

Grammars and Parsers for Validating Binary File Formats

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Research Forum

Chicago, Illinois

August 23, 2011

Research Motivation

- **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.**

Validation Tools for Binary File Formats

- **JHOVE – JSTOR Harvard Validation Environment**
- **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**

Specification of Binary File Formats

File Layouts

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

```
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;
```

Specification of Textual File Formats

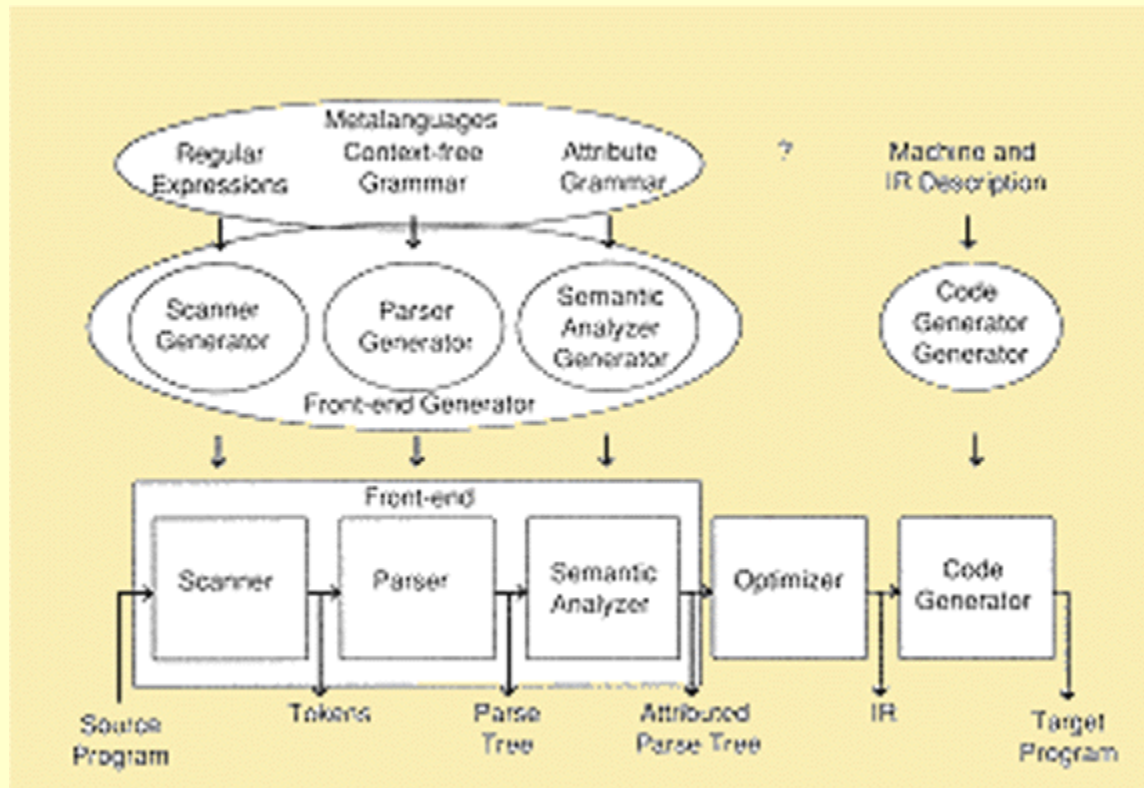
**Simple Grammar for LISP
Programming Language Syntax**

**Scalable Vector Graphics
Description of a 2D Image**

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

```
<?xml version="1.0" standalone="no"?>
<!DOCTYPE svg PUBLIC "-//W3C//DTD SVG 1.1//EN"
"http://www.w3.org/Graphics/SVG/1.1/DTD/svg11.dtd">
<svg width="100" height="60"
xmlns="http://www.w3.org/2000/svg">
  <rect fill="green" x="15" y="15" width="70" height="30"/>
  <rect fill="red" x="20" y="20" width="60" height="20"/>
</svg>
```

Compiler-Compiler Technology



Research Questions

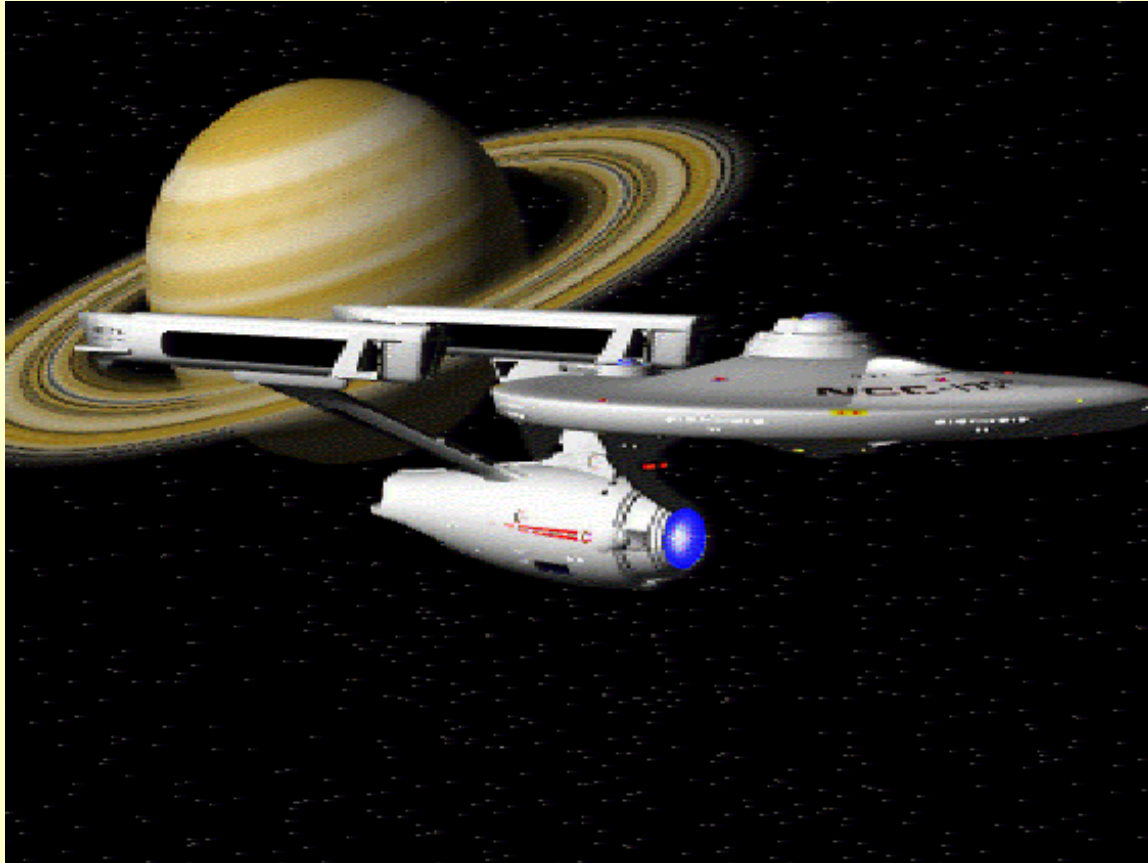
- **Is it possible to extend the concept of context-free grammars from textual languages to binary file formats?**
- **Is it possible to specify binary file formats using these extended context-free binary file grammars?**
- **Is it possible to develop a parser generator that takes a binary file grammar for a binary file format and generates a parser that can validate the file format?**

Chunk-based Binary File Formats

- **Interchange File Format (IFF)**
- **Electronic Arts & Commodore-Amiga**
- **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**

Chunk-based File Format Family

- **Apple Audio Interchange File Format (AIFF)**
- **Resource Interchange File Format (RIFF) – WAV, AVI, ANI, Riff MIDIfile, Device-Independent Bitmap, Webp**
- **JPEG**
- **Advanced Systems Format – WMA, WMV**
- **Portable Network Graphics -- PNG, MNG, JNG**
- **Binary Interchange File Format (Microsoft Excel)**
- **3D Studio – 3ds**
- **Autodesk Animator Pro – fli, flc, pic**
- **CorelDRAW Vector Graphics-cdw**
- **Apple QuickTime – mov, qt**
- **and many more**



Starship Enterprise Bitmap in ILBM IFF Binary File Format

Bytes 0-511 of the ILBM Binary 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 3A 20 57 72 - 69 74 74 65 6E 20 62 79 $UER: 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".wUwww..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 .....?...
0120: 36 6F 37 E6 FA FF 03 FE - 6F F3 7F FA FF D5 00 FC 6o?...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 .....?
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 .....e.....
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 .....

```

Binary File Grammar for Interleaved Bitmap File 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” <cksize type=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 File

<ILBM> : Start Symbol of the Grammar

File Signature

- ‘FORM’ at offset 0
- ‘ILBM’ at offset 7

<ILBM> chunk size – unsigned 32-bit integer with decimal value 50,456

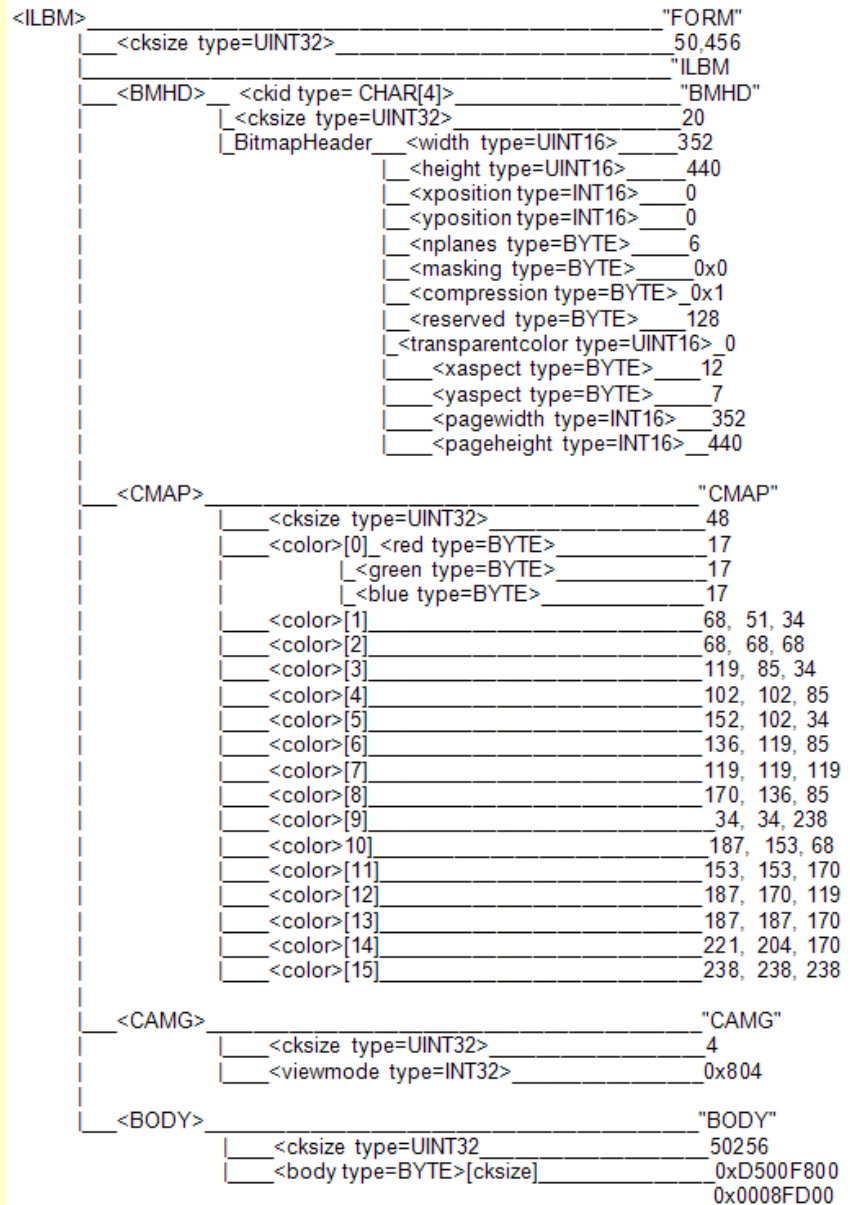
<BMHD chunk id = ‘BMHD

<BMHD> Chunk size = 20

Data chunk BitmapHeader has metadata about the Bitmap

Color pallet is stored in the CMAP> chunk

Bitmap is stored in the <BODY> chunk.



Results

- **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

url: <http://perpos.gtri.gatech.edu>

W. Underwood and S. Laib. Attribute Grammars for Validating Chunk-based Binary File Formats. ICL/ITDSD Working Paper 11-03, Georgia Tech Research Institute, Atlanta, Georgia, July 2011.

Acknowledgement

This research was sponsored by the Army Research Laboratory (ARL) and the Applied Research Division of the National Archives and Records Administration (NARA) and was accomplished under Cooperative Agreement Number W911NF-10-2-0030. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the Army Research Laboratory, NARA, or the US Government.