE database forensic
Windows forensic

A B S T R A C T

The Extensible Storage Engine (ESE) database is a data storage technology developed by Microsoft. It is mainly used by Windows OS and its web browser. It is possible to easily delete a table or a record in the database using the ESENT API. However, there are insufficient papers and relevant information how about recovering deleted records. Previous works apply only to some tables and fail to recover deleted data perfectly. In this paper, we analyzed the structure of the ESE database and present a general-use technique to recover deleted records and tables. We developed a tool to implement the technique, and assessed the performance of the proposed tool.

Introduction

The Extensible Storage Engine (ESE) database has been used mainly in web browsers (e.g. Internet Explorer, and Edge) and Window systems (e.g. Windows Search, and System Resource Usage Monitor). In terms of forensics, research on ESE database is important because the database is used to save and manage the main records of systems and users in the Window OS.

For example, Windows Search uses the ESE database to maintain files, emails, programs and Internet history (Chivers and Hargreaves, 2011). Also Microsoft Edge and Internet Explorer version 10 and 11 use it to save the web browsing history and information about temporary files (Chivers, 2014; Gratchoff and Kroon, 2015). Numerous other Windows components such as Windows Mail, Active Directory, Windows Live and Windows Update use it.

As with other databases, it is possible to delete records in the database in order to maintain the latest data and to efficiently manage storage space. Tables or records can be easily deleted from the database using the ESENT API (Microsoft ESENT API; Kim). The ability to obtain information about deleted records often more important than information about normal records in the database. This paper explores a universal recovery method for deleted ESE database records and presents the experimental results through development of tool.

This paper is organized as follows. Chapter 2 discusses related work on ESE database structure analysis and deleted record recovery. Chapter 3 details the database structure. Chapter 4 examines the internal changes after deleting records. Chapter 5 presents a technique to recover deleted records based on information observed in Chapter 4. Chapter 6 discusses our tool that implements the technique, and assesses its performance. Finally, Chapter 7 concludes this paper and introduces future work.

Related works

Metz analyzed the schema of many ESE databases which is used in Window Search, Windows Help and Support Services, Windows Mail, Windows Search, Windows Security, and Windows Update files (Metz). Metz analyzed the file format of the ESE database, but some

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http://dx.doi.org/10.1016/j.diin.2016.04.003

areas were only partly explained. Thus, it is difficult to fully grasp the database based on his work alone (Metz). To recover deleted records in database, the study of the ESE database format is essential and additional analysis is required.

There has been research on ESE database file recovery applied to Windows Search and Internet Explorer. However, this method applies only to some tables and cannot recover the last column entry (Chivers and Hargreaves, 2011; Chivers, 2014).

Gratchoff and Kroon studied a built-in browser called Edge, since Windows version 10, and found that there was a great deal of similarity in where and how artifacts are saved, with the previous version of Internet Explorer (Gratchoff and Kroon, 2015). This indicates that the ESE database is used in the latest version of Windows OS.

Our previous work in this area also had some issues (Kim et al., 2015). Without performing experimentation on the recovery of deleted records and tables in an ESE database, we only recovered unused records. The prior analysis of long value page record format was not accurate, resulting in errors during recovery. We were also previously unable to recover deleted tables.

ESE database format analysis

To classify the deleted area in the database file and to recover records in that area, the structure of the record should be exactly analyzed. So, we studied the ESE database format based on Metz's works. In this section, we describe the structure that should be known for recovering deleted records or the part that is not in Metz's works.

ESE database files are comprised of multiple pages except for the database header, and Pages are managed in a B-Tree structure (Microsoft). Fig. 1 illustrates internal structure of the ESE database.

Table

There are multiple tables inside the ESE database, and table information is managed by a catalog table called MSysObject (Metz). Certain tables include sub-tables called LV, in order to save big-sized data. Tables have their own identification numbers. This is specified in all page headers in tables. The sub-tables called LV also use distinct identification numbers, and are managed in the same way as the superordinate table.

Page

A page is a logical unit used to save and manage records in the ESE database, and composed of header, data, and tag areas. A tag exists at the end of a page and increases in a reverse order. This value has the offset and the size of records, and 2 bytes are allotted for each.

Several page types have been identified, including root, data, branch, empty, space tree, index, long value; pages can be distinguished by page flag values. A record storage method is page-type dependent, and can be identified by analyzing data, branch, and long value pages.

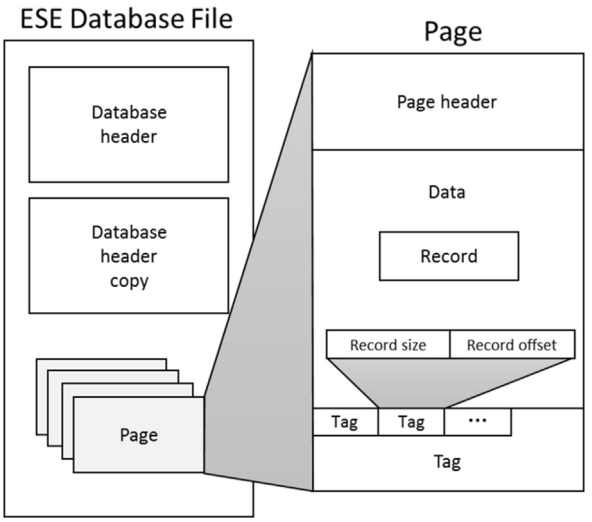

Fig. 1. ESE database structure.

Data page

A data page refers to a page in which real data of a table is recorded. A page tag area records the offset and the size of records, and MSysObject saves information about records. This information can be used for parsing records in the data area. A record consists of the record header, the fixed size data, the variable size data, and the tagged data.

The item that should be analyzed in the record header is the page tag flag, the jump size, the last fixed size data ID, the last variable size data ID, and the first variable size data offset. Fig. 2 is a figure of the structure of a record in the data page. A page tag flag exists in the top 2 bytes of the record header when the page size is more than 16 KB. The value of the page tag flag determines parsing method. The last 4 bytes of the record header is an essential part for reading data area of records, and there are the final ID of fixed size data, and the offset of variable size data.

A fixed size data is a field to save data with the fixed size. Information about the field can be identified from the record whose type is 2 and ID is less than 256, in the MSysObject table.

A variable size data is a field that saves up to 255 characters. Information about the field can be identified from the record whose type is 2 and ID is more than 256, in the MSysObject table. The size of each item is recorded at the front and then real data is saved.

A tagged data is a field that saves up to 65,535 data. Tagged data have their unique IDs. Each item's ID and offset are recorded at the front and then real data are saved. The size of the final item can be identified through the record size of a tag, not through the value in the record. If a record is deleted and the tag does not remain, we cannot know the last point of the record.

Branch page

Pages are managed in B-Tree structure. If the level of the tree increases, a data page and a long value page change into a branch page which is used to record the page number of sub-levels. Fig. 3 shows the structure of a record in a branch page.

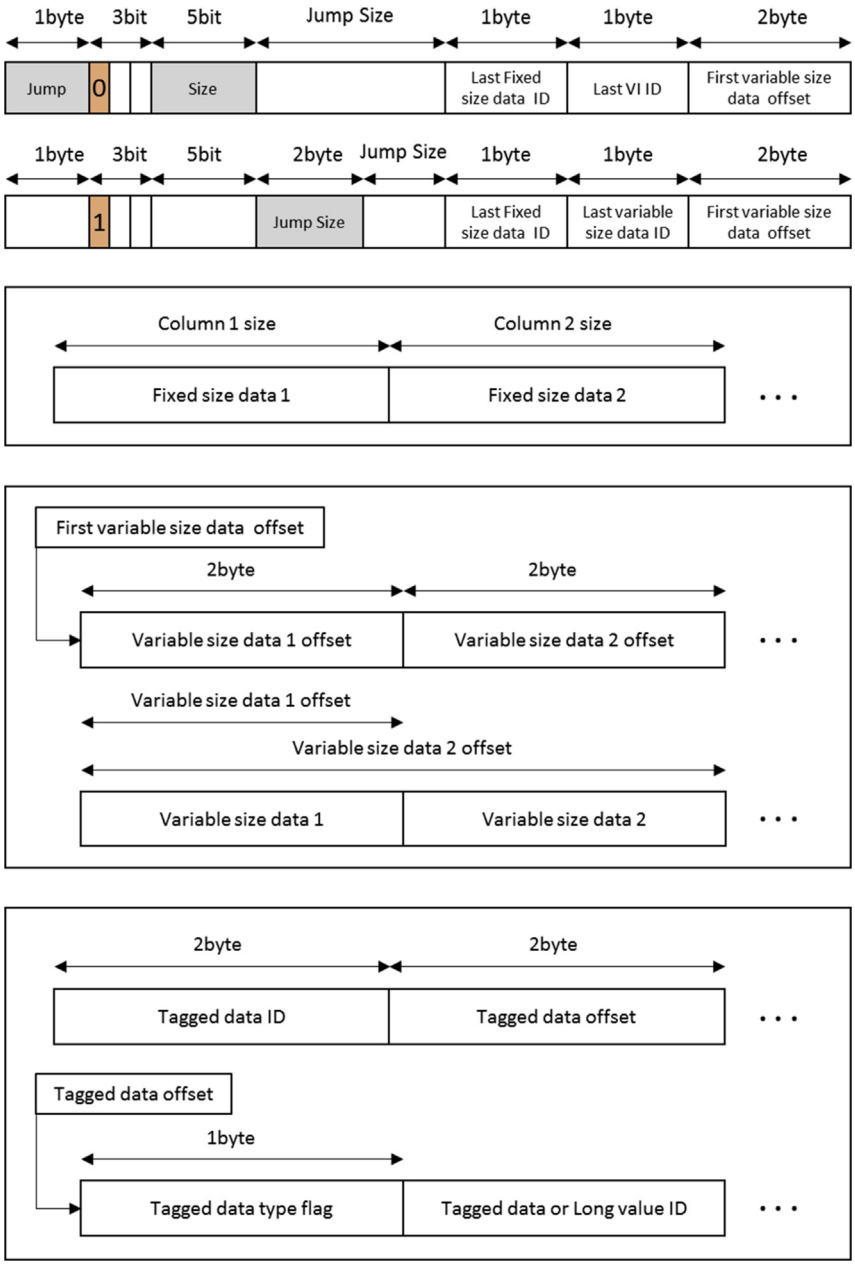

Fig. 2. Record format in data page.

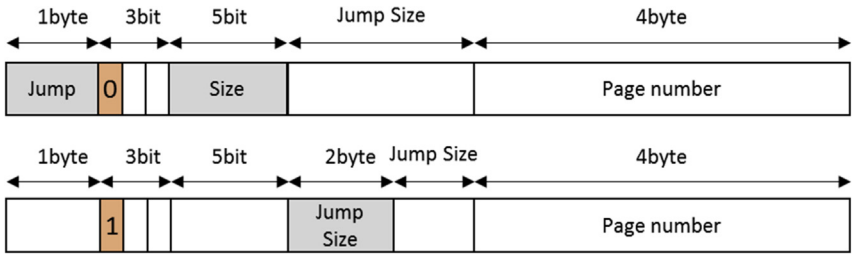

Fig. 3. Record format in branch page.

Long value page

A specific type of table for large data uses sub-tables by using pointers, without saving big data directly in records. A Long Value (LV) table uses LV pages, and saves data by using multiple records when the size of data is bigger than that of a page.

LV pages record data using a LV header and multi separated data. Fig. 4 shows the structure of a record in an LV page.

Verifying changes after deleting records

To verify changes after deleting record, we developed a tool (Kim). We then deleted records using a 'Microsoft.Isam.Esent.Interop.Api' class function called 'JetDelete'. As a result, the B-tree structure was modified and the tag area was changed. When we deleted many records or removed a specific table using the 'JetDeleteTable' function, some pages were no longer needed. While the data area and the tag area were not deleted, the value changed for the available page tag item in the header area, which represents the number of records. If the pages are not used, the Empty page flag was set in the Page flags item.

Proposed record recovery technique

There are two reasons that it is possible to recover deleted records in the ESE database file. Firstly, if a data page or LV page are turned into a branch page, the pre-existing data remains in the branch page. Secondly, when records are deleted, the tags and the data are not deleted; only the number of records and the kind of pages are changed.

Fig. 5 illustrates a flow chart which expresses the recovery procedures of deleted records in the ESE database file. In the beginning of the ESE database file, the database header and its copy exist. Basic information is recorded in the database header such as the unique signature, the page size, the file state, the version, etc. The page offset and the record storage method are determined by the version and the page size.

For recovering records, the schema information is required about a page to determine what belongs to a certain page. Deleted tables and related records can exist in the data page of the catalog table. Thus, the schema information of deleted tables can be identified if the deleted records of the catalog table are recovered.

There may be some unrecorded pages in the branch page because they are not now in use by the ESE database

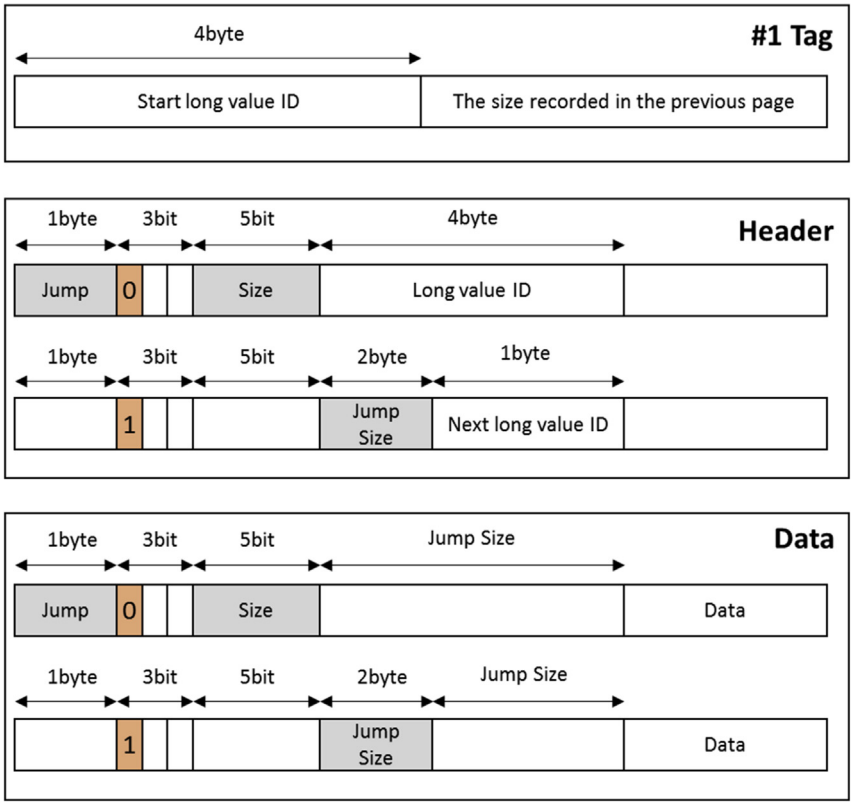

Fig. 4. Record format in long value page.

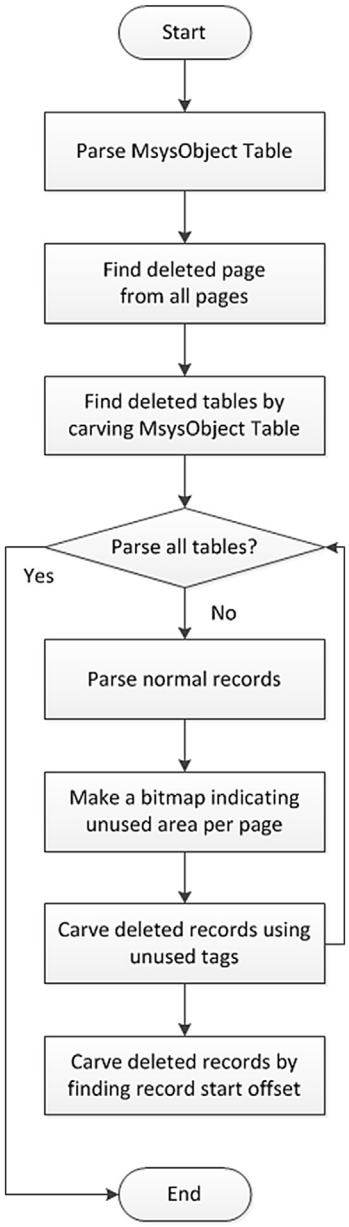

Fig. 5. Recovery procedure for deleted records in the ESE Database.

file. The header of these abnormal pages has numbers for the tables where the deleted records existed, so that if the schema information about this table is known, deleted records can be recovered. Therefore, it is necessary to add abnormal pages in the file to the recovery page list as well as the pages being executed.

The record size is variable and unpredictable; without this information records cannot be recovered accurately. However, the record size can be obtained by using tag information of undeleted pages. Additionally, the starting location of the next record can be identified by the offset of the previous record, because of the ESE characteristic that records are written in series without void.

The starting offset of deleted records can be found through the table schema information and the record structure. Data records are made up of the record header, the last fixed size data ID, the last variable size data ID, the first variable size data offset, the fixed size data, the variable size data, and the tagged data. The start offset of deleted records can be found by using the range of possible values for the record header, the last fixed size data ID, the last variable size data ID, and the first variable size data offset. Table 1 describes how to find the starting offset of deleted records by using those items.

Records can be recovered through already-known table information. For example, the container table of the WebCacheV01.dat file which IE10, IE11, and Edge saves records with a fixed structure where a fixed 4-byte value, or 0x117f7700h exists after the record header.

Implementation and performance

In order to verify the recovery method mentioned in the previous section, we developed a tool to extract normal records in the ESE database and recover deleted records, without using the database API. The tool development environment is Python 2.7. This tool is designed to be run from a command line interface and the output file is in the SQLite format. The program is executed as follows:

EDBForensic.py <Input Path> <Output Path>

The results are extracted in one database file, and the deleted tables are recovered as 'Carved_TableName'. Fig. 6 shows the SQLite-format result of recovering deleted records from the WebCacheV01.dat file used in the Edge, by using our tool.

In order to assess how exact the performance of our tool is, we used various kinds of ESE database files which have been studied before, as the test set. Table 2 gives related information and the data collection environment.

In order to assess the performance of extracting normal records, we compared our result with that of the analysis of the EseDbViewer tool which was developed as a database-API-based tool (woanware). The result that this tool produced was equivalent to our result in terms of the number and the contents of records.

We also compared our results to those produced by the ESECarve tool designed to be a recovery tool for deleted records. ESECarve only recovers data from

Table 1
Method for finding start point of deleted records.

No.	Conditional statements		
1	The first byte	!=	0
2	Record size, Offset	<	Page size
3	Jump size	<	The rest of the slack area, 100
4	Last fixed size data ID	In	Fixed item column
5	Last variable size data ID	In	Variable size data columns ID, 127
6	Last variable size data offset	<	The rest of the slack area
7	Last variable size data offset	<	Fixed size data's area

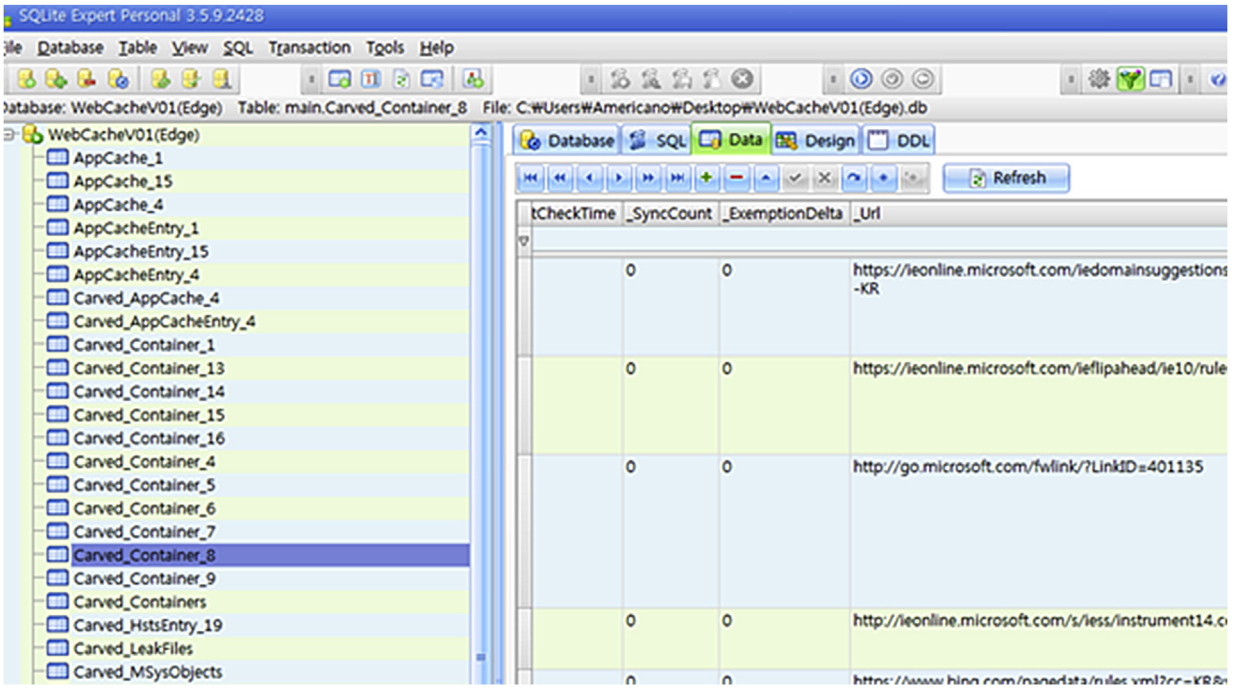

Fig. 6. Recovery results after using our tool.

WebCacheV01.dat and Windows.edb files, and only some of the tables can be recovered (Chivers and Hargreaves, 2011; Chivers, 2014). For a better side-by-side comparison, we excluded the overlapped items and only compared results against the table records that ESECarve was able to recover, so that the number of recovered records was the same. While ESECarve could not recover the final field items of all the records our tool recovered records normally. For example, The ResponseHeaders field saves important information such as visited web sites, download paths (see Fig. 7), and cache file information in WebCacheV01.dat. Because it is the final field, ESECarve failed to recover it.

We experimented on recovering deleted records by utilizing the ESE database files which have not been researched, except for WebCacheV01.dat and Windows.edb files. As a result, we could recover deleted records of those files.

Table 2
Test set to measure performance.

File name	OS version	Path	Program
WebCacheV01.dat	Windows 10	%LOCALAPPDATA%\Spartan\Database	Edge
WebCacheV01.dat	Windows 7	%LOCALAPPDATA%\Microsoft\Windows\WebCache	Internet Explorer
Windows.edb	Windows 7	%PROGRAMDATA%\Microsoft\Search\Data\Applications\Windows	Windows Search
WindowsMail.MSMessageStore	Windows 7	%USERPROFILE%\AppData\Local\Microsoft\Windows Mail\WindowsMail.MSMessageStore	Windows Mail
DataStore.edb	Windows 7	%WINDIR%\SoftwareDistribution\DataStore	Windows Update
contacts.edb	Windows server 2008	%LOCALAPPDATA%\Microsoft\Windows Live\Contacts\[accountname]\ version\DBStore	Windows Live
WLCalendarStore.edb	Windows server 2008	%LOCALAPPDATA%\Microsoft\Windows Live\Calendars\[account name]\DBStore	Windows Live
meta.edb	Windows 10	%LOCALAPPDATA%\Microsoft\Windows\SettingSync\remotemetastore\v1	Windows store
meta.edb	Windows 10	%LOCALAPPDATA%\Microsoft\Windows\SettingSync\metastore	Windows store
CortanaCoreDb.dat	Windows 10	%LOCALAPPDATA%\ Packages\Microsoft.Windows.Cortana_xxxx\LocalState\ESEDatabase_CortanaCoreInstance	Cortana

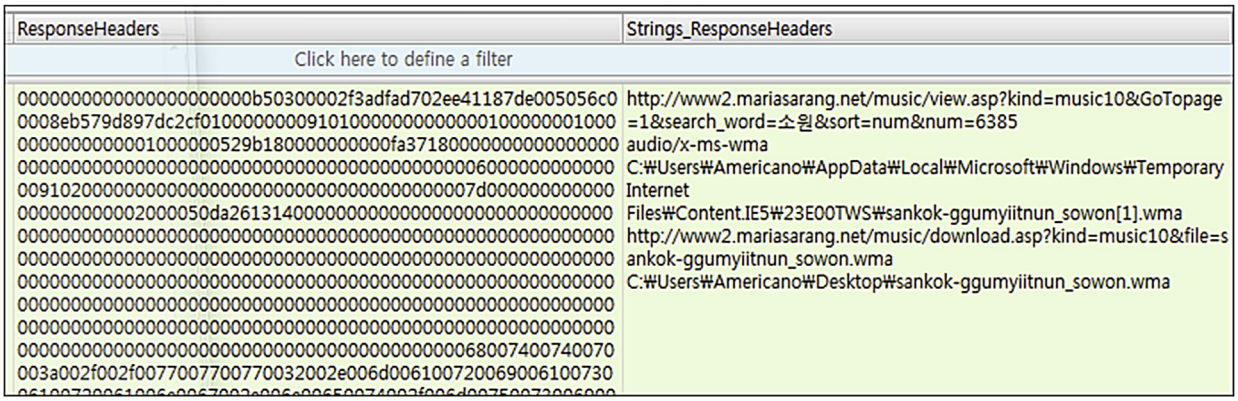

Fig. 7. Download paths in ResponseHeaders Field.

Conclusion

The ESE database is used to save and manage the main records of systems and users in Windows OS. Much work has been done to recover deleted records in ESE database files; however, the previous work is limited to Internet Explorer and Windows Search, and did not solve the problems of recovering dirty-state files and final-column data. Our research builds upon prior work and knowledge to address these issues and provide a tool that is forensically meaningful.

In this paper, we analyzed the ESE database file structure to extract normal records without using the database API, and compared the results with one based on the Database API. There was no difference between the results, which means that our analysis was accurate. We also studied a recovery technique for deleted data based on the database structure, and as a result, developed a tool that can recover deleted records from various versions of files to solve the problems of the previous work. The tool is available by contacting the authors.

This tool has a limitation that it cannot recover deleted data with damaged record header which contains information about the record structure of unknown records. Deleted records without the record header can be recovered if the schema information of the table to be recovered is known. Future work will address a technique to analyze varied ESE database files used in Windows, outline table structures, and recover damaged records.

Acknowledgements

This research was supported by the Public Welfare & Safety Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (2012M3A2A1051106).

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