Smart Unpacking Research:
Using Mathematics To Unpack More

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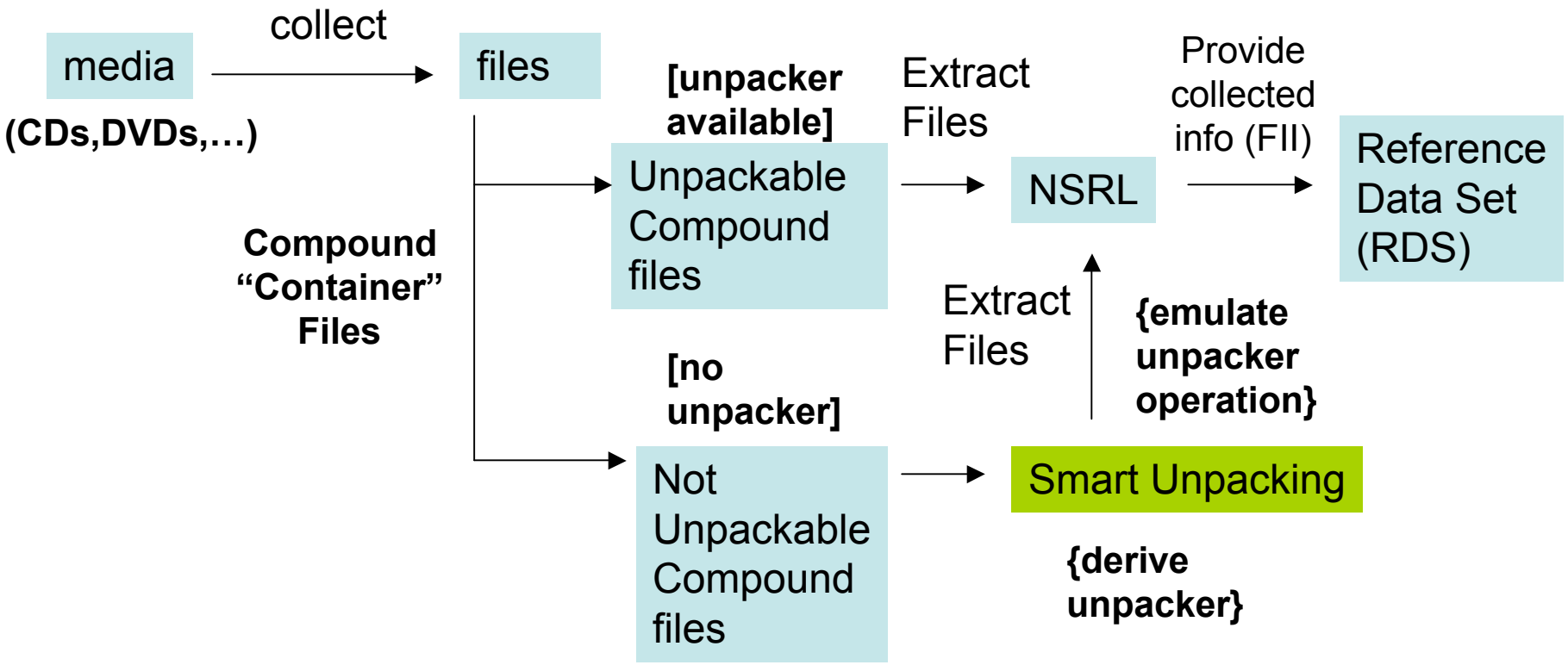
Context – Smart Unpacking and NSRL Operations



Smart Unpacking

- NSRL collects files by unpacking
- New file types appear faster than new unpackers
- NSRL goal: unpack and provide FII for as many files as possible
- SU – attempts to facilitate this goal by
  - Unpacking files when have no unpacker
  - Forming measurements (completeness,accuracy) of unpacking ops

Nature of Unpacking

- Unpacking: locate, identify, and extract files completely and accurately from compound structures
- SU studies and formalizes
  - How to use mathematical methods to find structure in content and nonstandard packaging
  - How to use this to detect, extract, and measure files

SU Research – Early Stages

- To date has –
  - Established basis for theoretical and practical implementation
  - Not yet formalized unpacking systems
  - Implemented specific prototypes and experiments
- Experiments have shown capability to
  - Do basic inline extractions
  - Do similarity and grammatical pattern correlation across many file types (binary and non-binary)

Experiment – Binary Similarity – MSI File Type

```
$ ./cmpB.exe 1.msi.pt 2.msi.pt | more
+ STATUS: analyzing f1([1.msi.pt], size=[2233724]), f2([2.msi.pt], size=[3609563])
0x00000000

a   b       d       f                   k           n
012 067     003     002                 002         002
a   b       d       f                   k
021 080     017     002                 010
 - != same = 201, diff = 181
match = 76.425856, mismatch = 23.574144
        f1: b+z+kzbzbfwzbz+ z+bz+bz+bz+ z+bf+z+ z+bz+bz+bz+          bz+  z+  z+b+z+
+z+b+z+b+z+b+z+  z+  z+  z+  z+  z+  z+  z+b+z+  z+b+z+  z+  z+  z+  z+  z+  z+  z+
+z+b+z+b+z+b+z+b+z+b+z+  z+  z+b+z+
        f2: b+z+kzbzbfwzbz+ z+bz+bz+bz+ z+bf+z+ z+bz+bz+bz+          bz+  z+  z+b+z+
+z+b+z+b+z+b+z+  z+  z+  z+  z+  z+  z+  z+b+z+  z+b+z+  z+  z+  z+  z+  z+  z+  z+
+z+b+z+b+z+b+z+b+z+b+z+  z+  z+b+z+
     match: ............... ........... ....... ...........          ...  ..  ......
..............  ..  ..  ..  ..  ..  ..  ......  ......  ..  ..  ..  ..  ..  ..  ..
......................  ..  ......
```

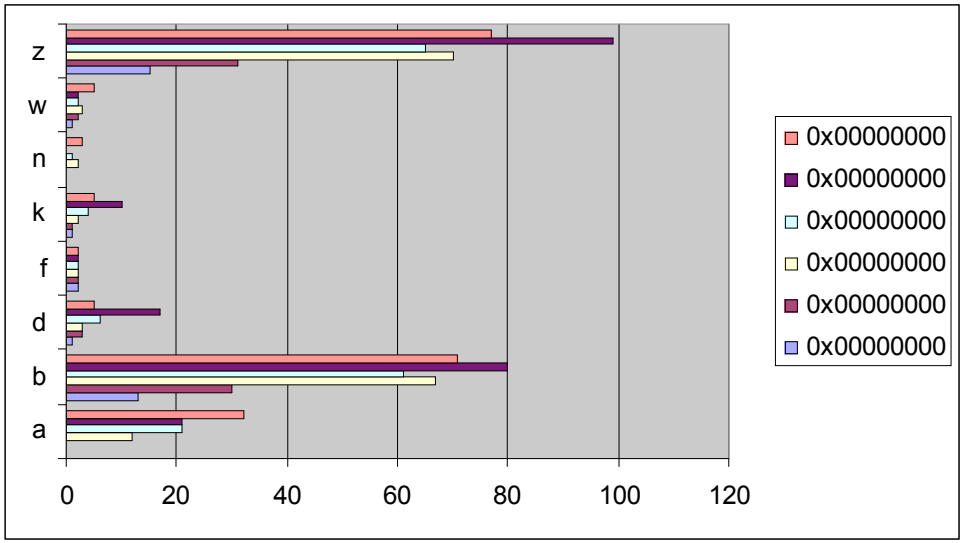
legend	
a	alpha
b	binary
d	delimiter
f	0xff
k	brackets
n	numeric
w	white-space
z	0x00

-Grammatical/location-specific similarity in binary data

-Graph of location-specific content-class frequencies

- basis for preliminary unpacker development

- **metadata types:** file size, location, data size, unpacker version, user/group ids, storage volume used



Technical and Scientific Basis and Methods

Methods used to Discern Structure and Metadata
-Modeling
-Uniqueness features in – syntax, content, abstract pattern representations

Pattern Theory

$$G = \{g_0, g_1, ..., g_i, g_i^0\} = generator\_space$$
$$S : G \longleftrightarrow G, s \in S = similarity\_group$$
$$G = \bigcup_{\alpha \in A} G^{\alpha} = partition\_of\_generators$$
$$b_1, b_2, ..., b_{\omega} = bond\_values$$
$$\mathrm{B}_s(g) = \{b_j; j = 1,2,3,..., w(g)\} = bond\_structures$$
$$B_v(g) = \{\beta j = 1,2,..., w(g)\}$$
$$...$$

Formal Language Theory

Context-free grammars

$$G = (V, \sum, R, S) = grammar$$
$$V = nonter \min als$$
$$\sum = ter \min als$$
$$S = start\_rule$$
$$R = rules$$
$$...$$

Mathematical Modeling based on:

- Information Theory
- Statistics
- Probability
- Universal Algebra
- Topology
- Graph Theory, and more …

Parser Theory

- Variable lookahead mechanisms
- Multi-channel token processors
- Augmentation with syntactic and semantic predicates for context-sensitivity

Measurements and Measurability

- Derived from mathematical models

Spectrum of Unpacking Scenarios

- Simplest – very little knowledge req'd, inline metadata and content; just need an unpacker
- More complex – more complicated structure, nesting, intermingled file, content, and encoding types, alignment considerations (MSI experiment)
- Harder – req's knowledge of metadata and structure relationships; mathematical + experimental models
- Even Harder – at least 1 transform – compressed, encrypted, etc – but still can get metadata and op properties
- Hardest – 2 or more transforms, little to no metadata – will often still get some metadata and specific properties

Unpacking Operation Measurement

- Measuring (at least) – accuracy and completeness of unpacking operation
  - Per file – from a given compound file
  - Across all files/content from a given compound file
- Beginning – focus on simple, coarse-grained ratios – total found/total extracted (files, content)
- Ongoing Objective –
  - develop content and format-specific measures – entropy-, probabilistic-, algebraic-based properties of content and structure
  - Simplify into classes of overall properties per file type

Work From Here

- Integrate prototype tools and experiments into automated unpacking framework
- Research and integrate
  - methods for harder cases
  - Relevant measurements
- Track ability to increase overall coverage of the NSRL

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