A new VOTable library in Rust (and more!)

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VOTable

- VOTable: the **first** IVOA standard **(2003)**
  - **XML hype** at the time
  - Precursor: Astrores
    - XML for metadata
    - ASCII/CSV for table rows
- IVOA VOTableSoftware wiki page (up-to-date ?)
- Existing libraries (I am aware of, very limited!)
  - STIL (TOCPAT/STILTS): **Java**
  - Astropy: **Python**
  - Savot: Java, maintained ?
  - votable.js: JavaScript, maintained ?
  - votpp: C++, updated in 2014 (maintained?)
  - ...

A new library?!

- **Motivations** for a new library in Rust
  - **Needed for other** CDS **Rust tools**
    - **Aladin Lite v3** core is in Rust
    - ExXmatch is in Rust
    - **VizieR large catalogues** query code (switching to Rust)
    - ...
  - Usual argument: **write once, re-use in various places**
    - natively in Rust projects
    - Python wrapper
    - JavaScript/WASM wrapper
    - ...
  - **VOTable as a "model"** (de)serializable in **various formats**?
    - XML: current VOTable format
    - JSON: for web browsers
    - TOML: to update metadata manually
    - YAML: why not?
    - **preservation** in round-trip transformations possible?

Build functionality

- Build VOTable programmatically
  - **in memory objects** for each tag
    - but data can be in memory **or** generated on-the-fly
  - **coherent** with the schema **by construction**
    - but (e.g.) fields vs actual data not checked (yet?)

Struct votable::field::Field

```
pub struct Field {
[–]
    pub id: Option<String>,
    pub name: String,
    pub datatype: Datatype,
    pub unit: Option<String>,
    pub precision: Option<Precision>,
    pub width: Option<u16>,
    pub xtype: Option<String>,
    pub ref_: Option<String>,
    pub ucd: Option<String>,
    pub utype: Option<String>,
    pub arraysize: Option<String>,
    pub extra: HashMap<String, Value>,
    pub description: Option<Description>,
    pub values: Option<Values>,
    pub links: Vec<Link>,
}
```

Enum votable::datatype::Datatype

```
pub enum Datatype {
    Logical,
    Bit,
    Byte,
    ShortInt,
    Int,
    LongInt,
    CharASCII,
    CharUnicode,
    Float,
    Double,
    ComplexFloat,
    ComplexDouble,
}
```

Programmatic build 1/3

```
let table = Table::new()
  .set_name("V/147/sdss12")
  .set_description("SDSS photometric catalog".into())
  .push_field(
    Field::new("RA_ICRS", Datatype::Double)
      .set_unit("deg")
      .set_ucd("pos.eq.ra;meta.main")
      .set_width(10)
      .set_precision(Precision::new_dec(6))
      .set_description("Right Ascension (ICRS)".into())
  ).push_field(
     ...
  ).set_data(Data::new_empty().set_tabledata(...));
```

Programmatic build 2/3

```
let resource = Resource::default()
  .set_id("yCat_17011219")
  .set_name("J/ApJ/701/1219")
  .set_description(r#"Photometric catalog ..."#.into())
  .push_coosys(
    CooSys::new("J2000", System::new_default_eq_fk5())
  ).push_coosys(
    CooSys::new(
      "J2015.5",
      System::new_icrs().set_epoch(2015.5))
  ).push_table(table)
  .push_post_info(
     Info::new("QUERY_STATUS", "OVERFLOW")
       .set_content("Truncated result")
  );
```

Programmatic build 3/3

```
let votable = VOTable::new(resource)
  .set_id("my_votable")
  .set_version(Version::V1_4)
  .set_description(r#"VizieR Astronomical Server"#.into())
  .push_info(
    Info::new("votable-version", "1.99+ (14-Oct-2013)")
      .set_id("VERSION")
  );
```

Parsing a VOTable

Build from existing VOTable, multiple ways to parse a VOTable

- one hybrid DOM / SAX(push) / StAX(pull) like mode
  - parse everything except table data
    - (similar to the M. Taylor choice in TOPAT/STILT ?)
  - **generic class to delegate table data parsing**
  - either **built-in:** load everything **in memory**
    - **either** each **row is an array of** `String` (not for base64)
    - **or** each **row is an array of objects** `(f64, int, ...)`
  - or implement your own table data parser
    - SAX call to table data parser
    - table data parser rely on StAX parsing (quick_xml reader)
    - allows for **streaming**
- one hybrid DOM/StAX like parser
  - **iterator on table objects** providing:
    - access to the **table metadata** objects
    - + **iterator on table rows**
  - also allows for **streaming**
  - (current limitation: no access to RESOURCE metadata)

(De)serialization

- (De)serialize VOTable/JSON/TOML/YAML to/from memory objects (built-in)

```
fn from_ivoa_xml_reader>(...) -> ...
fn from_json_reader(...) -> ...
fn from_toml_reader(...) -> ...
fn from_yaml_reader(...) -> ...

fn to_ivoa_xml_writer>(...) -> ...
fn to_json_writer(...) -> ...
fn to_toml_writer(...) -> ...
fn to_yaml_writer(...) -> ...

...
```

VOTCli and MOCWasm

- Tools to convert (memory manageable) VOTables in XML/JSON/TOML/YAML
  - from the command line: VOTCli
    - pre-compiled for various architecture
    - .deb packages
    - pypi: `https://pypi.org/project/votable-cli/`
  - in a Web Browser: VOTWasm
    - JS/WebAssembly library, 100% Rust (wasm-bindgen)
    - rely on intermediary `JsObject`
    - available in github release

VOTCli

```
fxpineau@cds-dev-fxp-7300:~$ vot --help
Command-line to convert IVOA VOTables in XML, JSON, YAML and TOML

Usage: vot [OPTIONS] <INPUT_FMT> <OUTPUT_FMT>

Arguments:
  <INPUT_FMT>   Format of the input document ('xml', 'json', 'yaml' or 'toml')
  <OUTPUT_FMT>  Format of the output document ('xml', 'json', 'yaml' or 'toml')

Options:
  -i, --input <FILE>   Input file (else read from stdin)
  -o, --output <FILE>  Output file (else write to stdout)
  -p, --pretty         Pretty print (for JSON and TOML)
  -h, --help           Print help
  -V, --version        Print version
```

```
> vot --input gaia_dr3.b64.vot xml yaml
> vot -i vot.xml -o vot.toml xml toml --pretty
> cat b64.vot |\
>   vot xml json --pretty 2> /dev/null | more
```

Missing: options to switch TABLEDATA/BINARY/BINARY2

VOTCli Example

- Convert a VizieR output VOTable into TOML
  - in: 2.5 MB XML (TABLEDATA) file
  - out: 2.0 MB TOML file
  - conversion time: 70ms

```
fxpineau@cds-dev-fxp-7300:~$ time vot -i 2p5mega.vot -o vot.toml xml toml --pretty 2> /dev/null

real    0m0,067s
user    0m0,067s
sys     0m0,000s
fxpineau@cds-dev-fxp-7300:~$ head -10 vot.toml
[votable]
version = '1.4'
"xmlns:xsi" = 'http://www.w3.org/2001/XMLSchema-instance'
xmlns = 'http://www.ivoa.net/xml/VOTable/v1.3'
"xsi:schemaLocation" = 'http://www.ivoa.net/xml/VOTable/v1.3 http://www.ivoa.net/xml/VOTable/v1.3'
description = '''

   VizieR Astronomical Server vizier.u-strasbg.fr
    Date: 2020-11-17T10:05:52 [V1.99+ (14-Oct-2013)]
   Explanations and Statistics of UCDs:                 See LINK below
```

VOTWasm

- Download JS/Wasm files from github releases
- Available functions

```
vot.fromXML(string) -> JsObject
vot.toXML(JsObject) -> String
vot.fromJSON(string) -> JsObject
vot.toJSON(JsObject) -> String
vot.fromTOML(string) -> JsObject
vot.toTOML(JsObject) -> String
vot.fromYAML(string) -> JsObject
vot.toYAML(JsObject) -> String
```

- No API to build a conform `JsObject`
  - error in case of not -conform `JsObject`

Rust Serde!

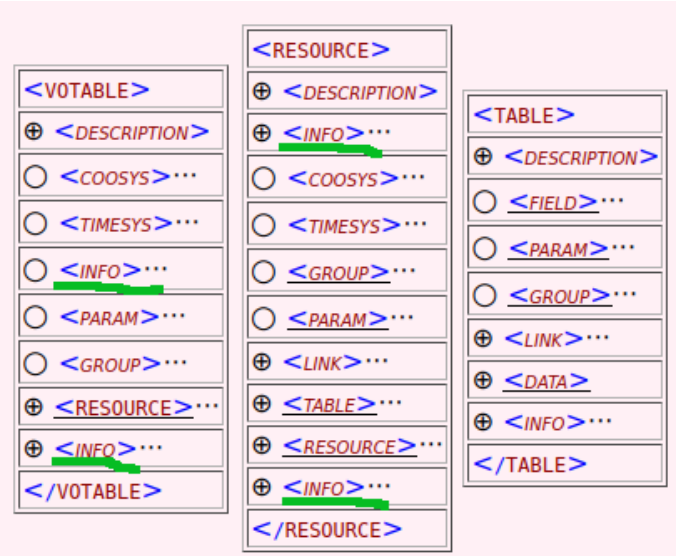
- Internally the magic happens thanks to serde

```rust
#[derive(Clone, Debug, serde::Serialize, serde::Deserialize)]
pub struct Group {
  // attributes
  #[serde(rename = "ID", skip_serializing_if = "Option::is_none")]
  id: Option<String>,
  #[serde(skip_serializing_if = "Option::is_none")]
  name: Option<String>,
  #[serde(rename = "ref", skip_serializing_if = "Option::is_none")]
  ref_: Option<String>,
  #[serde(skip_serializing_if = "Option::is_none")]
  ucd: Option<String>,
  #[serde(skip_serializing_if = "Option::is_none")]
  utype: Option<String>,
  // Sub-elems
  #[serde(skip_serializing_if = "Option::is_none")]
  description: Option<Description>,
  #[serde(default, skip_serializing_if = "Vec::is_empty")]
  elems: Vec<GroupElem>,
}
```

Figure 1: Serde annotations on GROUP

Design choices 1

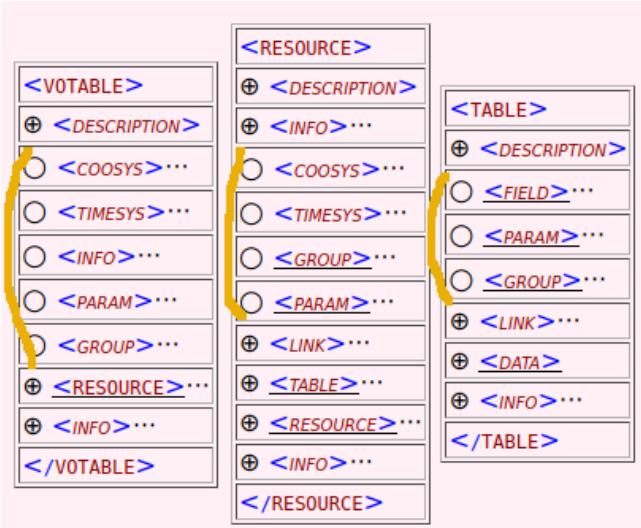
- The `INFO` problem?
  - *"The INFO element may occur before the closing tags /TABLE and /RESOURCE and /VOTABLE (enables post-operational diagnostics)"*
  - one solution: make a difference between `info` and `post-info`




```rust
pub struct Resource<C: TableDataContent> {
    pub id: Option<String>,
    pub name: Option<String>,
    pub type_: Option<String>,
    pub utype: Option<String>,
    pub extra: HashMap<String, Value>,
    pub description: Option<Description>,
    pub infos: Vec<Info>,
    pub elems: Vec<ResourceElem>,
    pub links: Vec<Link>,
    pub tables: Vec<Table<C>>,
    pub resources: Vec<Resource<C>>,
    pub post_infos: Vec<Info>,
}
```

Design choices 2

- Multiple possible sub-elements at a given place
  - one solution: group them in a same `enum`




```rust
pub struct Resource<C: TableDataContent> {
    pub id: Option<String>,
    pub name: Option<String>,
    pub type_: Option<String>,
    pub utype: Option<String>,
    pub extra: HashMap<String, Value>,
    pub description: Option<Description>,
    pub infos: Vec<Info>,
    pub elems: Vec<ResourceElem>,
    pub links: Vec<Link>,
    pub tables: Vec<Table<C>>,
    pub resources: Vec<Resource<C>>,
    pub post_infos: Vec<Info>,
}
```

```rust
pub enum ResourceElem {
    CooSys(CooSys),
    TimeSys(TimeSys),
    Group(Group),
    Param(Param),
}
```

Design choice 3

(I am actually no sure any more about this one)

- GROUP:
  - cannot contain FIELDRef in VOTABLE and RESOURCE
  - may contain FIELDRef in TABLE
- one solution: 2 different structures/classes (internally)
  - **Group**
  - **TableGroup**

```
pub enum GroupElem {
    ParamRef(ParamRef),
    Param(Param),
    Group(Group),
}
```

```
pub enum TableGroupElem {
    FieldRef(FieldRef),
    ParamRef(ParamRef),
    Param(Param),
    TableGroup(TableGroup),
}
```

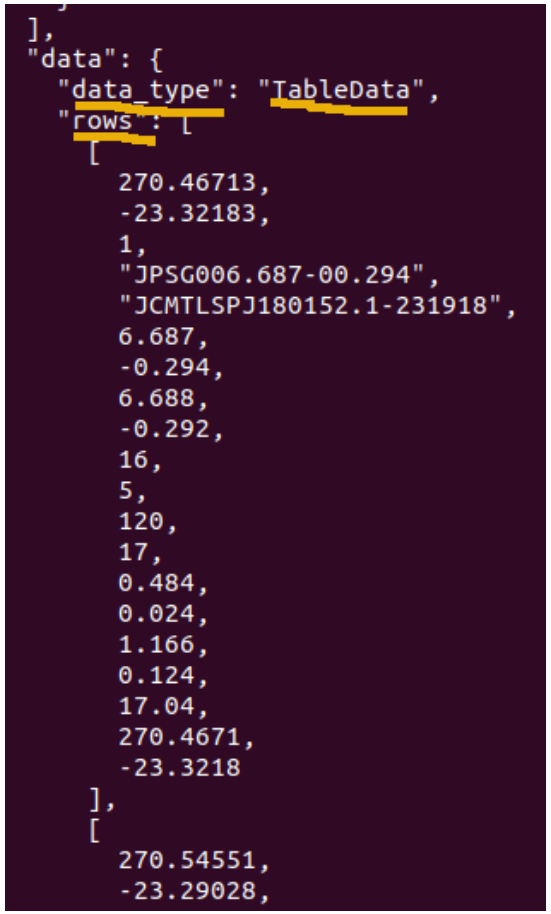
Other debatable choices 1/3

- XML **TAGs** in **lower case**
- **'s'** after a TAG name
  - if multiple occurence allowed (JSON array)
- **'elems'** + **'elem_type'** + camel case class/struct name
  - when multiple TAGs are possible

```
"votable": {
  "version": "1.4",
  ...
  "description": "VizieR Astronomical Server ...",
  "elems": [
    {
      "elem_type": "Info",
      "ID": "VERSION",
      "name": "votable-version",
      "value": "1.99+ (14-Oct-2013)"
    }, ...
  ],
  "resources": [
    {
      "ID": "yCat_74692163",
      "name": "J/MNRAS/469/2163",
      "description": "JCMT Plane Survey. first complete dat
      "elems": [
        {
          "elem_type": "CooSys",
          "ID": "G",
          "system": "galactic"
        }, ...
      ],
      "tables": [
        {
          "id": "J_MNRAS_469_2163_table2",
          "name": "J/MNRAS/469/2163/table2",
          "description": "JPSPR1 compact source catalogue",
          "elems": [
            {
              "elem_type": "Field",
              "name": "_RAJ2000",
              "datatype": "double",
```

Other debatable choices 2/3

- **'data_type'** to differentiate
  - TableData
  - Binary
  - Binary2
  - Fits
- **'rows** for the TableData content



Other debatable choices 3/3

- **'infos'** != **'post_infos'**
- **'content'** to store an XML TAG content having possible attributes

Other alternatives for JSON

- Python package xml2json?
- Python lxml + xml2dic + json tested by L. Michel, see votable-rust README file
  - pros:
    - few lines of Python
    - generic (for all XML files)
  - cons:
    - order of sub-elements is lost (e.g. no INFO/POST-INFO; order important in DALI)
    - no in-memory structure
    - no JON to XML VOTable conversion
- . . . ?
- In any case: we have to agree on choices to be inter-operable (do we want to)!!

Remark on Rust

- Writing each tag code is TEDIOUS!!
  - lot of duplicated/almost duplicated code
    - setters, getters, push element, test if null, ...
- But Rust has declaratives macros : objects boilerplate code
- Serde's procedural macros: serialization boilerplate code!

```
// attributes
impl_builder_opt_string_attr!(id);
impl_builder_opt_string_attr!(unit);
impl_builder_opt_attr!(precision, Precision);
impl_builder_opt_attr!(width, u16);
impl_builder_opt_string_attr!(xtype);
impl_builder_opt_string_attr!(ref_, ref);
impl_builder_opt_string_attr!(ucd);
impl_builder_opt_string_attr!(utype);
impl_builder_opt_string_attr!(arraysize);
// extra attributes
impl_builder_insert_extra!();
// sub-elements
impl_builder_opt_attr!(description, Description);
impl_builder_opt_attr!(values, Values);
impl_builder_push!(Link);
```

```
pub fn set_id<I: Into<String>>(mut self, id: I) -> Self {
    self.id = Some(id.into());
    self
}
pub fn set_unit<I: Into<String>>(mut self, unit: I) -> Self {
    self.unit = Some(unit.into());
    self
}
pub fn set_precision(mut self, precision: Precision) -> Self {
    self.precision = Some(precision);
    self
}
pub fn set_width(mut self, width: u16) -> Self {
    self.width = Some(width);
    self
}
pub fn set_xtype<I: Into<String>>(mut self, xtype: I) -> Self {
    self.xtype = Some(xtype.into());
    self
}
pub fn set_ref<I: Into<String>>(mut self, ref_: I) -> Self {
    self.ref_ = Some(ref_.into());
    self
}
pub fn set_ucd<I: Into<String>>(mut self, ucd: I) -> Self {
    self.ucd = Some(ucd.into());
    self
}
pub fn set_utype<I: Into<String>>(mut self, utype: I) -> Self {
```

Final word

- VOTable Lib Rust:
  - repo https://github.com/cds-astro/cds-votable-rust
    - dual MIT/Apache 2.0 licensing
  - crates.io: https://crates.io/crates/votable
  - doc to be improved!!
  - **young** but **in production** in **Aladin Lite v3**!
    - bugs will be fixed quickly (send us VOTables!)
    - **but** parts are **still exploratory**: several way to read/write a VOTable (even for streaming)
    - async version?
- What about the **VOTable as model**?
  - who already did that?
    - different choices: **share experience**!
  - **should we agree** on VOTable JSON/TOML/YAML formats?
  - binary format (with FITS random access property) desirable?