#CHW061

Karl Traunmüller on Computable

http://computableapp.com

About Me

- CompSci degree JKU Linz ’93-98
- Embedded Systems ’99-00
- C++/MFC ’00-02
- Freelancer, Pocket PC Shareware ’02-06
- .NET, Java EE (never, never, ever...) ’06-10
- Some teaching FH Hagenberg ’06-09
- Freelancer, Mac/iOS apps ’10-now

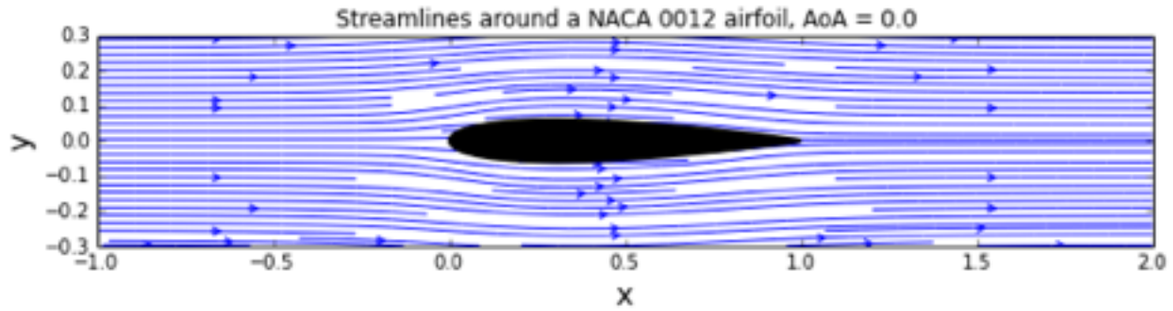
The Computable Story

How IPython found a new home on the iPad

IPython

- “Open Source MATLAB”
- Would be cool to have on the iPad

In [20]:
```
# plots the velocity field
size=10
plt.figure(figsize=(size, (y_end-y_start)/(x_end-x_start)*size))
plt.xlabel('x', fontsize=16)
plt.ylabel('y', fontsize=16)
plt.streamplot(X, Y, u, v, density=1, linewidth=1, arrowsize=1, arrowstyle='->')
plt.fill([panel.xc for panel in panels],
         [panel.yc for panel in panels],
         color='k', linestyle='solid', linewidth=2, zorder=2)
plt.xlim(x_start, x_end)
plt.ylim(y_start, y_end)
plt.title('Streamlines around a NACA 0012 airfoil, AoA = %.1f' % alpha);
```



We can now calculate the pressure coefficient. In Lesson 9, we computed the pressure coefficient on the surface of the circular cylinder. That was useful because we have an analytical solution for the surface pressure on a cylinder in potential flow. For an airfoil, we are interested to see how the pressure looks all around it, and we make a contour plot in the flow domain.

In [21]:
```
# computes the pressure field
cp = 1.0 - (u**2+v**2)/freestream.u_inf**2

# plots the pressure field
size=12
plt.figure(figsize=(1.1*size, (y_end-y_start)/(x_end-x_start)*size))
plt.xlabel('x', fontsize=16)
plt.xlabel('y', fontsize=16)
```

IPython on iPad

- Doable?
- Why has nobody done it before?
- 1.5 mio apps in the store, but not this?

Getting Started

- Let’s run a feasibility study!
  - Answer the doable question in 1-2 weeks
    - late Jan

Up-front Questions

- We need an embeddable Python runtime
  - Should be no problem
- Will IPython work at all?
  - Architecture looking good
  - Kernel – Messaging – UI (ZeroMQ on iOS?)
  - Nice, simple messaging protocol
  - Notebooks are JSON (good)

Up-front Questions

- We’ll have to port the full SciPy stack
  - numpy
  - matplotlib
  - SciPy
  - SymPy
  - pandas

Up-front Questions

- Can we get all core packages to compile?
  - Heavy use of native (C) extensions
  - Quite a bit of Fortran code in scipy
    - Translation to C required (f2c)
    - Extend numpy's distutils setup framework
- Plotting: Matplotlib
  - AGG software rendering (good)

Cross Compiling Fun

```
export CC="$ARM_CC -I$BUILDROOT/include $ARM_CFLAGS -fno-builtin"
export CFLAGS="$ARM_CFLAGS"
export CFLAGS="$CFLAGS -I$BUILDROOT/python/include/python2.7"
export CFLAGS="$CFLAGS -I$TMPROOT/numpy-$NUMPY_VERSION/sources/src/private"
export CFLAGS="$CFLAGS -I$TMPROOT/numpy-$NUMPY_VERSION/sources/include"
export CFLAGS="$CFLAGS -iquote$TMPROOT/numpy-$NUMPY_VERSION/sources/numpy/core...
export LD="$ARM_LD $ARM_LDFLAGS"
export AR="$ARM_AR"
export LDFLAGS="$ARM_LDFLAGS"
export LDSHARED="$PRJROOT/tools/liblink"

...

echo "compiling sources..."
cp -f $PRJROOT/src/numpy_files/make_Makefile Makefile
make

echo "creating libnumpy.a..."
cp -f $PRJROOT/src/numpy_files/link_Makefile Makefile
make

cp -r $TMPROOT/numpy-$NUMPY_VERSION/numpy/core/include $BUILDROOT/include
cp libnumpy.a $BUILDROOT/lib
```

Cross Compiling Fun

- Getting the static libraries to compile standalone is one thing
- Fixing all “unresolved symbol” linker errors in the app project is another

Other Issues

- We’re in a single-process, multi-threaded environment
  - Violates some core assumptions
    - Singletons, argh!
- We’re in a static linking environment
  - Symbol name clashes
  - No dynamic loading of Python modules

Other Issues

- Some Patching required
  - Duplicate/unresolved symbols
  - Non-matching prototype/impl. (Fortran)
- Python Module initialization
  - numpy and pandas require special setup
- Python runtime
  - Very easy to lock up (GIL)

Other Issues

- Private API usage
  - BLAS clashes with Accelerate framework

Doable?

- Yes
- early Feb
- large parts of SciPy stack ported by now

App Architecture

- Python runtime
  - Static module initialization
- IPython application
  - kernel and notebook mgmt.
  - custom, based on HTML notebook app
- ZeroMQ backend/frontend messaging
- Frontend (sessions, notebooks, UI)

Execution Model

- Frontend submits request (code to execute)
- Kernel receives request over ZMQ
- Kernel replies with several messages
  - status, execute reply, display data, ...
- Frontend collects responses, updates UI
- Very nicely decoupled

Notebook Rendering

- Markdown parser + obj model + renderer
- Parser
  - libsoldout (pluggable backend)
- Renderer
  - First attempt: NSAttributedString
  - (La)TeX: Oops! (no lib?!)
  - Rewrite for HTML / MathJax

Notebook Rendering

- Markdown → “DOM” → HTML+Javascript
- Load into UIWebView
- Cache rendered output for performance
- Works, but very slow

Step 4: Burgers' Equation

You can read about Burgers' Equation on its wikipedia page.

Burgers' equation in one spatial dimension looks like this:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} = \nu\frac{\partial^2 u}{\partial x^2}$$

As you can see, it is a combination of non-linear convection and diffusion. It is surprising how much you learn from this neat little equation!

We can discretize it using the methods we've already detailed in Steps 1 to 3. Using forward difference for time, backward difference for space and our 2nd-order method for the second derivatives yields:

$$\frac{u_i^{n+1} - u_i^n}{\Delta t} + u_i^n\frac{u_i^n - u_{i-1}^n}{\Delta x} = \nu\frac{u_{i+1}^n - 2u_i^n + u_{i-1}^n}{\Delta x^2}$$

As before, once we have an initial condition, the only unknown is u_i^{n+1}. We will step in time as follows:

$$u_i^{n+1} = u_i^n - u_i^n\frac{\Delta t}{\Delta x}(u_i^n - u_{i-1}^n) + \nu\frac{\Delta t}{\Delta x^2}(u_{i+1}^n - 2u_i^n + u_{i-1}^n)$$

Initial and Boundary Conditions

To examine some interesting properties of Burgers' equation, it is helpful to use different initial and boundary conditions than we've been using for previous steps.

Our initial condition for this problem is going to be:

$$u = -\frac{2\nu}{\phi}\frac{\partial \phi}{\partial x} + 4$$
$$\phi = \exp\left(\frac{-x^2}{4\nu}\right) + \exp\left(\frac{-(x-2\pi)^2}{4\nu}\right)$$

This has an analytical solution, given by:

$$u = -\frac{2\nu}{\phi}\frac{\partial \phi}{\partial x} + 4$$
$$\phi = \exp\left(\frac{-(x-4t)^2}{4\nu(t+1)}\right) + \exp\left(\frac{-(x-4t-2\pi)^2}{4\nu(t+1)}\right)$$

Our boundary condition will be:

$$u(0) = u(2\pi)$$

Some Git History

kernels starting on iPad, although not with correct configuration file	1eacc1e	Karl Traunmüller…	04.03.2014 23:03
fixed kernel poller (now using heartbeat channel instead of poll)	91dfd5a	Karl Traunmüller…	04.03.2014 18:48
IPKernelApp running again!	c085671	Karl Traunmüller…	04.03.2014 01:49
we need a custom kernel launcher…	9fabb08	Karl Traunmüller…	04.03.2014 01:26
multi-kernel app basically running!	710f57c	Karl Traunmüller…	04.03.2014 00:16
notebook app refactoring partially working	e115c8a	Karl Traunmüller…	03.03.2014 23:34
new NotebookApp is launching	67d2efd	Karl Traunmüller…	02.03.2014 21:11
before kernel manager refactoring	8576046	Karl Traunmüller…	02.03.2014 16:44
added kernel version info log output	a46a8fa	Karl Traunmüller…	02.03.2014 15:05
IPython upgrade to 1.2.1	7d3853d	Karl Traunmüller…	02.03.2014 14:50
second kernel doesn't launch…	4dbd665	Karl Traunmüller…	12.02.2014 00:31
2 tests running	efac136	Karl Traunmüller…	11.02.2014 20:28
fixed notebook startup & shutdown	f01554b	Karl Traunmüller…	11.02.2014 14:23
basic start sequence test runs through, but blocks main thread (todo: run interpreter in thread)	17163a2	Karl Traunmüller…	11.02.2014 00:30
unit tests	27116f8	Karl Traunmüller…	09.02.2014 19:34
python parser, unit test target	4d87d75	Karl Traunmüller…	09.02.2014 19:11
cell collection view, tab control	551753b	Karl Traunmüller…	09.02.2014 16:38
basic view controller setup	3776d3c	Karl Traunmüller…	09.02.2014 14:24
added session delegate, message parsing	1a15431	Karl Traunmüller…	06.02.2014 23:30
basic UI	2681897	Karl Traunmüller…	06.02.2014 22:03
initial commit	6e05ada	Karl Traunmüller…	06.02.2014 21:42

Some Git History

fixed Markdown rendering, added hyphenation	fb9e85d	Karl Traunmüller…	14.04.2014 23:47
HTML formatting	e225ded	Karl Traunmüller…	13.04.2014 20:00
added Computer Modern fonts	6552c01	Karl Traunmüller…	13.04.2014 19:09
basic Markdown HTML rendering with MathJax	77f063d	Karl Traunmüller…	13.04.2014 17:39
before Markdown rendering refactoring	a053ef5	Karl Traunmüller…	13.04.2014 13:15

fixed toolbar positioning when keyboard is visible	10ce66c	Karl Traunmüller…	28.04.2014 21:17
added matplotlibrc setup	59fb137	Karl Traunmüller…	28.04.2014 21:17
added check to prevent exception on message dispatch	51f40c0	Karl Traunmüller…	28.04.2014 20:54
added pandas	58f372d	Karl Traunmüller…	27.04.2014 20:18
added padding to output cells	a263616	Karl Traunmüller…	24.04.2014 00:14
fixed a crash when image output is nil	1c884c0	Karl Traunmüller…	24.04.2014 00:13
toolbar positioning fixes	627e0df	Karl Traunmüller…	24.04.2014 00:13
using matplotlib rcParams for Retina handling	920eae7	Karl Traunmüller…	24.04.2014 00:13
added sympy	ef1e7b9	Karl Traunmüller…	24.04.2014 00:12

added basic notebook parsing	ecc82bb	Karl Traunmüller…	21.03.2014 00:18

we have image output!!!	1fa6cf2	Karl Traunmüller…	14.03.2014 01:11
we get display data!	f98ed08	Karl Traunmüller…	14.03.2014 00:34
zmq message buffer now allocated on heap	1333c8a	Karl Traunmüller…	13.03.2014 01:24
numpy and matplotlib seem to be ok now	b49d8a2	Karl Traunmüller…	13.03.2014 00:27
added faulthandler	d531469	Karl Traunmüller…	10.03.2014 01:21
fixed matplotlib dependencies	4c12fe6	Karl Traunmüller…	10.03.2014 00:06
added matplotlib, libbz2	fbdcf51	Karl Traunmüller…	09.03.2014 23:11
fixed libscipy	549fbb7	Karl Traunmüller…	09.03.2014 22:36

The Computable Icon

- We’ll need that for submission
- Make it create its own icon :)

$$\frac{z}{cos(1 - z^{0.4})}$$

App Store Submission

- It’s end of June
  - 5 months of late-nighters
- You’re exhausted when reaching 1.0
  - Your build system shows last-minute flaws
  - What do you do?
    - Submit a fully unlocked beta build!
    - http://bit.ly/1mOCunh

Computable 1.1

- Python code completions
- Inline documentation
- Important step towards better usability

Computable 1.2

- Get rid of HTML and MathJax
- Use (La)TeX for all Markdown rendering
- Status
  - Plain TeX + DVI rendering up & running
    - ~10x faster than previous approach
  - Currently working on LaTeX
  - Paginated PDF export as nice byproduct

Computable 1.2

```objc
@implementation DviRenderer

- (void)renderPage:(Page *)page intoContext:(CGContextRef)context
{
    CGContextSetAllowsAntialiasing(context, true);
    CGContextSetAllowsFontSmoothing(context, true);
    CGContextSetAllowsFontSubpixelPositioning(context, true);
    CGContextSetShouldSubpixelPositionFonts(context, true);
    CGContextSetAllowsFontSubpixelQuantization(context, true);
    CGContextSetShouldSubpixelQuantizeFonts(context, true);

    CGContextSetRGBFillColor(context, 0, 0, 0, 1);
    CGContextSetTextDrawingMode(context, kCGTextFill);
    CGContextSetTextMatrix(context, CGAffineTransformMakeScale(1, -1));

    for (Run *run in page.runs)
    {
        [self renderRun:run intoContext:context];
    }
}

- (void)renderRun:(Run *)run intoContext:(CGContextRef)context
{
    CGContextSetFont(context, run.cgFont);
    CGContextSetFontSize(context, CTFontGetSize(run.ctFont) * kFontScale);
    CGContextShowGlyphsAtPositions(context, run.glyphs, run.positions, run.length);
}

@end
```

Computable 1.3

- More Python packages
  - scikit-learn, seaborn, plotly, ...

Future

- Computable for R
  - would be great, but GPL
- Computable for Julia?
- LaTeX for iPad (and Mac)?