Conduit

Scientific Data Exchange Library for HPC Simulations

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Data coupling is a key aspect in simulation software design and user workflows.

Today:

I/O libraries have evolved into defacto interfaces between:

- Simulation Components
- Simulations and Pre- and Post-processing tools:
  - meshing, visualization, analysis, etc

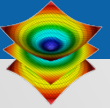
I/O is acceptable as a coarse-grain and low-frequency data coupling solution.

Data coupling is a key aspect in simulation software design and user workflows.

The Future:

- Increased CS emphasis on modular physics package design
- In-situ APIs for components that are usually I/O isolated as Pre- and Post-processing

To achieve fine-grain and high-frequency data coupling we need tools to help with in-core data exchange.



Supporting in-core data exchange throughout the simulation eco-system is quite different from trivial single component use cases.

Key Requirements:

- A description mechanism for numeric primitives:
  - Scalars, ragged arrays, etc with explicit precision
- Mixed memory ownership semantics:
  - Enables Zero-copy where feasible
  - Plays friendly with existing data structures
- Enable higher level conventions:
  - Hierarchical context
  - Human readable descriptions

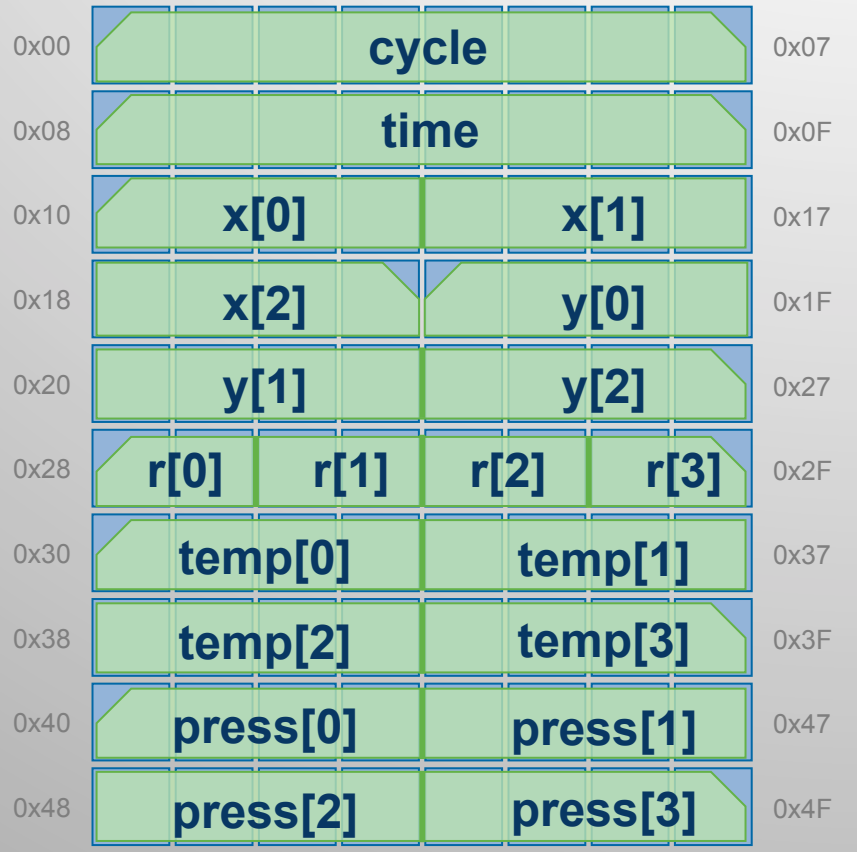
Conduit is a new open source development effort at LLNL aimed at simplifying in-core data exchange.

Conduit provides:

- A flexible way to ***describe*** complex data:
  - A JSON-based schema for describing the layout of hierarchical in-core data.
- A sane API to ***access*** complex data:
  - A dynamic API for rapid construction and consumption of hierarchical data in C++, C, Python, and FORTRAN.

Our goal is to create a small library that can be used for data description and exchange in HPC codes.

Example: Describing in-core data using a Conduit Schema.



Data (80 bytes)

```
{
 "cycle": "uint64",
 "time": "float64",
 "coords":
 {
  "x": {"dtype":"float32", "length": 3},
  "y": {"dtype":"float32", "length": 3}
 },
 "fields":
 {
  "region": {"dtype":"uint16", "length": 4},
  "temp": {"dtype":"float32", "length": 4},
  "pressure": {"dtype":"float32", "length": 4}
 }
}
```

Conduit JSON Schema

Example: Accessing in-core data via a Conduit Schema using C++.

```
// start with a data pointer and our example schema
void   *data_ptr    = ...
string  json_schema = ...

// construct a Node from the schema and data
Node n(json_schema,data_ptr);

// print the cycle and time values
cout << "cycle = " << n["cycle"].as_uint64() << endl;
cout << "time  = " << n["time"].as_float64() << endl;
```

```
cycle = 100
time  = 2.8
```

Example: Accessing in-core data via a Conduit Schema using C++.

```
// print the x coordinate values
float32 *x_coords = n["coords/x"].as_float32_ptr();
cout << "x[0]  = " << x_coords[0] << endl;
cout << "x[1]  = " << x_coords[1] << endl;
cout << "x[2]  = " << x_coords[2] << endl;
```

```
x[0]  = 0
x[1]  = 0.25
x[2]  = 1
```

Example: Accessing in-core data via a Conduit Schema using C++.

```
// access the region field and print its first value
Node &fields = n["fields"];
uint16 *reg_ptr = fields["region"].as_uint16_ptr();
cout << "r[0]  = " << reg_ptr[0] << endl;
```

```
r[0]  = 0
```

Example: Accessing in-core data via a Conduit Schema using C++.

```
// print entire node in a human readable fashion
n.print();
```

```
{
  "cycle": 100,
  "time": 2.8,
  "coords":
  {
    "x": [0, 0.25, 1],
    "y": [0, 0.5, 1]
  },
  "fields":
  {
    "region": [0, 1, 0, 1],
    "temp": [1, 2, 3, 4],
    "pressure": [0.1, 0.3, 0.5, 0.7]
  }
}
```

Example: Dynamic object construction with Conduit in C++.

```
// create a Node instance
Node n;
// add cycle and time values
uint64  cyc  = 100;
float64 time = 2.8;
n["cycle"] = cyc;
n["time"]  = time;
n.print();
```

```
{
  "cycle": 100,
  "time": 2.8
}
```

Example: Dynamic object construction with Conduit in C++.

```
// add x and y coords
float32 x[3] = {0.0,0.25,1.0};
float32 y[3] = {0.0,0.5,1.0};

n["coords/x"].set(x,3);
n["coords/y"].set(y,3);
n.print();
```

```
{
  "cycle": 100,
  "time": 2.8,
  "coords":
  {
    "x": [0, 0.25, 1],
    "y": [0, 0.5, 1]
  }
}
```

Example: Dynamic object construction with Conduit in C++.

```
// add fields
uint16  r[4] = {0,1,0,1};
float32 t[4] = {1.0,2.0,3.0,4.0};
float32 p[4] = {0.1,0.3,0.5,0.7};

n["fields/region"].set(r,4);
n["fields/temp"].set(t,4);
n["fields/pressure"].set(p,4);
n.print();
```

```
{
  "cycle": 100,
  "time": 2.8,
  "coords":
  {
    "x": [0, 0.25, 1],
    "y": [0, 0.5, 1]
  },
  "fields":
  {
    "region": [0, 1, 0, 1],
    "temp": [1, 2, 3, 4],
    "pressure": [0.1, 0.3, 0.5, 0.7]
  }
}
```

The heart of Conduit is a hierarchical variant type named *Node*.

A *Node* acts as one of following basic types:

- Object
  - An ordered associative array mapping names to children.
- List
  - An ordered list of unnamed children.
- Leaf (Scalar or Array of bitwidth-specified primitives)
  - Signed Integers: int8, int16, int32, int64
  - Unsigned Integers: uint8, uint16, uint32, uint64
  - Floating Point Numbers: float32, float64
  - Strings: char8_str

Conduit was designed with software engineering eco-system logistics in mind.

- Completely runtime focused
  - Avoids incompatible (or unsharable) code-generation solutions.
- Language agnostic
  - C++ API which underpins developing Python, C, and Fortran APIs.
  - JSON is used for data layout
- Data description as a core capability
  - Does not require repacking
  - Helps build serialization, I/O, and messaging features.

Philosophy: Share data without massive code infrastructure.

Conclusion

- **Conduit** can help ease in-core data exchange in our simulation codes and are working eagerly to test this hypothesis.

- **Conduit** is released under a BSD-Style License.

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