Capturing the iccMAX Calculator Element: A Case Study on Format Design

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Talk Structure

- Background: ICC, iccMAX, DARPA SafeDocs
- Security Evaluation Method
- iccMAX Primer
- Findings & Suggestions
- General Takeaways

The Creation of the International Color Consortium

- Early 1990s:
  - Devices (e.g., scanners, printers, monitors) must communicate color information.
  - No standard exists for color management.
- 1993: eight vendors come together to create the ICC.
- Within a year, the first ICC profile specification is released.

The iccMAX Specification

- The iccMAX specification expands upon ICC v4.
- Notably, it supports the encoding of functions.
- And it...
  - was carefully designed with security/predictability in mind.
  - is relatively new.
  - is not widely adopted.
  - has an open-source reference implementation.
- We did a security evaluation of the specification.

The SafeDocs Project

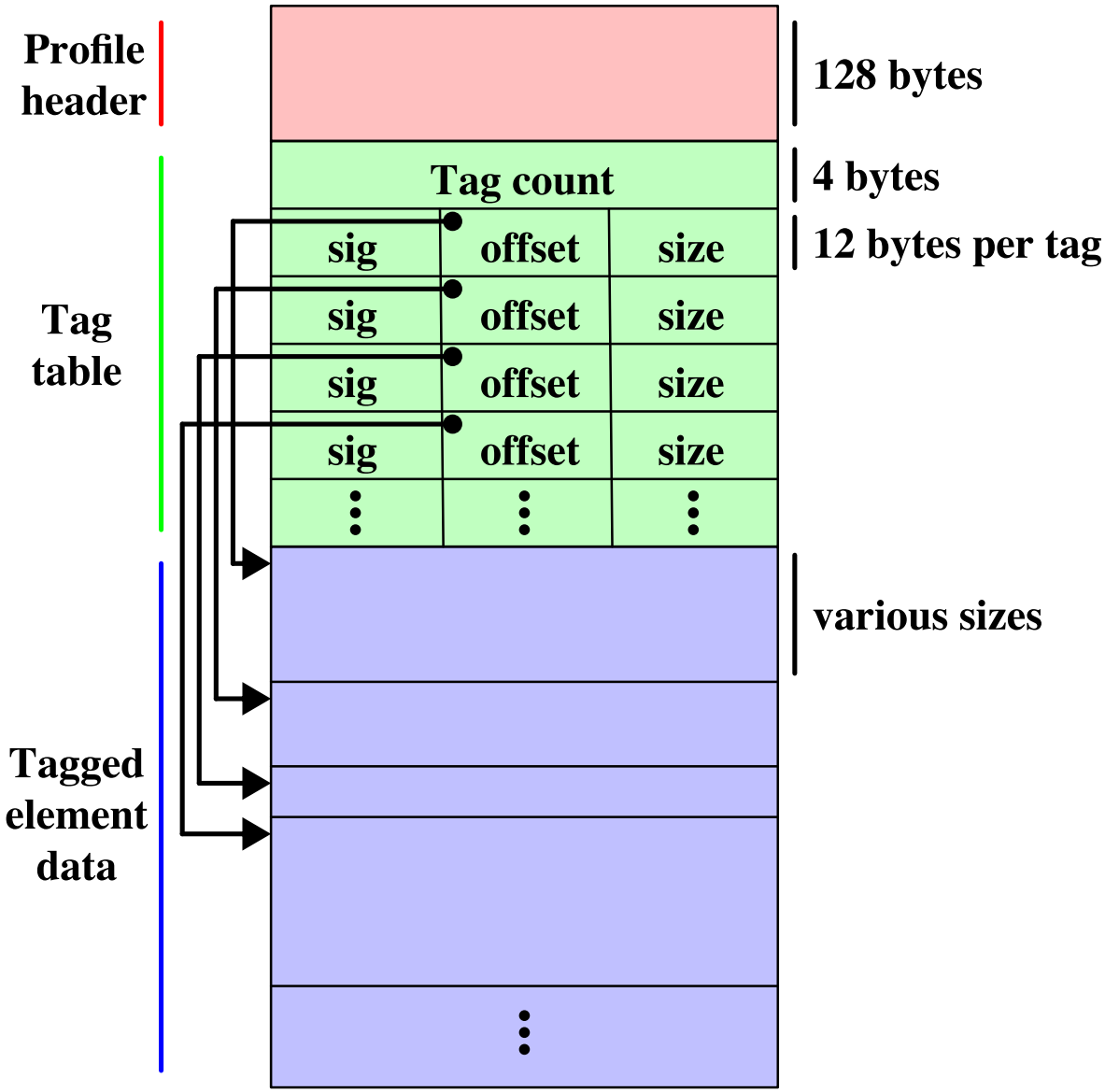
- The SafeDocs Project:
  - Problem: manually-written parsers and specification complexity breed insecurity
  - Solutions:
    - identify de facto grammars
    - identify safe subsets of them
    - create tools for safe-and-verified parsing

Security Evaluation Method

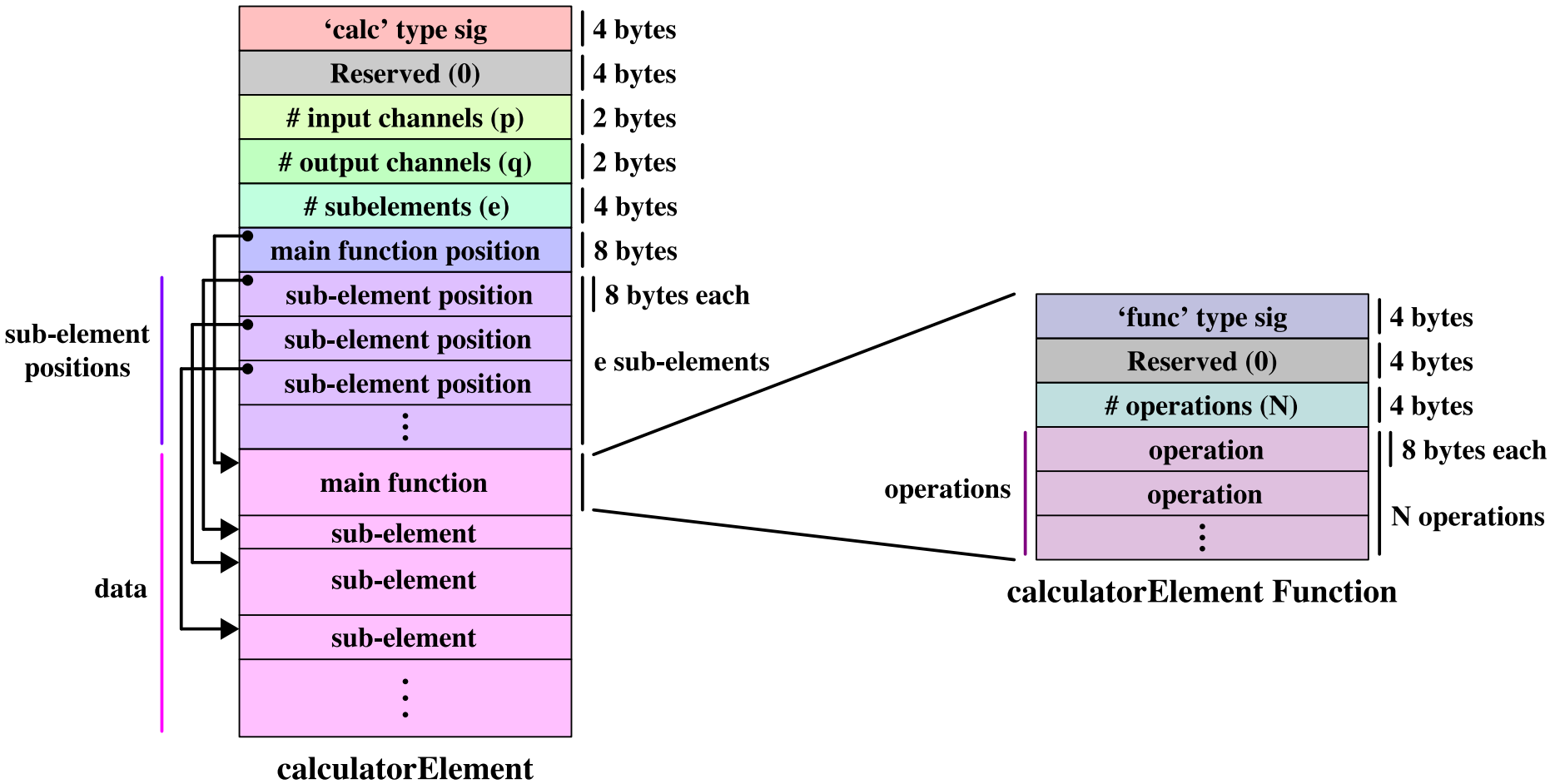
- We used various tools to conduct a security evaluation of the iccMAX specification.
  - We = {SRI/Dartmouth, BAE, Galois}
  - Tools include:
    - PVS
    - Parsley language
    - Parsley-Rust Static Analyzer
    - ACL2
    - DaeDaLus
  - Security evaluation aligns with security and predictability objectives for iccMAX. [1].

[1] https://www.color.org/whitepapers/ICC_White_Paper_52_calculatorElement_security_implementation_notes.pdf

The High-Level Structure of iccMAX Files



The calculatorElement



Findings: Completing the Resource Contract

- The calculatorElement currently specifies:
  - the number of expected input channels
  - and the number of expected output channels
- We proposed completing the resource contract w.r.t.:
  - the number of temporary channels
  - the data stack size
  - computational effort or execution cost
- Doing so would:
  - enable resource-constrained applications to quickly determine whether they can invoke a given calculator element
  - allow applications to create bounded compartments for untrusted computation

Findings: Conditional Operators are Insufficiently Defined

Should we treat nested conditional operations (and contained operations) as a single operation or multiple operations?

if 5
if 4
pi 0
pi 0
NaN 0
+INF 0

Findings: Operators Missing from the Specification

Some operations (`fJab`, `tJab`, `fLab`, and `not`) appear in the demo implementation, but they do not appear in the specification.

Findings: Non-Numeric Values Allow Parser Differentials

The specification defines exceptional values, but computation on them is left as implementation dependent.

x:=-1.0/0.0;
if x then output(1.0)
else output(2.0)

Findings: Minor Errors & Issues

- The `flip` operator (Table 96) is described to act on $S + 1$ elements but the description suggests $S + 2$ elements.

'flip' (666c6970h)	A_0 ... A_{S+1}	Reverse the top S+1 elements on the stack (T shall be zero)	A_{s+1} ... A_0

- The fourth field has field length of 8 instead of $8N$.

Table 86 — calculatorElement Function encoding

Byte position	Field length (bytes)	Content	Encoded as...
0...3	4	'func' (66756e63h) type signature	
4...7	4	Reserved, shall be 0	
8...11	4	Number of operations (N)	uInt32Number
12...12 + N*8 - 1	8	Function operations	

Updates to iccMAX

This work led to many revisions in the iccMAX specification, e.g.:

- revising select operator definitions
- adding a metadata structure after the operator table that specifies
  - position and number of sub-elements
  - maximum stack size
  - size of variables
  - maximum number of operations in code path
- adding the cost of operations to the calculatorElement metadata.
- revising the specification so that it states that floating point arithmetic should (not shall) fully implement IEEE 754

Some General Takeaways

- Format design should utilize formal methods parsing tools.
- Data should be orderly sequenced.
- Size restrictions and operations should be designed to minimize unnecessary overhead.

Thank you!

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