BioImage Suite Web

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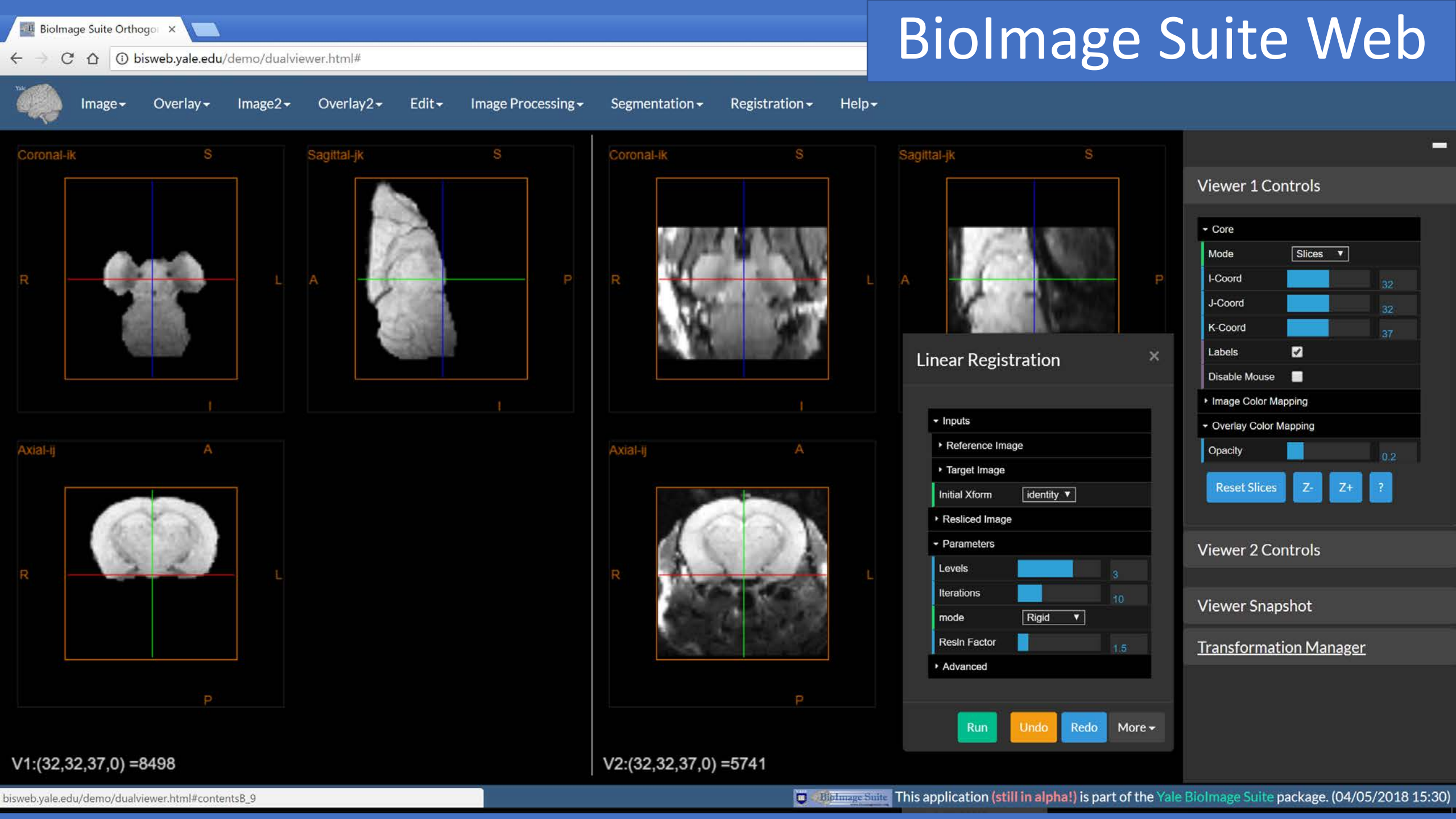
Yale School of Medicine

Note

This Slides are adapted by a presentation made at the NIH Brain Initiative Annual Meeting in April 2018.

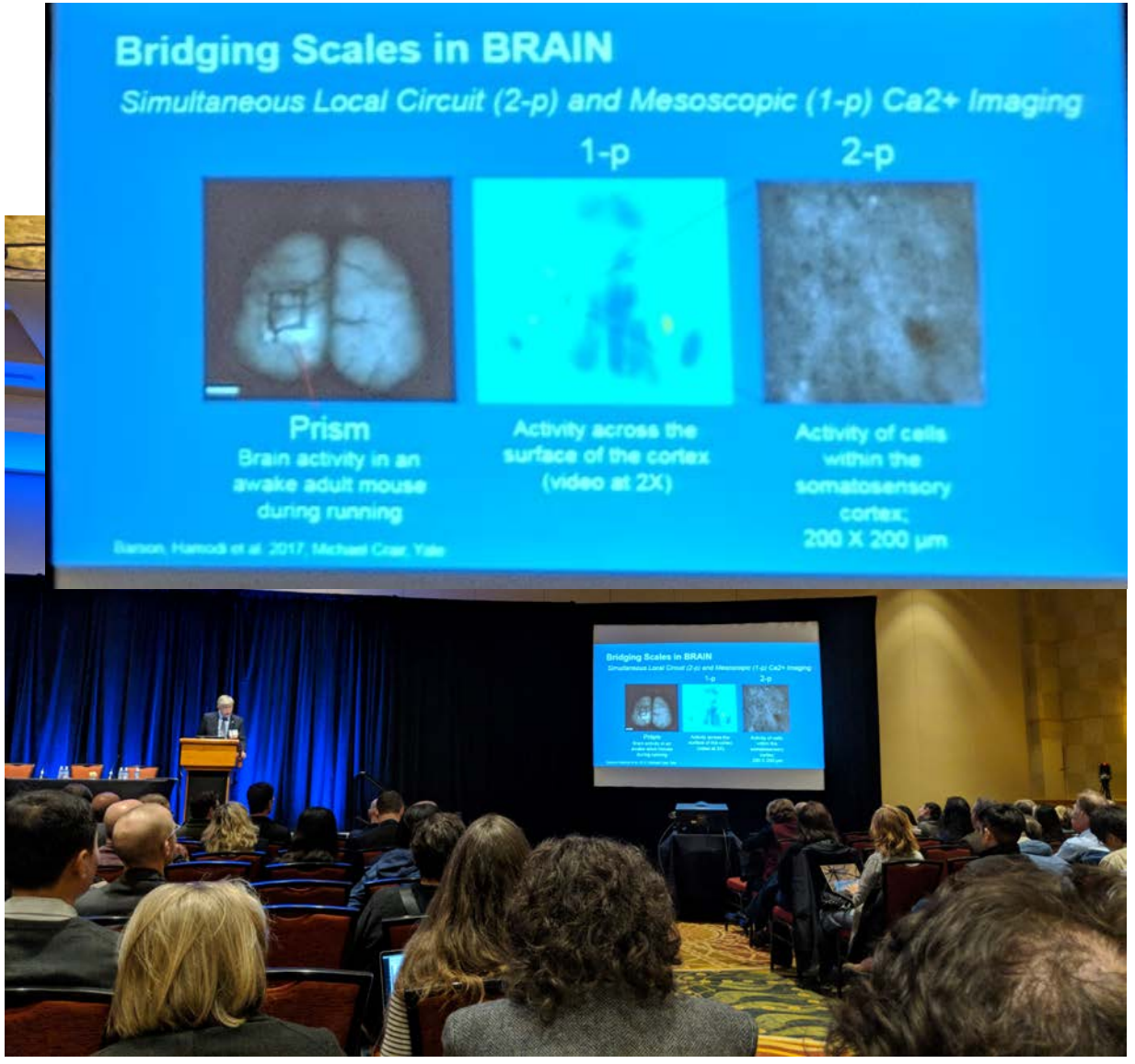
BioImage Suite Web



Collaborators/Partners/Beta Testing Labs

- Radiology & Biomedical Imaging
  - Todd Constable (Human fMRI)
  - Fahmeed Hyder (Small Animal fMRI)

- Neuroscience
  - Michael Crair (Mesoscale Calcium Optical Imaging)
  - Jessica Cardin & Michael Higley (Two Photon Optical Imaging)



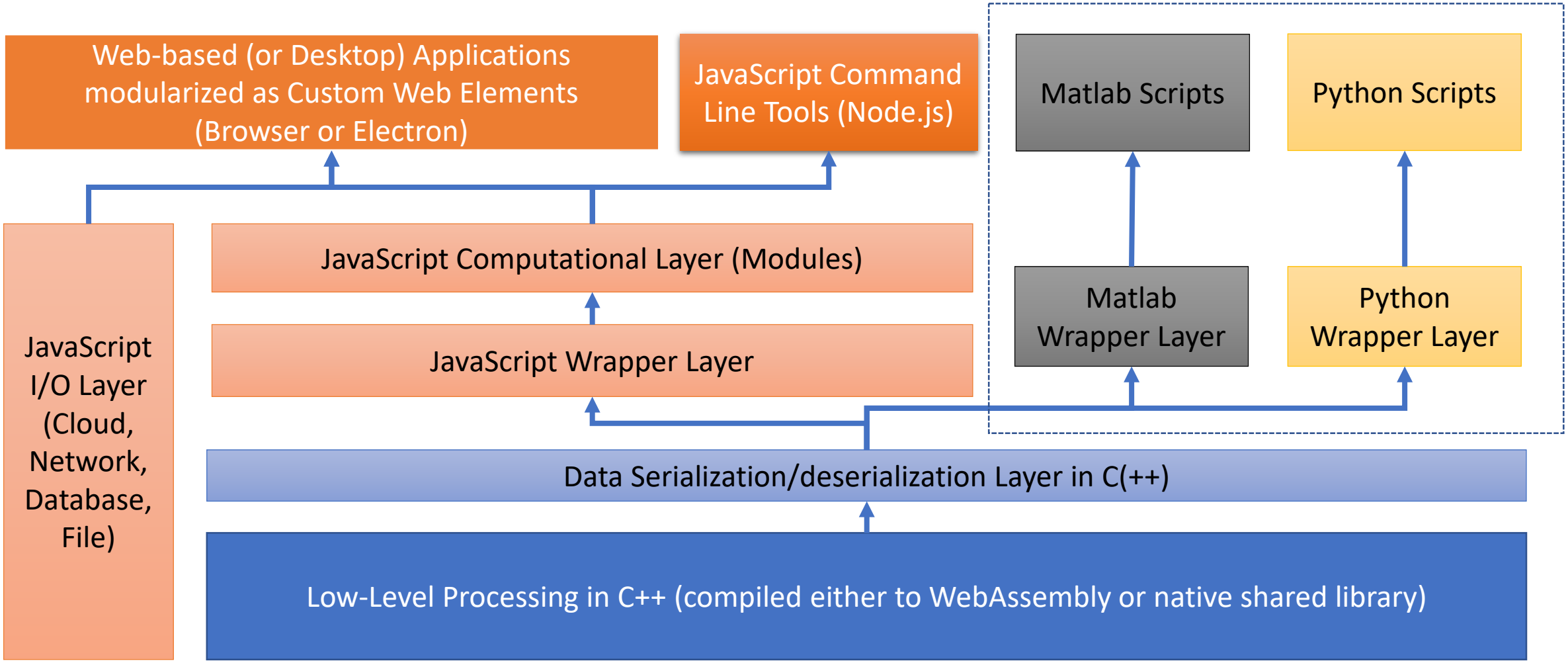
Aims

- Algorithms for Image Analysis of Multimodal/Multispecies neuroimaging data
  - *Registration (linear, nonlinear, 2D → 3D, motion correction)*
  - *Connectome Processing (Prefiltering, parcellation, connectivity …)*
  - Atlas Integration
- Software Architecture
  - *JavaScript/Web-based with cloud integration*
  - *Data Provenance and file storage*
- Testing
  - *Regression*
  - Formalized human testing
- Documentation & Dissemination

Key Technological (Software) Innovations

- Multi-context: same code commandline (via Node.js), desktop (via Electron) and Web
  - Each context has unique strengths
  - Tune to technical sophistication of the user and her needs
- Formal module architecture for automatic GUI and command line implementations of algorithmic modules.
- WebAssembly implementation of computationally expensive code (C++ compiled to WASM) e.g. Non Linear Registration ~90% native performance
- Custom Web Elements to modularize the applications
- No server, all computation is done in the client (your browser)
- A lot of this work builds on our previous experience with the Yale BioImage Suite (www.bioimagesuite.org) software package → This is really the web version of this.

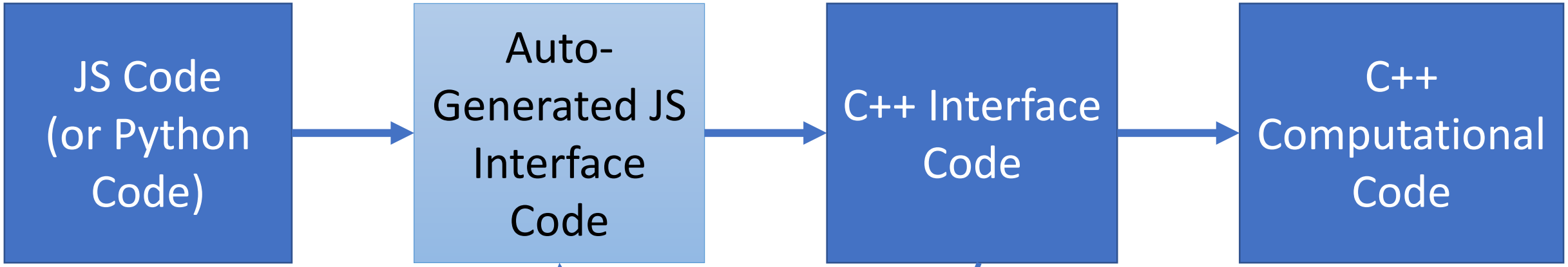
Software Architecture



C++/Web Assembly

- ~18,000 lines of C++ code (per wc) (much of this adapted from BioImage Suite but stripped of dependencies to VTK/ITK/..)
- Only external dependency is Eigen numerical library
- Compile into bytecode using Emscripten
- Serialization/Transfer layer
  - JS ←→ C++ data transfer is restricted to simple “C”-style objects, essentially numbers and arrays

C++ JS Integration




```
/** Compute butterworthFilter Output
 * @param input the input matrix to filter (time = rows)
 * @param jsonstring the parameters { "type": "low", "cutoff": 0.15, 'sampleRate': 1.5 };
 * @param debug if > 0 print debug messages
 * @returns a pointer to the filtered matrix (rows=frames,cols=rois)
 */
// BIS: { 'butterworthFilterWASM', 'Matrix', [ 'Matrix', 'ParamObj',  'debug' ] }
BISEXPORT  unsigned char* butterworthFilterWASM(unsigned char* input,const char* jsonstring,int debug);
```

JS Code

- 45,000 lines of JS Code
- Abstraction of File I/O
- Computational Modules
  - Automatic user interface generation
  - Automatic commandline generation
- User Interface packaged as Custom Web Elements

Formal Module Architecture

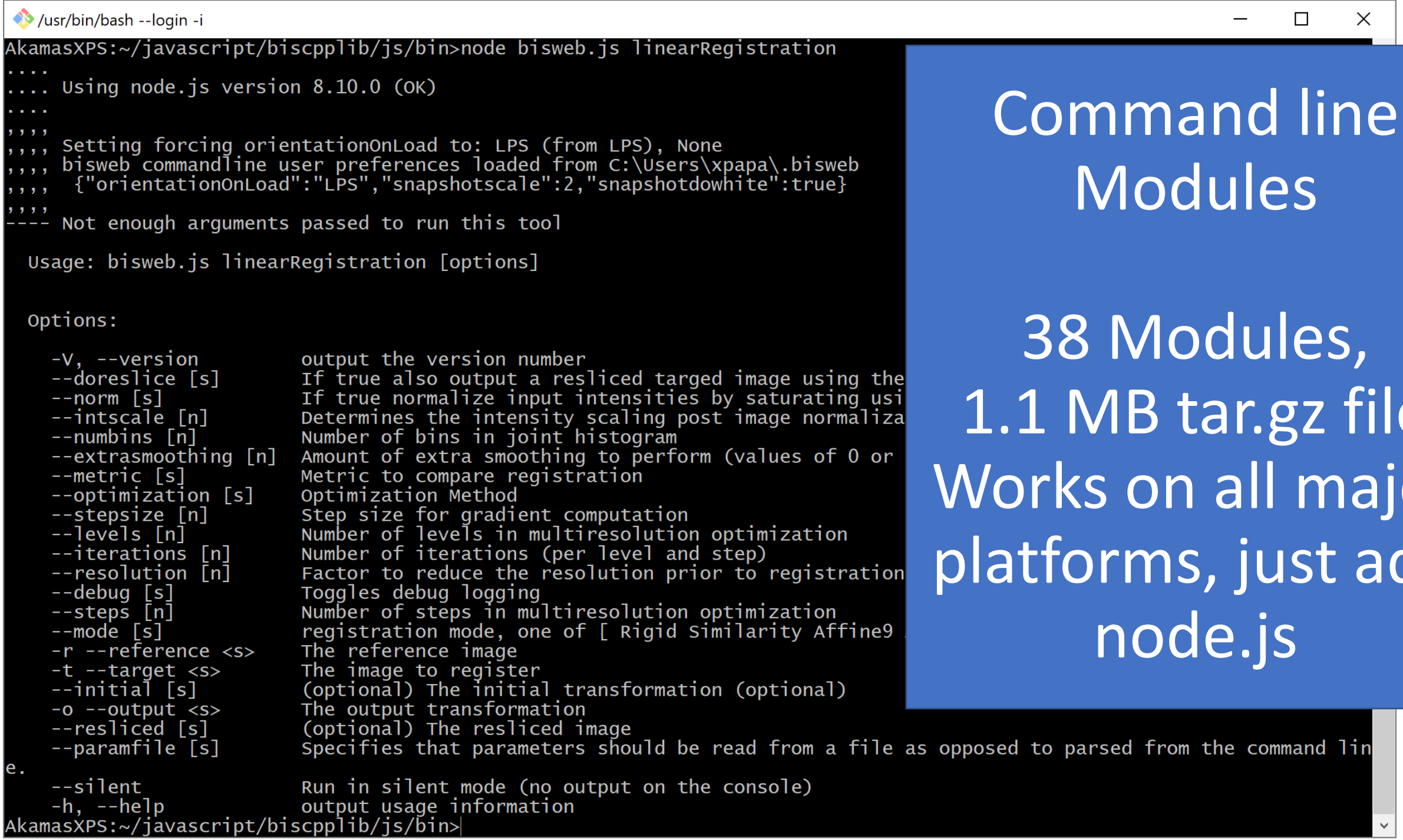
(Inputs, Outputs, Parameters specified using JSON)

JS

```
class SmoothImageModule extends BaseModule {

    constructor() {
        super();
        this.name = 'smoothImage';
    }

    execute(vals) {
        console.log('oooo executing: smoothImage with vals’,vals));
        return new Promise( (resolve, reject) => {
            let input = this.inputs['input'];
            let s = parseFloat(vals.sigma);

            biswrap.initialize().then(() => {
              this.outputs['output'] =
                biswrap.gaussianSmoothImageWASM(input, {
                    "sigmas": [s, s, s],
                    "inmm": super.parseBoolean(vals.inmm),
                    "radiusfactor": parseFloat(vals.radiusfactor)
                }, super.parseBoolean(vals.debug));
                resolve();
            }).catch( (e) => {
                reject(e);
            });
        });
    }
}
```

Python

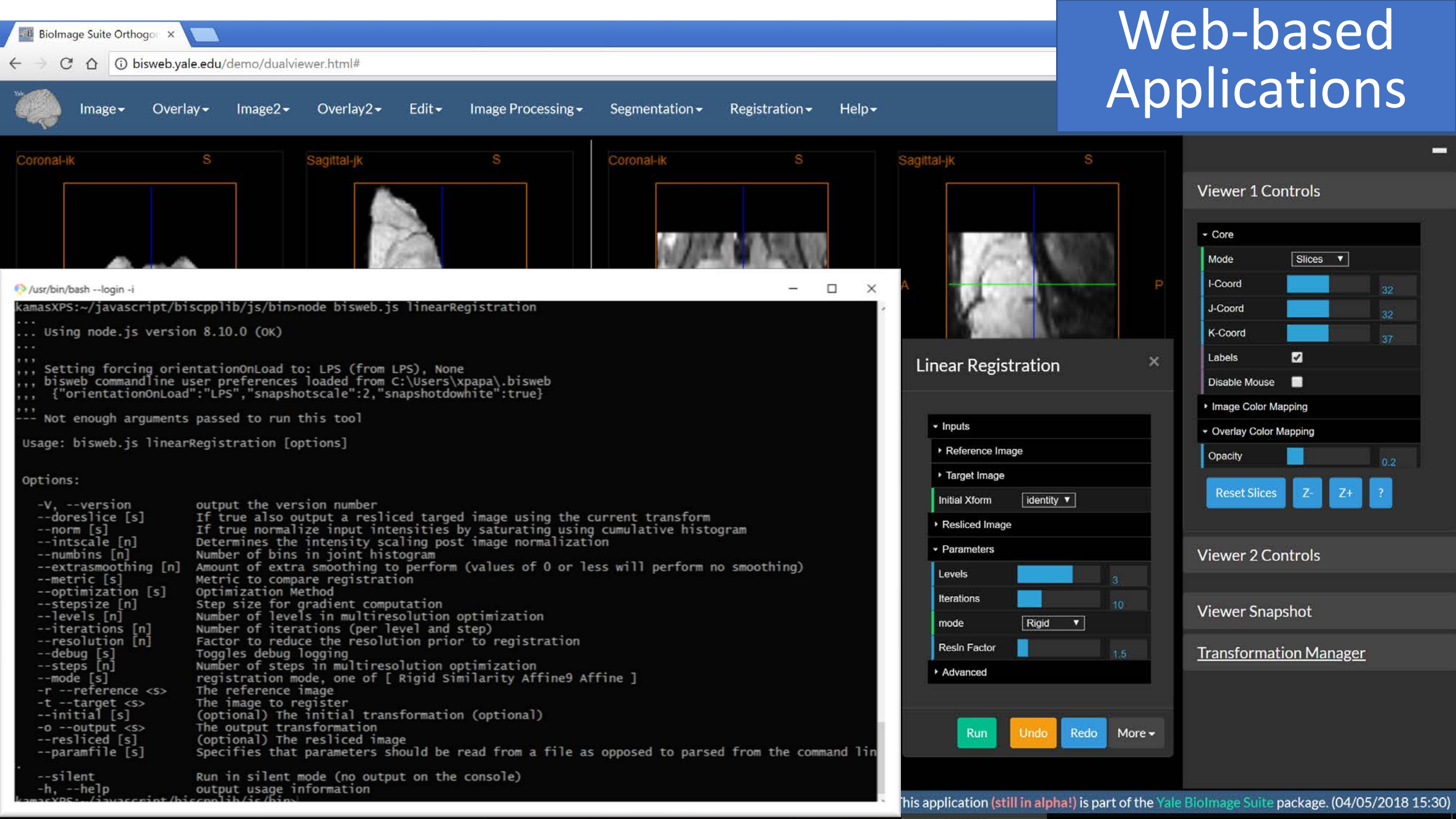
```
class smoothImage(bis_basemodule.baseModule):

    def __init__(self):
        super().__init__();
        self.name='smoothImage';


 def execute(self,vals):
        print('oooo executing: smoothImage with vals', vals);

        input = self.inputs['input'];
        s = (vals['sigma']);

        try:
            self.outputs['output’]=
              libbis.gaussianSmoothImageWASM(input,
                    paramobj={
                        "sigmas": [s, s, s],
                        "inmm": self.parseBoolean(vals['inmm']),
                        "radiusfactor": vals['radiusfactor'],},
                        debug=self.parseBoolean(vals['debug']))
        except:
            return False

        return True
```



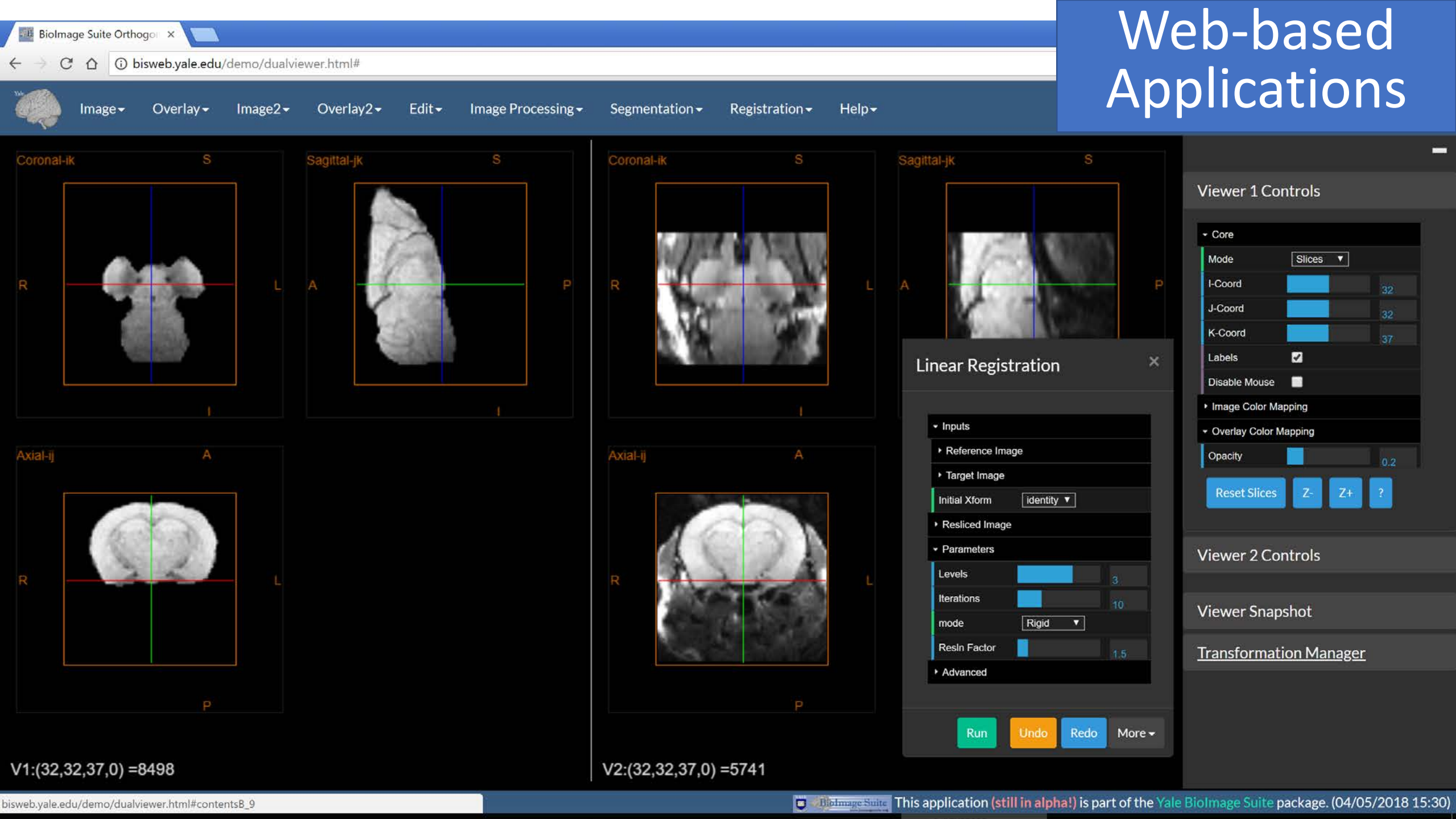
Command line Modules

38 Modules,
1.1 MB tar.gz file
Works on all major platforms, just add node.js

Web-based Applications



Web-based Applications



Web Components

```
<body oncontextmenu="return false;" ondragstart="return fa
lse;" ondrop="return false;">

  <bisweb-topmenubar   id="viewer_menubar">
          </bisweb-topmenubar>

  <div id="viewerwidget">

    <bisweb-viewerlayoutelement
       id="viewer_layout"
       bis-sidewidth="310"
       bis-coreopen="false"
       bis-wholescreen="1"
       bis-defaulttext="">
    </bisweb-viewerlayoutelement>

    <bisweb-colormapcontrollerelement id="viewer_cmap">
            </bisweb-colormapcontrollerelement>

    <bisweb-orthogonalviewer
       id="viewer"
       bis-layoutwidgetid="#viewer_layout"
       bis-colormapeditorid="#viewer_cmap">
    </bisweb-orthogonalviewer>

    <bisweb-snapshotelement
      bis-layoutwidgetid="#viewer_layout"
      bis-dowhite="false"
      bis-viewerid="#viewer">
    </bisweb-snapshotelement>

    <bisweb-simplealgorithmcontrollerelement
       id="algoelement"
       bis-viewerid="#viewer">
    </bisweb-simplealgorithmcontrollerelement>

    <bisweb-painttoolelement
       id="painttool"
       bis-layoutwidgetid="#viewer_layout"
       bis-viewerid="#viewer"
      bis-algorithmcontrollerid="#algoelement">
    </bisweb-painttoolelement>

    <bisweb-console id="bisconsole"></bisweb-console>

    <bisweb-viewerapplication
       bis-menubarid="#viewer_menubar"
       bis-painttoolid="#painttool"
       bis-consoleid="#bisconsole"
       bis-viewerid="#viewer">
    </bisweb-viewerapplication>

  </div>

  <bisweb-botmenubar></bisweb-botmenubar>
</body>
</html>
```

Web Components

```
<body oncontextmenu="return false;" ondragstart=
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  <bisweb-topmenubar   id="viewer_menubar">
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      bis-viewerid="#viewer">
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```

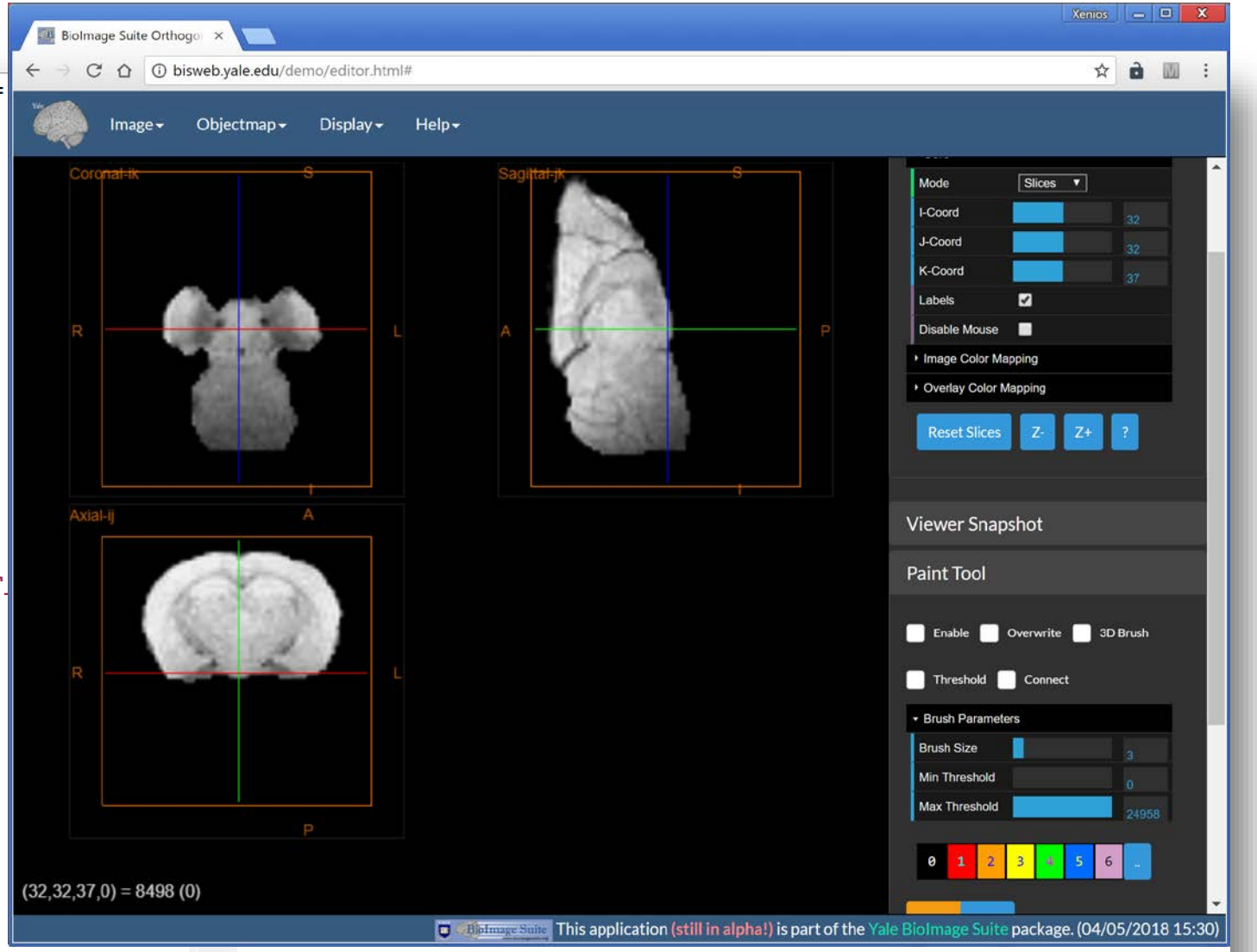

Data Provenance

- Store data provenance information as JSON-extensions to files
- Who generated this file, when, where, with what and how?
- For images embed the JSON info as extensions to NIFTI Headers
- For matrices and transformations we are formalizing new JSON based file formats
- Same applies to higher level outputs (e.g. motion parameters)

Data Format Example


```
{
    "bisformat": "BisDataObjectCollection",
    "filename": "testdata/test_motion_correction__test_motion_correction__mot.json",
    "comments": [
        {
            "ModuleOutput": {
                "command ": "/usr/bin/node /home/xenios/javascript/biscplib/js/bin/bisweb.js motionCorrection -t testdata/test_motion_correction.nii.gz -r testdata/test_motion_correction.nii.gz --doreslice true -o /home/xenios/winhome/Desktop/motionparams.json --resliced /home/xenios/winhome/Desktop/motioncorrect.nii.gz",
                "output": "output",
                "parameters": {
                    "doreslice": true,
                    "norm": true,
                    "intscale": 1,
                    "numbins": 1024,
                    "extrasmoothing": 0,
                    "metric": "CC",
                    "optimization": "HillClimb",
                    "stepsize": 0.25,
                    "levels": 3,
                    "iterations": 32,
                    "resolution": 1.01,
                    "debug": false,
                    "steps": 4,
                    "refno": 0
                },
                "systeminfo": {
                    "os": "linux",
                    "arch": "x64",
                    "hostname": "z230pc",
                    "user": "xenios",
                    "date": "2018-04-02T20:13:52.377Z",
                    "nodeversion": "v8.9.4",
                    "biswebversion": "04/02/2018"
                }
            }
        }
    ],
    "numitems": 5,
    "itemlist": [
        {
            "type": "transform",
            "data": "{\"bisformat\":\"BisLinearTransformation\",\"filename\":\"identity.matr\",\"comments\":[],\"matrix\":[[1,0,0,0],[0,1,0,0],[0,0,1,0],[0,0,0,1]],\"parameters\":[0,0,0,0,0,0]}",
            "metadata": {
                "frame": 0
            }
        },
        {
            "type": "transform",
            "data": "{\"bisformat\":\"BisLinearTransformation\",\"filename\":\"identity.matr\",\"comments\":[],\"matrix\":[[0.9049245715141296,-0.425572007894516,0,61.54688262939453],[0.425572007894516,0.9049245715141296,0,-39.15327453613281],[0,0,1,0],[0,0,0,1]],\"parameters\":[2.651249885559082,-1.7674999237060547,0,0,0,-25.186874389648438]}",
            "metadata": {
                "frame": 1
            }
        },
        {
            "type": "transform",
            "data": "{\"bisformat\":\"BisLinearTransformation\",\"filename\":\"identity.matr\",\"comments\":[],\"matrix\":[[0.9049245715141296,0.425572007894516,0,-39.15327453613281],[-0.425572007894516,0.9049245715141296,0,61.54688262939453],[0,0,1,0],[0,0,0,1]],\"parameters\":[-1.7674999237060547,2.651249885559082,0,0,0,25.186874389648438]}",
            "metadata": {
                "frame": 2
            }
        },
        {
            "type": "transform",
            "data": "{\"bisformat\":\"BisLinearTransformation\",\"filename\":\"identity.matr\",\"comments\":[],\"matrix\":[[0.9081797003746033,0,-0.41858047246932983,34.94537353515625],[0,1,0,0],[0.41858047246932983,0,0.9081797003746033,-43.92396545410156],[0,0,0,1]],\"parameters\":[0.8837499618530273,0,-1.7674999237060547,0,-24.744998931884766,0]}",
            "metadata": {
                "frame": 3
```

Data Format Example


```
{
    "bisformat": "BisDataObjectCollection",
    "filename": "testdata/test_motion_correction__test_motion_correctio
n__mot.json",
    "comments": [
        {
            "ModuleOutput": {
                "command ": "/usr/bin/node /home/xenios/javascript/bisc
plib/js/bin/bisweb.js motionCorrection -t testdata/test_motion_correcti
n.nii.gz -r testdata/test_motion_correction.nii.gz --doreslice true -o
home/xenios/winhome/Desktop/motionparams.json --resliced /home/xenios/w
nhome/Desktop/motioncorrect.nii.gz",
                "output": "output",
                "parameters": {
                    "doreslice": true,
                    "norm": true,
                    "intscale": 1,
                    "numbins": 1024,
                    "extrasmoothing": 0,
                    "metric": "CC",
                    "optimization": "HillClimb",
                    "stepsize": 0.25,
                    "levels": 3,
                    "iterations": 32,
                    "resolution": 1.01,
                    "debug": false,
                    "steps": 4,
                    "refno": 0
                },
                "systeminfo": {
                    "os": "linux",
                    "arch": "x64",
                    "hostname": "z230pc",
                    "user": "xenios",
                    "date": "2018-04-02T20:13:52.377Z",
                    "nodeversion": "v8.9.4",
                    "biswebversion": "04/02/2018"
                }
            }
        }
    ],
    "numitems": 5
```



```
            {
                "ModuleOutput": {
                    "command ": "/usr/bin/node /home/xenios/jav
plib/js/bin/bisweb.js motionCorrection -t testdata/test_mot
n.nii.gz -r testdata/test_motion_correction.nii.gz --dores
home/xenios/winhome/Desktop/motionparams.json --resliced /
nhome/Desktop/motioncorrect.nii.gz",
                    "output": "output",
                    "parameters": {
                        "doreslice": true,
                        "norm": true,
                        "intscale": 1,
                        "numbins": 1024,
                        "extrasmoothing": 0,
                        "metric": "CC",
                        "optimization": "HillClimb",
                        "stepsize": 0.25,
                        "levels": 3,
                        "iterations": 32,
                        "resolution": 1.01,
                        "debug": false,
                        "steps": 4,
                        "refno": 0
                    },
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                    }
                }
            }
        ],
0.8837499618530273,0,-1.7674999237060547,0,-24.74499893188476,0]}",
            "metadata": {
                "frame": 3
```

Data Format Example

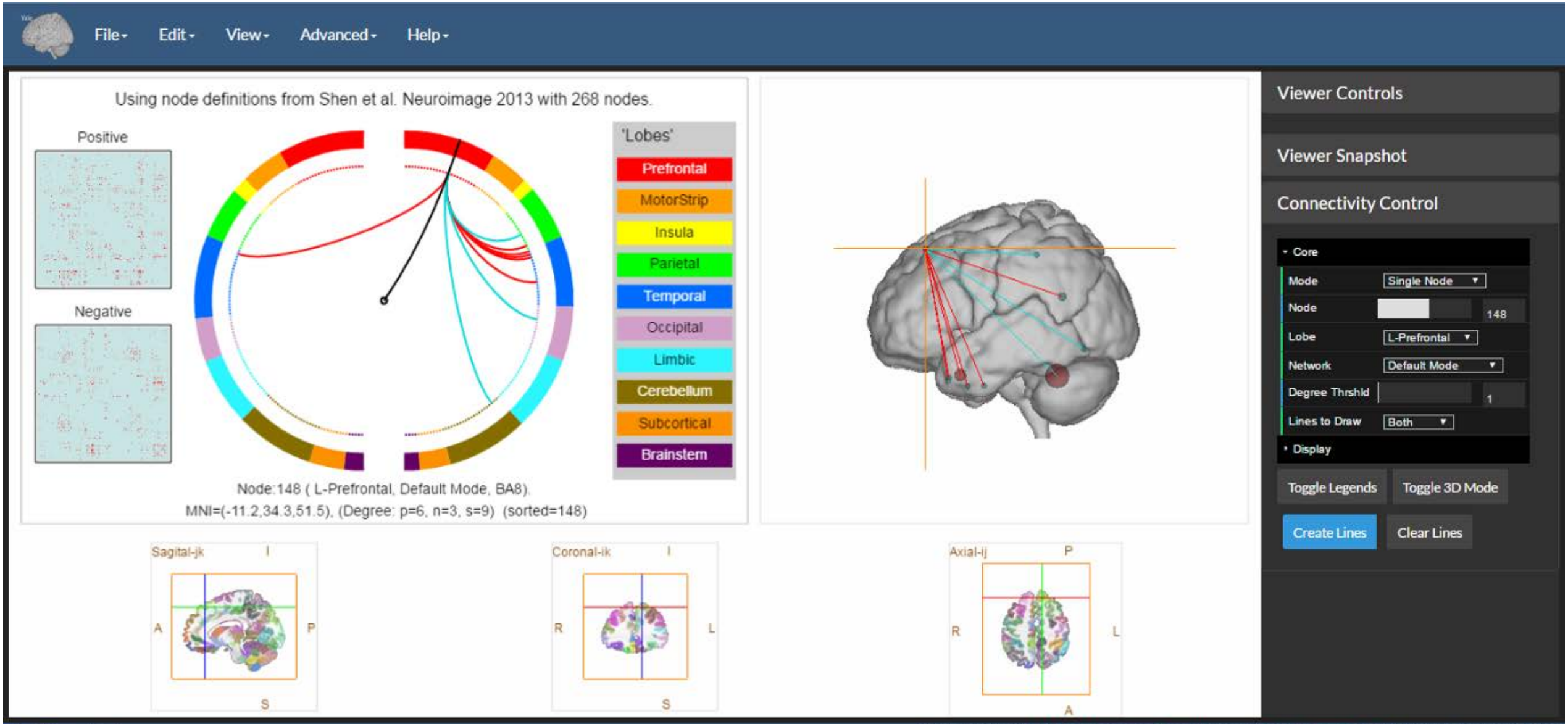

```
{
    "bisformat": "BisDataObjectCollection",
    "filename": "testdata/test_motion_correction__test_motion_correctio
n__mot.json",
    "comments": [
        {
            "ModuleOutput": {
                "command ": "/usr/bin/node /home/xenios/javascript/biscp
lib/js/bin/bisweb.js motionCorrection -t testdata/test_motion_correcti
n.nii.gz -r testdata/test_motion_correction.nii.gz --doreslice true -o
home/xenios/winhome/Desktop/motionparams.json --resliced /home/xenios/w
nhome/Desktop/motioncorrect.nii.gz",
                "output": "output",
                "parameters": {
                    "doreslice": true,
                    "norm": true,
                    "intscale": 1,
                    "numbins": 1024,
                    "extrasmoothing": 0,
                    "metric": "CC",
                    "optimization": "HillClimb",
                    "stepsize": 0.25,
                    "levels": 3,
                    "iterations": 32,
                    "resolution": 1.01,
                    "debug": false,
                    "steps": 4,
                    "refno": 0
                },
                "systeminfo": {
                    "os": "linux",
                    "arch": "x64",
                    "hostname": "z230pc",
                    "user": "xenios",
                    "date": "2018-04-02T20:13:52.377Z",
                    "nodeversion": "v8.9.4",
                    "biswebversion": "04/02/2018"
                }
            }
        }
    ],
    "numitems": 5
```



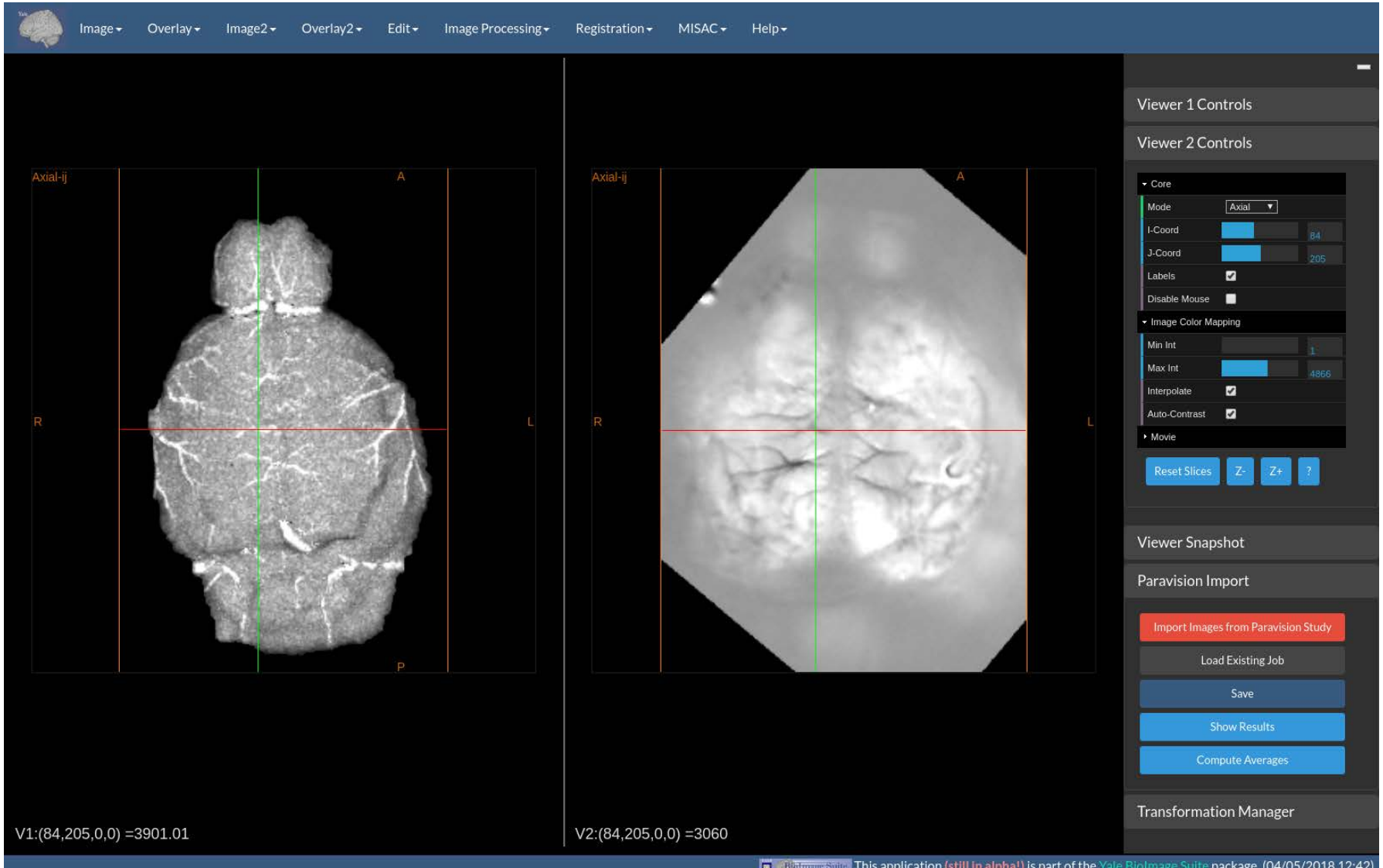
```
            {
                "ModuleOutput": {
                    "command ": "/usr/bin/node /home/xenios/jav
lib/js/bin/bisweb.js motionCorrection -t testdata/test_mot
n.nii.gz -r testdata/test_motion_correction.nii.gz --dores
home/xenios/winhome/Desktop/motionparams.json --resliced /
nhome/Desktop/motioncorrect.nii.gz",
                    "output": "output",
                    "parameters": {
                        "doreslice": true,
                        "norm": true,
                        "intscale": 1,
                        "numbins": 1024,
                        "extrasmoothing": 0,
                        "metric": "CC",
                        "optimization": "HillClimb",
                        "stepsize": 0.25,
                        "levels": 3,
                        "iterations": 32,
                        "resolution": 1.01,
                        "debug": false,
    },
    "systeminfo": {
        "os": "linux",
        "arch": "x64",
        "hostname": "z230pc",
        "user": "xenios",
        "date": "2018-04-02T20:13:52.377Z",
        "nodeversion": "v8.9.4",
        "biswebversion": "04/02/2018"
    }
```

Web-based Connectome Visualization

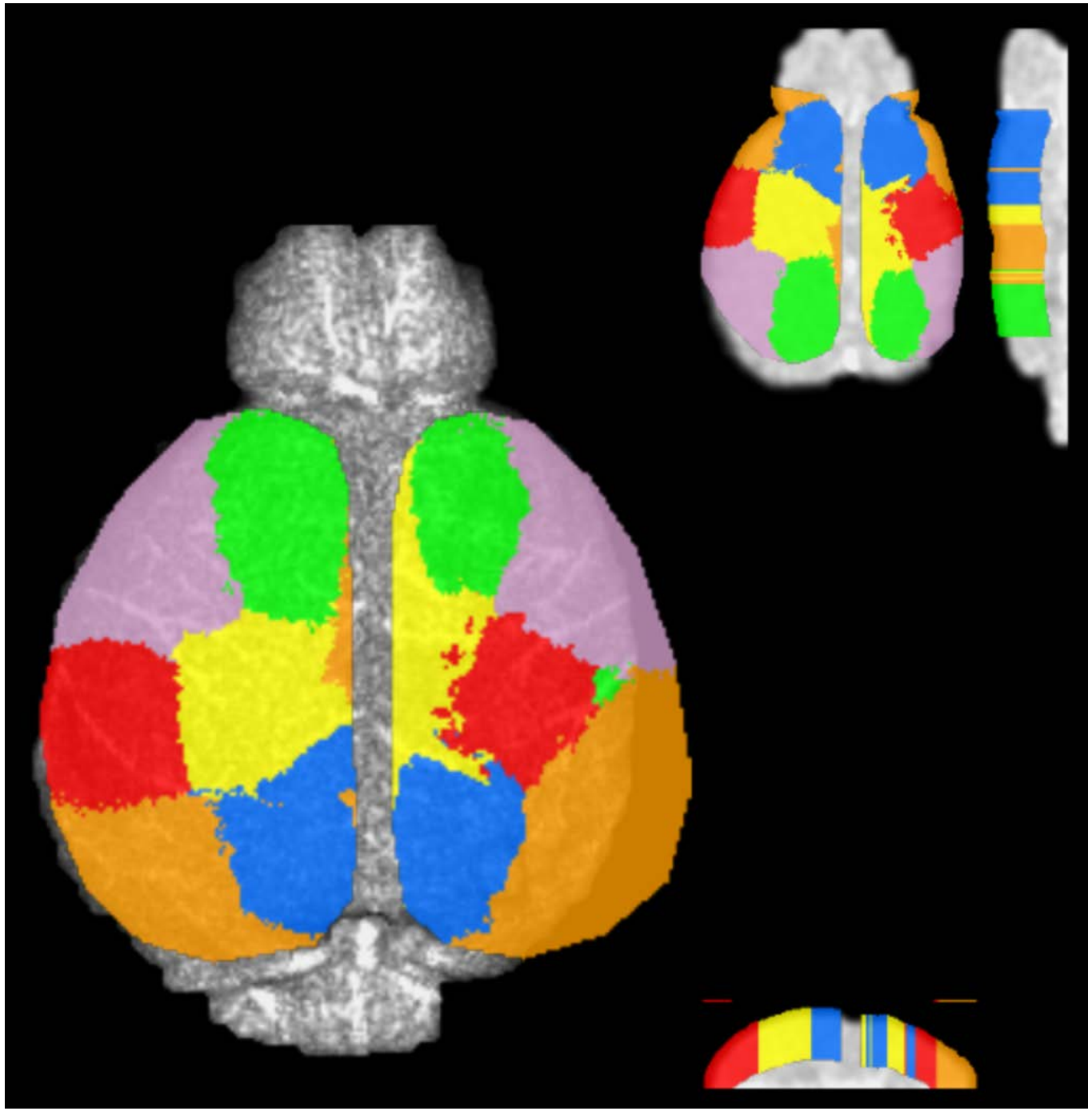
Shen et al. Nature Protocols 2017



Mapping 2D Optical to fMRI (via Angio MRI)



Mapping Parcellations from Optical to MRI



Testing

- Almost all modules (~35) have one or more module regression tests
  - Implement module regression tests as part of module development
  - Subset of tests also in Python (2/3 of the modules have Python versions)
  - Testing is the “fourth context” (commandline, desktop, web) with its own adaptor framework

```
{
    "command" : "butterworthFilter -i testdata/newtests/but_low_inp.matr  --type  high --tr 1.0 --high 0.03 --debug true",
    "test"    : "--test_target testdata/newtests/but_high_out.matr --test_type matrix --test_comparison ssd --test_threshold 0.01",
    "result"  : true,
    "dopython": true
},
```

- We have another 100+ unit tests (in about 30 scripts) to test lower level code (e.g. C++ to JS data transfer)
- Manual user testing
- Initial applications for the Yale MISAC Project (talk yesterday)

Status

- Beta-ish version online bisweb.yale.edu/demo

- Source code coming end of this month (BSD style license)
  - Code is build using a combination of cmake and gulp
  - Emscripten used for the WebAssembly
  - Delay is administrative (need to finish build documentation)

- Low level code is basically almost finished

- Working on documentation (including YouTube channel with direct links to the software)

Acknowledgments

- Zach Saltzman
- John Onofrey
- Cheryl Lacadie
- Haley Garbus
- Michelle Lim
- Noah Amsel
- Pranav Chandrasekaran
- Users, testers, ...

- Eigen
- CMake/CTest/CPack
- Emscripten
- Node.js
- Gulp
- Webpack
- Bootstrap
- JQuery
- dat.gui
- Three.js
- Electron
- Electron-Packager

NIH/NIHMH R24 MH114805