Sirepo: Low Code Control System GUIs

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Introduction

- Evan Carlin
  - Software Group Leader at RadiaSoft
- RadiaSoft (https://www.radiasoft.net/)
  - Software company in Boulder, CO that specializes in R&D and consulting for beamline physics
- Sirepo
  - Browser based gateway that provides GUIs around legacy codes for particle physics simulations, 3D visualization, tool for designing ML models, a Jupyter server, and recently a way to connect to controls system (https://www.sirepo.com)
  - It wears many hats => it is a framework
  - Open source https://github.com/radiasoft/sirepo

Overarching GUI Themes

- Start with the browser
  - People are familiar with using it
  - They are fast enough for the tasks we encounter
  - Familiar development technologies that integrate well with other systems (ex authentication)
  - Applications are easy to update
- Allow users of different skill levels
  - Power users need to be supported along with beginners
  - Find your user and tailor the GUI to them. Expose "advanced settings" behind buttons
  - Give the most advanced users the ability to download the underlying code, data, etc
- Make the deployments easy too
  - GUIs that involve low code / no code generally need to be deployed in an easy manner as well

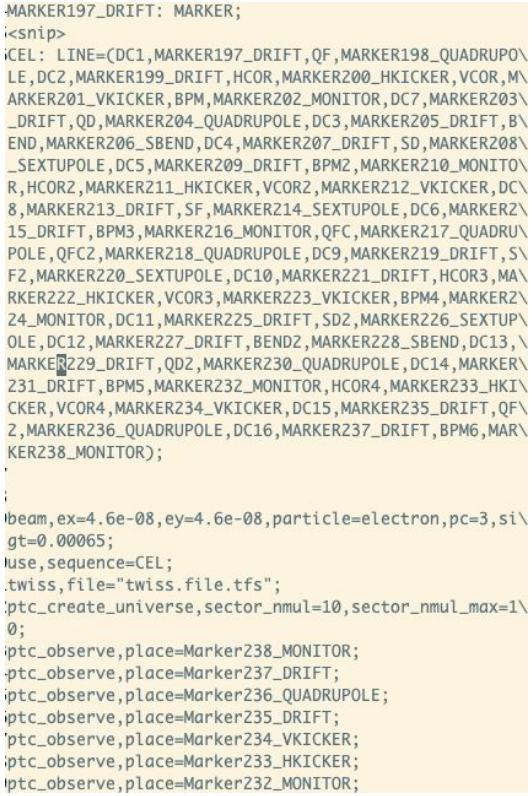
Demo

- Start with a MAD-X input file
  - MAD (Methodical Accelerator Design) is a popular tool for the modeling of particle accelerators
  - Provides a DSL to specify a lattice, initial conditions, and run simulations
- Upload to sirepo.com/madx
  - Lattice is imported and visualized
  - You can edit it and run a simulation
  - You can build a lattice without uploading a MAD-X input file
- Import into sirepo.com/controls
  - See process variables
  - Run optimization
  - Connect to live-system to monitor

Demo

Common data model

- To go from MAD-X input file, to MAD-X Sirepo app, to Controls app (and back) we have a common data model that underpins our system



```
MARKER197_DRIFT: MARKER;
<snip>
CEL: LINE=(DC1,MARKER197_DRIFT,QF,MARKER198_QUADRUPO\
LE,DC2,MARKER199_DRIFT,HCOR,MARKER200_HKICKER,VCOR,M\
ARKER201_VKICKER,BPM,MARKER202_MONITOR,DC7,MARKER203\
_DRIFT,QD,MARKER204_QUADRUPOLE,DC3,MARKER205_DRIFT,B\
END,MARKER206_SBEND,DC4,MARKER207_DRIFT,SD,MARKER208\
_SEXTUPOLE,DC5,MARKER209_DRIFT,BPM2,MARKER210_MONITO\
R,HCOR2,MARKER211_HKICKER,VCOR2,MARKER212_VKICKER,DC\
8,MARKER213_DRIFT,SF,MARKER214_SEXTUPOLE,DC6,MARKER2\
15_DRIFT,BPM3,MARKER216_MONITOR,QFC,MARKER217_QUADRU\
POLE,QFC2,MARKER218_QUADRUPOLE,DC9,MARKER219_DRIFT,S\
F2,MARKER220_SEXTUPOLE,DC10,MARKER221_DRIFT,HCOR3,MA\
RKER222_HKICKER,VCOR3,MARKER223_VKICKER,BPM4,MARKER2\
24_MONITOR,DC11,MARKER225_DRIFT,SD2,MARKER226_SEXTUP\
OLE,DC12,MARKER227_DRIFT,BEND2,MARKER228_SBEND,DC13,\
MARKER229_DRIFT,QD2,MARKER230_QUADRUPOLE,DC14,MARKER\
231_DRIFT,BPM5,MARKER232_MONITOR,HCOR4,MARKER233_HKI\
CKER,VCOR4,MARKER234_VKICKER,DC15,MARKER235_DRIFT,QF\
2,MARKER236_QUADRUPOLE,DC16,MARKER237_DRIFT,BPM6,MAR\
KER238_MONITOR);

beam,ex=4.6e-08,ey=4.6e-08,particle=electron,pc=3,si\
gt=0.00065;
use,sequence=CEL;
twiss,file="twiss.file.tfs";
ptc_create_universe,sector_nmul=10,sector_nmul_max=1\
0;
ptc_observe,place=Marker238_MONITOR;
ptc_observe,place=Marker237_DRIFT;
ptc_observe,place=Marker236_QUADRUPOLE;
ptc_observe,place=Marker235_DRIFT;
ptc_observe,place=Marker234_VKICKER;
ptc_observe,place=Marker233_HKICKER;
ptc_observe,place=Marker232_MONITOR;
```

MAD-X input file

```
{
  "models": {
    "beamlines": [
      {
        "angle": 0.369599135716446,
        "count": 68,
        "distance": 11.583932593720583,
        "id": 185,
        "items": [
          101,
          143,
          <snip>
        ],
        "length": 11.691414678740419,
        "name": "CEL"
      }
    ],
    "elements": [
      {
        "_id": 101,
        "l": 1.53667,
        "name": "DC1",
        "type": "DRIFT"
      },
      <snip>
    ],
    "commands": [
      {
        "_id": 186,
        "_super": "_COMMAND",
        "_type": "beam",
        "bcurrent": 0,
        "beta": 0,
        "brho": 0,
        "bunched": "1",
        "bv": 1,
```

Sirepo data model for MAD-X

```
{
  "models": {
    <snip>
    "controlSettings": {
      "bpmPlotSize": 0.0021,
      "defaultFactor": 100,
      "deviceServerMachine": "",
      "deviceServerProcId": "",
      "deviceServerProcName": "",
      "deviceServerURL": "",
      "deviceServerUser": "",
      "inputLogFile": "",
      "operationMode": "madx",
      "particlePlotSize": 0.1,
      "processVariables": [
        {
          "elId": 143,
          "isWritable": "0",
          "pvDimension": "horizontal",
          "pvName": ""
        },
      "readOnly": "1",
      "selectedTimeIndex": 0,
      "simMode": "singleUpdates"
    },
    "externalLattice": {
      "models": {
        "beamlines": [
          {
            "angle": 0.369599135716446,
            "count": 68,
            "distance": 11.583932593720583,
            "id": 185,
            "items": [
              101,
```

Sirepo data model for Controls

Schema to data model


```
"command_beam": {
    "_super": ["_", "model", "_COMMAND"],
    "particle": ["PARTICLE", "ParticleType", "positron", "The name of particles in the beam."],
    "mass": ["MASS [GeV]", "RPNValue", 0.0005109989461, "The restmass of the particles in the beam."],
    "charge": ["CHARGE [qp]", "RPNValue", 1, "The electrical charge of the particles in the beam in units of the proton charge"],
    "energy": ["ENERGY [GeV]", "RPNValue", 0.0, "Total energy per particle."],
    "pc": ["PC [GeV/c]", "RPNValue", 0.0, "Momentum per particle."],
    "gamma": ["GAMMA", "RPNValue", 0.0, "Relativistic factor, ie the ratio between total energy and rest energy of the particles."],
    "beta": ["BETA [v/c]", "RPNValue", 0.0, "Ratio between the speed of the particles and the speed of light."],
    "brho": ["BRHO [P/abs(q)]", "RPNValue", 0.0, "Magnetic rigidity of the particles."],
    "ex": ["EX [m]", "RPNValue", 1.0, "The horizontal emittance."],
    "exn": ["EXN", "RPNValue", 0.0, "The normalised horizontal emittance."],
    "ey": ["EY [m]", "RPNValue", 1.0, "The vertical emittance."],
    "eyn": ["EYN", "RPNValue", 0.0, "The normalised vertical emittance."],
    "et": ["ET [m]", "RPNValue", 0.001, "The longitudinal emittance $\\epsilon_t$"],
    "sequence": ["SEQUENCE", "OptionalLatticeBeamlineList", "", "Attaches the beam command to a specific sequence."],
    "sigt": ["SIGT [m]", "RPNValue", 1.0, "The bunch length $c\\space \\sigma_t$."],
    "sige": ["SIGE", "RPNValue", 0.001, "The relative energy spread $\\sigma_E / E$."],
    "kbunch": ["KBUNCH", "Integer", 1, "The number of particle bunches in the machine."],
    "npart": ["NPART", "Integer", 1, "The number of particles per bunch."],
    "bcurrent": ["BCURRENT", "RPNValue", 0.0, "The bunch current."],
    "bunched": ["BUNCHED", "Boolean", "1", "The beam is treated as bunched whenever this makes sense."],
```


MAD-X Schema


```
{
    "models": {
        "beamlines": [
            {
                "angle": 0.369599135716446,
                "count": 68,
                "distance": 11.583932593720583,
                "id": 185,
                "items": [
                    101,
                    143,
                    <snip>
                ],
                "length": 11.691414678740419,
                "name": "CEL"
            }
        ],
        "elements": [
            {
                "_id": 101,
                "l": 1.53667,
                "name": "DC1",
                "type": "DRIFT"
            },
            <snip>
        ],
        "commands": [
            {
                "_id": 186,
                "_super": "_COMMAND",
                "_type": "beam",
                "bcurrent": 0,
                "beta": 0,
                "brho": 0,
                "bunched": "1",
                "bv": 1,
```


MAD-X data model

Schema in detail

- Models
  - Define a "type" which encapsulates some data

```
"KICKER": {
    "_super": ["_", "model", "_APERTURE_ELEMENT"],
    "l": ["L [m]", "RPNValue", 0.0, "The length of the closed orbit corrector."],
    "hkick": ["HKICK", "RPNValue", 0.0, "The horizontal momentum change $\\delta PX$"],
    "vkick": ["VKICK", "RPNValue", 0.0, "The vertical momentum change $\\delta PY$"],
    "tilt": ["TILT [rad]", "RPNValue", 0.0, "The roll angle about the longitudinal axis."]
},
```

- Views
  - Define a GUI layout

```
"bunchReport": {
    "title": "Bunch Report",
    "advanced": [
        [
            ["Horizontal",
                ["x"]
            ],
            ["Vertical",
                ["y"]
            ]
        ],
        "histogramBins",
        "colorMap",
        "notes"
    ],
    "basic": []
},
```

GUI generation and app specific code

- Generalized components

```
SIREPO.app.directive('fieldEditor', function(appState, keypressService, panelState, utilities) {
    return {
        restrict: 'A',
        scope: {
            modelName: '=',
            field: '=fieldEditor',
            model: '=',
            viewName: '=',
            <snip>
        },
        template: `
            <div data-ng-class="utilities.modelFieldID(modelName, field)">
            <div data-ng-show="showLabel" data-label-with-tooltip="" class="control-label" data-ng-class="labelClass" data-label="{{ customLabel || info[0] }}" data-tooltip="{{ info[3] }}"></div>
            <div data-ng-switch="info[1]">
              <div data-ng-switch-when="Integer" data-ng-class="fieldClass">
                <input data-string-to-number="integer" data-ng-model="model[field]" data-min="info[4]" data-max="info[5]" class="form-control" style="text-align: right" data-lpignore="true" required />
              </div>
              <div data-ng-switch-when="Float" data-ng-class="fieldClass">
                <input data-string-to-number="" data-ng-model="model[field]" data-min="info[4]" data-max="info[5]" class="form-control" style="text-align: right" data-lpignore="true" required />
                <div class="sr-input-warning"></div>
              </div>
```

- Mixing in app specific behavior

```
SIREPO.app.config(() => {
    SIREPO.SINGLE_FRAME_ANIMATION = ['beamPositionAnimation', 'instrumentAnimationTwiss'];
    SIREPO.appFieldEditors += `
        <div data-ng-switch-when="MadxSimList" data-ng-class="fieldClass">
          <div data-sim-list="" data-model="model" data-field="field" data-code="madx" data-route="lattice"></div>
        </div>
        <div data-ng-switch-when="AmpTable">
          <div data-amp-table=""></div>
        </div>
        <div data-ng-switch-when="AmpField">
          <div data-amp-field=""></div>
        </div>
        <div data-ng-switch-when="ProcessVariables" class="col-sm-12">
          <div element-pv-fields=""></div>
        </div>
    `;
```

Deployment

- We work with many customers
  - We need to be able to deploy quickly/easily to systems we do not have much control over (no root access)
- Need to manage dependency chaos
  - Each deployment target (lab, beamline, individual) has their own unique dependencies
- Monolithic application bundled in Docker
  - Releases can be as simple as a `docker pull`
  - We "control our world". We need to make sure our code works inside of a docker container we control

Thanks! Questions?

Job system

- Manages processes using resources for users
- Initially this was designed for managing simulations (ex a user gets one agent with 4 cores and one agent with 1 core)
- The system was extended so agents that previously ran simulations are now connected to controls systems