Grammars and Parsers for Validating Binary File Formats

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Introduction

Automated tools are required for identifying and validating the formats of the huge number of files ingested into digital data and record archives.

Validation is required because

- If a file has been damaged, it may be possible to obtain an undamaged copy, or repair the file.
- File might need to comply with a standard format, e.g., PDF/A.

JHOVE (JSTOR Harvard Validation Environment) is an example of a set of programs for validating file formats

- JHOVE supports validation of the following file formats: AIFF, ASCII, GIF, HTML, JPEG, JPEG 2000, PDF, TIFF, UTF-8, WAVE, and XML
- JHOVE2 supports the validation of the following additional formats: ICC, SGML, Shapefile and ZIP

Each validation program is manually created from the specification for the file format.

Specification of File Formats

File (or record) Layouts for Binary Formats

Offset	Description
0	"RIFF" 4-byte tag
4	size of data chunk starting at offset 8
8	"WEBP" the form-type signature
12	"VP8 " 4-bytes tag, describing the raw video format used
16	size of the raw VP8 image data chunk, starting at offset 20
20	the VP8 image data

C Data Structures for Binary Formats

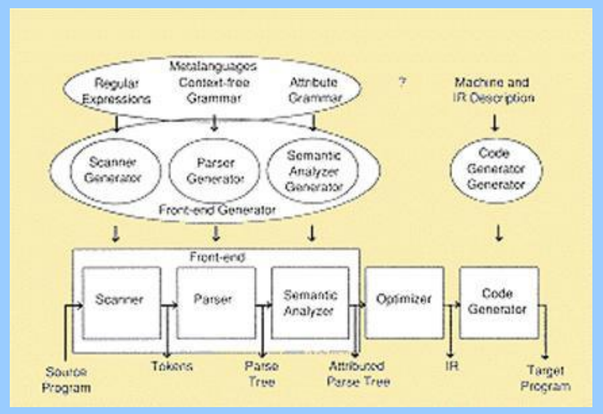
```
typedef struct {
        UWORD w, h;
        WORD  x, y;
        UBYTE nPlanes;
        Masking masking;
        Compression compression;
        UBYTE pad1;
        UWORD transparentColor;
        UBYTE xAspect, yAspect;
        WORD  pageWidth, pageHeight;
        } BitMapHeader;
```

Context-free Grammars for Textual Formats

Programming language syntax is usually defined using a combination of regular expressions (for lexical structure) and Backus–Naur Form rules (for grammatical structure)..

```
expression ::= atom | list
atom ::= number | symbol
number ::= [+-]?['0'-'9']+
symbol ::= ['A'-'Z''a'-'z'].*
list ::= '(' expression* ')'
```

Compiler-Compiler Technology



Given the specification of a programming language in terms of regular expressions and a context-free grammar, a compiler-compiler creates a program called a compiler that will take as input a source program and create an executable program in the target language.

One component of this technology is called a Parser Generator. It takes as input a context-free grammar for the language and generates a parser (syntax checker, validator) for the source programs.

Research Questions

Is it possible to extend the concept of context-free grammars from textual languages to binary file formats?

Is it possible to specify binary file formats using these extended context-free binary file grammars?

Is it possible to develop a parser generator that takes a binary file grammar for a binary file format and generates a parser that can validate the file format?

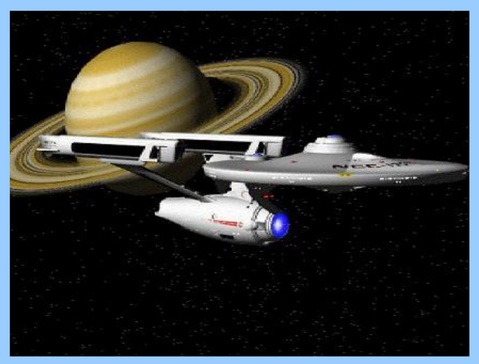
Family of Chunk-based Binary File Formats

Electronic Arts & Commodore-Amiga developed the Interchange File Format (IFF) in about 1985. It was the first chunk-based binary file format. A chunk consists of a chunk-id, a chunk-size and chunk-data. Chunk data can contain image, audio or text data. It can also contain sub-chunks and metadata. Sub-chunks can contain sub-sub-chunks

Examples of Chunk-based File Formats

(RIFF) – WAV, AVI, ANI, RMID, DIB, Webp
JPEG
Advanced Systems Format – WMA, WMV
Binary Interchange File Format (Microsoft Excel)
CorelDRAW Vector Graphics-cdw
Apple QuickTime - mo, qt
Portable Network Graphics -- PNG, MNG, JNG

Image in ILBM IFF File Format



Bytes 0-511 of the ILBM IFF File

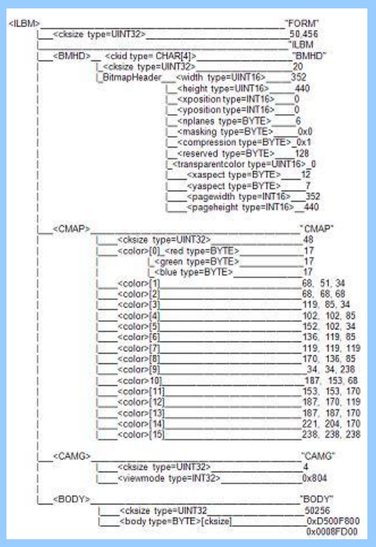
```
0000:   46 4F 52 4D 00 00 C5 18 - 49 4C 42 4D 42 4D 48 44   FORM....ILBMBMHD
0010:   00 00 00 14 01 60 01 B8 - 00 00 00 00 06 00 01 80   .....`..........
0020:   00 00 0C 07 01 60 01 B8 - 41 4E 4E 4F 00 00 00 48   .....`..ANNO...H
0030:   24 56 45 52 30 20 57 72 - 69 74 74 65 6E 20 62 79   $VER: Written by
0040:   20 41 53 44 47 27 73 20 - 41 72 74 20 44 65 70 61    ASDG's Art Depa
0050:   72 74 6D 65 6E 74 20 50 - 72 6F 66 65 73 73 69 6F   rtment Professio
0060:   6E 61 6C 20 49 46 46 33 - 2E 30 2E 34 20 28 31 39   nal IFF3.0.4 (19
0070:   2E 30 32 2E 39 35 29 00 - 43 4D 41 50 00 00 00 30   .02.95).CMAP...0
0080:   11 11 11 44 33 22 44 44 - 44 77 55 22 66 66 55 99   ...D3"DDDwU"ffU.
0090:   66 22 88 77 55 77 77 77 - AA 88 55 22 22 EE BB 99   f".wUwwww..U""...
00A0:   44 99 99 AA BB AA 77 BB - BB AA DD CC AA EE EE EE   D.....w.........
00B0:   43 41 4D 47 00 00 00 04 - 00 00 08 04 44 50 49 20   CAMG........DPI
00C0:   00 00 00 04 00 96 01 01 - 42 4F 44 59 00 00 C4 50   ........BODY...P
00D0:   D5 00 F8 00 00 08 FD 00 - 00 20 FE 00 00 80 FE 00   ......... ......
00E0:   03 81 00 80 10 FA 00 02 - 01 00 08 F9 00 D5 00 D5   ................
00F0:   00 00 BF F9 FF 00 F2 FD - FF 00 CB FE FF 00 2F FE   ............../.
0100:   FF 03 2E 5F 2F E5 FA FF - 02 FE 5F F2 F9 FF 00 DF   .../......._....
0110:   F9 FF 01 F3 7F FE FF 00 - CD FE FF 00 37 FE FF 03   ............7...
0120:   36 6F 37 E6 FA FF 03 FE - 6F F3 7F FA FF D5 00 FC   6o7.....o.......
0130:   00 00 20 FE 00 00 02 F9 - 00 02 20 00 01 FA 00 00   .. ....... .....
0140:   04 FC 00 00 20 FB 00 02 - 20 00 00 D5 00 D5 00 00   .... ... .......
0150:   BF FD FF 00 CB FE FF 01 - FC BF FA FF 03 CB FF FE   ................
0160:   5F FB FF 01 F9 7F FD FF - 00 CB FB FF 02 CB FF FF   _...............
0170:   00 DF FD FF 00 CD FE FF - 01 FC DF FA FF 03 CD FF   ................
0180:   FE 6F FB FF 01 F9 BF FD - FF 00 CD FB FF 02 CD FF   .o..............
0190:   FF D8 00 02 20 00 00 F8 - 00 00 08 FC 00 00 80 E5   .... ...........
01A0:   00 D5 00 D5 00 00 BF F9 - FF 00 F2 FC FF 00 2F E8   ............../.
01B0:   FF 02 CB FF FF 00 DF F9 - FF 01 F3 7F FD FF 00 37   ...............7
01C0:   E8 FF 02 CD FF FF D5 00 - D5 00 D5 00 D5 00 00 BF   ................
01D0:   D6 FF 00 DF D6 FF D5 00 - 04 00 40 00 00 08 FD 00   ..........@.....
01E0:   06 10 00 00 10 00 00 04 - F5 00 00 10 F8 00 00 04   ................
01F0:   FC 00 D5 00 D5 00 04 BF - 97 FF FF F2 FD FF 07 E5   ................
```

Grammar for ILBM Format

```
<ILBM> → "FORM" <cksize TYPE=UINT32> "ILBM" <BMHD> <CMAP> <CAMG> <BODY>
{ILBM.cksize = cksize.value}

<BMHD> → "BMHD" <cksize TYPE=uint32> <BitmapHeader>
<BitMapheader> →   <width type=UINT32>
                   <height type=UINT16>
                   <xposition type=INT16>
                   <yposition type=INT16>
                   <nplanes type=BYTE>
                   <masking type=BYTE>
                   <compression type=BYTE>
                   <reserved type=BYTE>
                   <transparentcolor type=UINT16>
                   <xaspect type=BYTE>
                   <yaspect type=BYTE>
                   <pagewidth type=INT16>
                   <pageheight type=INT16>
<CMAP> →"CMAP" <cksize type=UINT32> <color>[n] {n=cksize.val/3}
<CAMG> → "CAMG" <cksizetype=UINT32> <viewmode type=INT32>
<BODY> → "BODY" <cksize type=UINT32> <data type=BYTE>[cksize]
<color> → <red type=BYTE> <green type= BYTE> <blue type=BYTE>
```

Parse Tree for ILBM Binary File



Summary

It is possible to extend context-free grammars for textual languages to the specification of chunk-based binary file formats.

ANTLR, a parser generator for LL(k) grammars, has been successfully used to generate parsers for two chunk-based file formats.

Next Step: Binary file grammars for directory-based binary file formats, e.g., TIFF, OLE, OASIS Open Document, and Microsoft Open Office files.

Additional Information

W. Underwood and S. Laib. Attribute Grammars for Validating Chunk-based Binary File Formats. ICL/ITDSD Working Paper 11-03, GTRI, Atlanta, Georgia, July 2011 http://perpos.gtri.gatech.edu

Acknowledgement

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