eHive Workshop

part 2. How to create pipelines

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Before we begin, please:

- Make sure you have correct setup from part 1
- Get a username/password on the training MySQL server
- Update ensembl-hive repository to pick fresh bug fixes

```
export EHIVE_HOST=mysql-ehive-training.ebi.ac.uk
export EHIVE_PORT=4427
export EHIVE_USER=trainXX
export EHIVE_PASS=pswXX
```

- Breaks?

Nested loops and dimensions

```
foreach my $species (@all_species) {
    foreach my $chromosome (@{ $species->get_Chromosomes }) {
        foreach my $gene (@{ $chromosome->get_Genes }) {
            foreach my $transcript (@{ $gene->get_Transcripts }) {
                foreach my $exon (@{ $transcript->get_Exons }) {
                    # is this the Exon I was really looking for?
                }
            }
        }
    }
}
```

- A regular program has to fold all of this 5D into 1T
- A well-designed pipeline can “turn” some of these dimensions into “space” of the farm
- When planning a pipeline, first draw a diagram and think about these dimensions and their real dependence.

Modularity of pipelines. PipeConfigs & Runnables

- A Hive pipeline is defined in a PipeConfig file which references one or more Runnable modules.

- Many tasks can be solved by using “universal” Runnables provided by the Hive (SystemCmd, SqlCmd, JobFactory, Dummy), but sometimes you have to write your own application-specific Runnables.

- We shall learn to use universal Runnables before making our own
  (however it may be the opposite of what you do in practice)

- Hive’s “universal” Runnables live here:

  $ENSEMBL_CVS_ROOT_DIR/ensembl-hive/modules/Bio/EnsEMBL/Hive/RunnableDB/

  They are written in Perl.

- Hive’s PipeConfig files live here:

  $ENSEMBL_CVS_ROOT_DIR/ensembl-hive/modules/Bio/EnsEMBL/Hive/PipeConfig/

  They are written in a subset of Perl.

The simplest pipeline : AnyCommands_conf.pm

- Please open the file - this is the smallest PipeConfig possible:

```
use base ('Bio::EnsEMBL::Hive::PipeConfig::HiveGeneric_conf');#  or subclass

sub pipeline_analyses {
    return [
        {   -logic_name    => 'perform_cmd',
            -module        => 'Bio::EnsEMBL::Hive::RunnableDB::SystemCmd',
        },
    ];
}
```

```
$ init_pipeline.pl AnyCommands_conf.pm
```

```
$ generate_graph.pl -url $EHIVE_URL -out any_empty.png
```

or use http://guihive.ebi.ac.uk:8080/ instead

AnyCommands_conf.pm (2)

- No jobs - we will have to seed them:

```
$ seed_pipeline.pl -url $EHIVE_URL -logic_name perform_cmd
\
    -input_id '{"cmd" => "echo Hello, world"}'
```

- and run:

```
$ runWorker.pl -url $EHIVE_URL
```

- Practical to a certain extent (analysis_capacity, batch_size, resources)

Analysis-wide parameters and substitution

- We can define values for old parameters and create new ones:

```
sub pipeline_analyses {
    return [
        {   -logic_name    => 'perform_cmd',
            -module        => 'Bio::EnsEMBL::Hive::RunnableDB::SystemCmd',
            -parameters => {
                 "cmd" => "gzip #filename# ",
            },
        },
    ];
}
```

- Exercise: seed a few jobs and run them (you can copy some compressible files from ~lg4/work/pdfs)

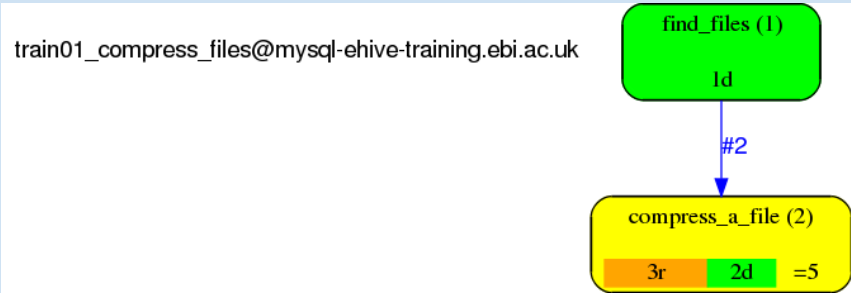
- Automated seeding of jobs?

```
for filename in `find pdfs/ -name '*.pdf'` ; do seed_pipeline.pl -url $EHIVE_URL \
     -logic_name perform_cmd -input_id "{ 'filename' => '$filename' }";
done
```

Factories and dataflow : CompressFiles_conf.pm

- Dataflow Rules can be used to make Jobs seed other Jobs
- Factory is an Analysis whose only aim is to seed other Jobs, create a “fan”, turn time into space
- Higher level input

```
sub pipeline_analyses {
    return [
        {   -logic_name => 'find_files',
            -module     => 'Bio::EnsEMBL::Hive::RunnableDB::JobFactory',
            -parameters => {
                'inputcmd'     => 'find #directory# -type f ',
                'column_names' => [ 'filename' ],
            },
            -flow_into => {
                2 => [ 'compress_a_file' ],
            },
        },
        {   -logic_name    => 'compress_a_file',
            -module        => 'Bio::EnsEMBL::Hive::RunnableDB::SystemCmd',
            -parameters    => {
                'cmd'       => 'gzip #filename#',
            },
            -analysis_capacity => 4,
        },
    ];
}
```



Dataflow conventions

- Each Dataflow Event is a pair (branch_number, hash_of_parameters+).

- Each Runnable has its own set of branch_numbers
  that it may emit Dataflow Events into.

- “Reserved” branch numbers that have their own meaning:
  - 1 is almost always present, it is the “continuation” after Job is ‘DONE’
  - 2 is used by many Factory Runnables to emit the “fan” of Jobs
  - -1 : “postmortem dataflow after MEMLIMIT” on LSF
  - -2 : “postmortem dataflow after RUNLIMIT” on LSF

- Check the Runnable (documentation or code) to make sure
  the dataflow you are wiring is live. What happens if it’s not?

- “Black boxing” exercise: modify **`MemlimitTest_conf.pm`** to dataflow into another Analysis with more memory if not enough.

pipeline_wide_parameters()
and the order of precedence of parameters

- The source of parameters is unknown to Jobs

```
sub pipeline_wide_parameters {
    my ($self) = @_;
    return {
        %{$self->SUPER::pipeline_wide_parameters},

        'gzip_flags'    => '',
        'directory'     => '.',
        'only_files'    => '*',
    };
}
```

- Parameters can be:
  - “local” to the Job (belonging/sent to the Job itself or its “stack” of ancestors)
  - analysis-wide
  - pipeline-wide
  - defaults set in the Runnable’s code

- Exercise: abstract the compressor (‘compress’, ‘gzip’, ‘bzip2’, ‘xz’ etc) out

Templates: the other kind of glue

- Runnables have fixed parameter names for input and output - comparison with Perl subroutine calls:
  - \+ more flexible - you can specify certain parameters and not others
  - \+ less error-prone - if you add parameters, there is no need to reshuffle them
  - − you need “glue” to link analyses together

- Two kinds of glue:
  - input transformation using parameter substitution:

```
'cmd' => 'gzip #filename#'
```

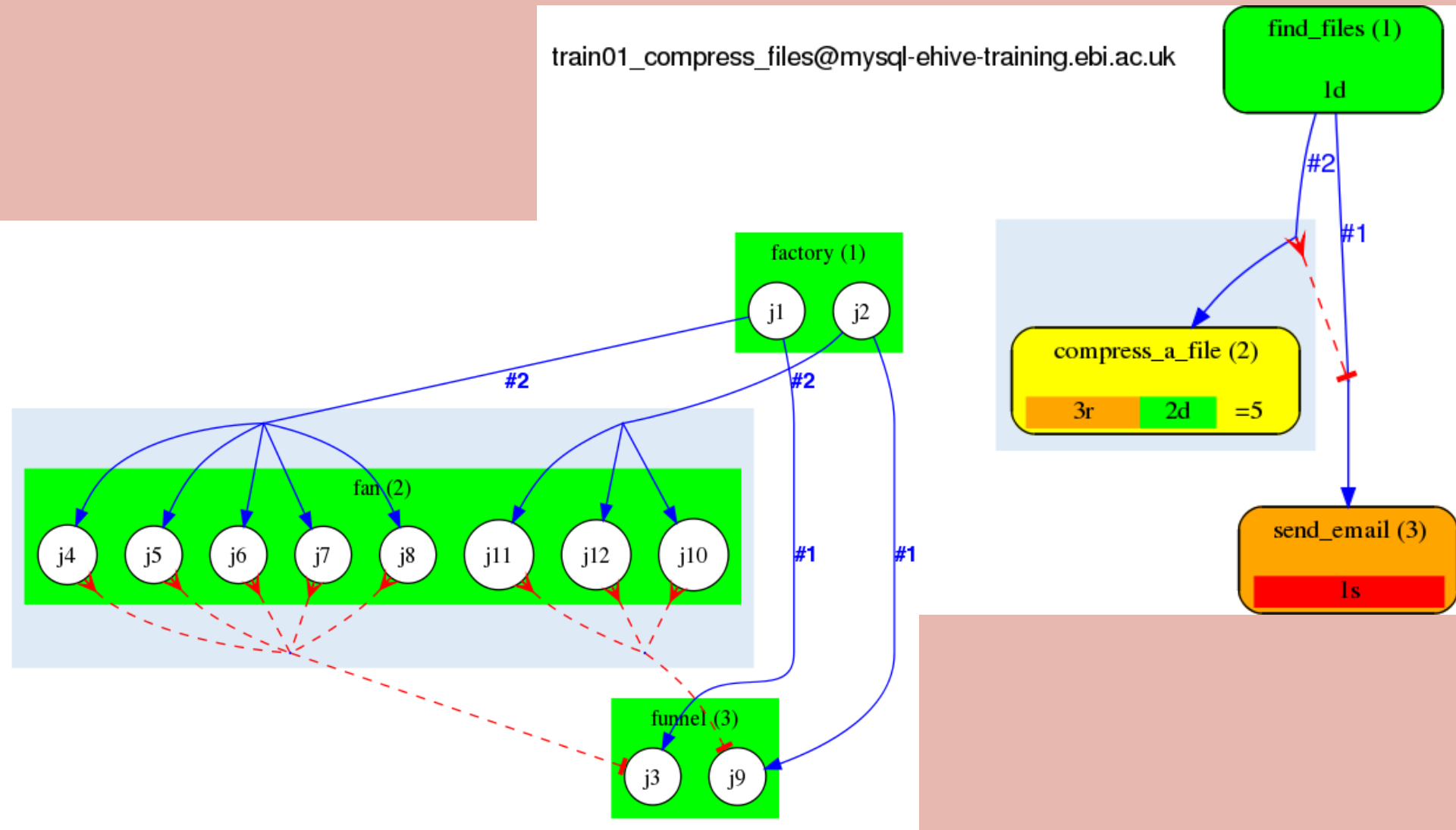
  - output transformation using templates:

```
2 => { 'compress_a_file' => {
            'input_filename' => '#output_filename#', # rename
            'check_input_once' => 1,                 # specific mode
            'gzip_flags' => '#gzip_flags#',          # propagation
          },
         'another_analysis' => undef,   # no template - use as is
},
```

- Templates work the same way independently of Dataflow’s *destination type*

Regaining single thread of control: semaphored dataflow

- Built-in mechanism for converging individual threads back together.
- Based on semaphores that can block an individual job by a set of prerequisite jobs.



Semaphored dataflow in a PipeConfig

- Creating a funnel Analysis : let the pipeline send us a notification:

```
{   -logic_name    => 'report',
      -module        => 'Bio::EnsEMBL::Hive::RunnableDB::NotifyByEmail',
      -meadow_type   => 'LOCAL',  # NB: farm nodes may not support sendmail
      -parameters    => {
          'email'   => $ENV{'USER'} . '@ebi.ac.uk',
          'subject' => 'pipeline has finished',
          'text'    => 'done compressing files in #directory#',
      },
},
```

- Linking two rules together happens in the emitting Analysis:

```
-flow_into => {
    '2->A' => { 'compress_a_file' =>
                 { 'filename' => '#filename#', 'gzip_flags' => '#gzip_flags#' },
         },
    'A->1' => [ 'send_email' ],
}
```

- Try running?

Capturing data from a command : JobFactory

- Both SystemCmd and SqlCmd only run your command, no output is captured in any structured way.
  - So SqlCmd is usually used to INSERT, DELETE, UPDATE, CREATE/ALTER/DROP TABLE, but not with SELECT.

- JobFactory is not specifically creating Jobs - it simply transforms streams of “things” into Dataflow Events that may be converted into Jobs, stored in database tables, or accumulated. It is the wiring that defines what happens next.

```
{   -logic_name    => 'post_compress_size',
    -module        => 'Bio::EnsEMBL::Hive::RunnableDB::JobFactory',
    -parameters    => {
        'inputcmd'      => "wc -c #filename#.gz | sed -e 's/^ *//' ",
        'delimiter'     => ' ',
        'column_names'  => [ 'comp_size', 'comp_filename' ],
    },
},
```

- Insert it correctly. Have we captured anything? We have. How to pass it outside?

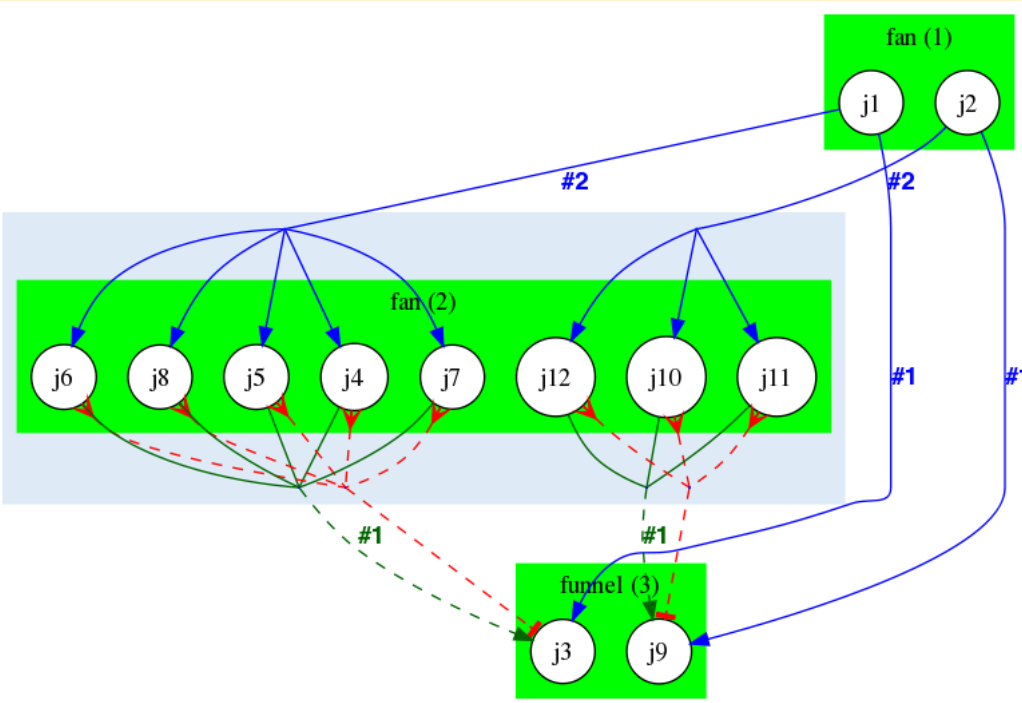
Accumulating data from a semaphore group

- How do we pass the data from the box into the funnel?
- The data can be passed from any job within the box into the correct funnel Job
- Different structures or combinations can be accumulated (hashes, arrays, piles, multisets)
- pseudo-Analysis names as targets for Dataflow (with or without templates).

```
':////accu?hash_name={key_name}'

':////accu?array_name=[index_name]'

':////accu?pile_name=[]'

':////accu?multiset_name={}'
```

- see LongMult_conf for example.

Flow the data into accu (which branch?)



Advanced parameter substitution : expressions

- What if we want to compute a value of #alpha#+1 rather than just a string?

```
'alpha_plus_one' => '#expr($alpha+1)expr#'
```

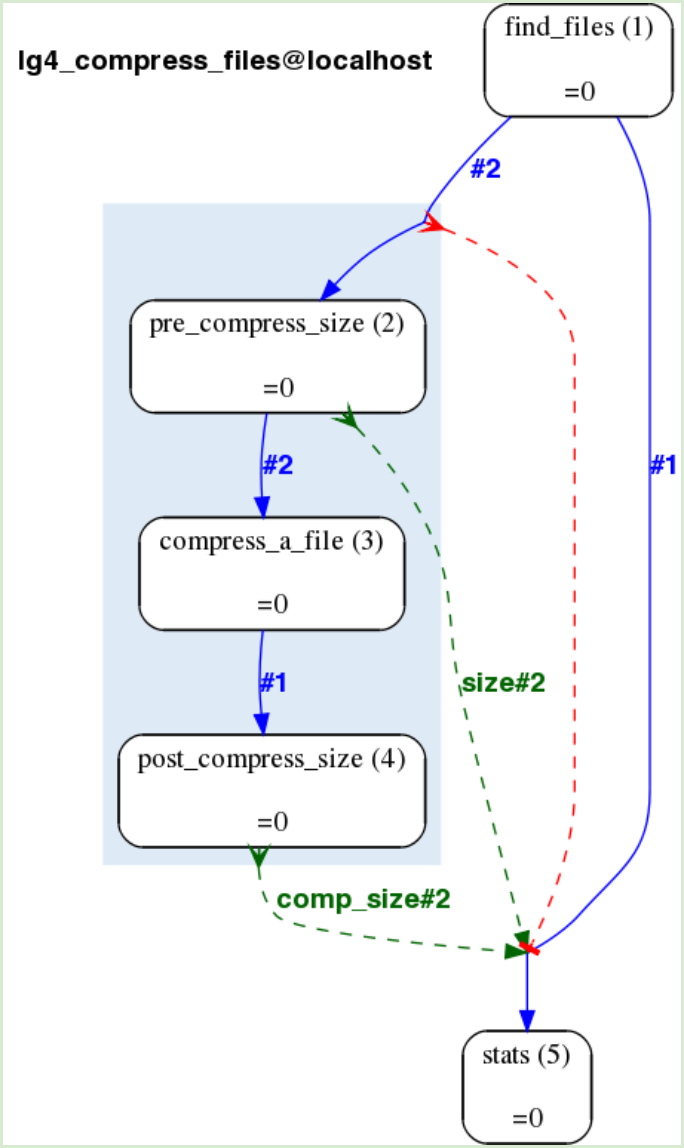
- Any Perl expression can be evaluated as follows:
  - first, $alpha will be text-substituted with the value of alpha parameter
  - then the resulting string will be evaluated
  - so put a space between dollar and the name ($ beta) if you want standard Perl interpretation of the variable

- We can flatten accumulated structures (that are not scalars) into scalars using #expr()expr# . For example,

```
'min_comp_size' => '#expr(min values %{$comp_size})expr#',
'max_comp_size' => '#expr(max values %{$comp_size})expr#',
'text'    => 'compressed sizes between #min_comp_size# and #max_comp_size#',
```

Exercise: accumulation + substitution

- Let's put it all together:
  - Factory on a directory to dataflow single filenames
  - compute their sizes and accumulate them
  - compress the files
  - compute the compressed sizes and accumulate
  - funnel flattens the accumulated structures and emails you the report



- Have a look at my PipeConfig/CompressFilesWithReport_conf.pm

Manual parameter propagation vs parameter stack

- There used to be only one way of propagating parameters into sub-branches - using templates. It gave full control over which parameters a Job sees, but was non-intuitive in comparison to structured programs with scoped variables.

- Open both LongMult_conf and LongMultSt_conf . Notice the difference.

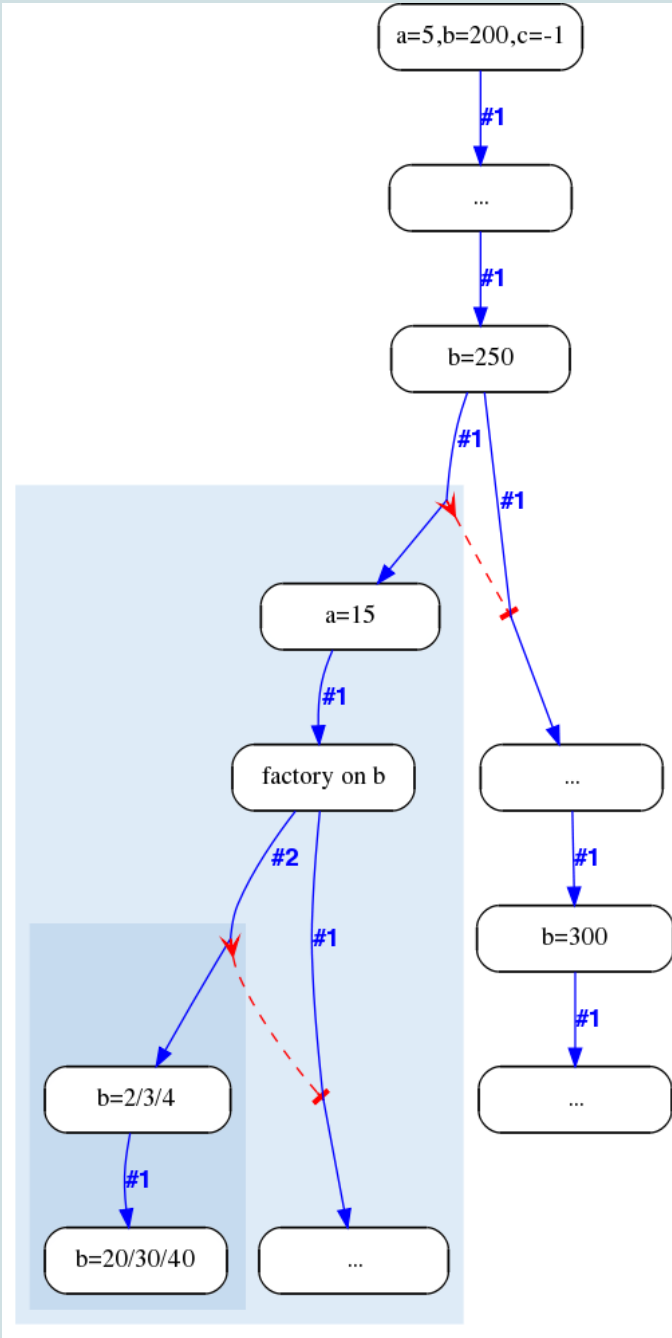
- Parameter stack approach may be less efficient but much more intuitive and easier to use for programmers. Once a variable was dataflown down a thread, its value becomes available to all its descendants until the end of that dataflow thread (Hive equivalent of end-of-scope).

- Parameter stack support is off by default, can be switched on in PipeConfig:

```
sub hive_meta_table {
    my ($self) = @_;
    return {
        %{$self->SUPER::hive_meta_table},
        'hive_use_param_stack'  => 1,
    };
}
```

How parameter stack works

```
{
    a=5 ; b=200 ; c=-1;
    …
    b=250 ;
    …
        {
            a=15;
            for b in (2,3,4) {
                b *= 10;
            }
            …
        }
    …
    b=300;
}
```



Writing your own Runnable. Lifecycle of a Job

- A Job goes through the following states:
  - [SEMAPHORED] -- if they are created in pre-blocked state
  - READY -- can be claimed by Workers
  - CLAIMED -- for a short period to ensure no race condition with other Workers
  - [PRE_CLEANUP] -- method -- mostly file/db cleanup after prev. attempt
  - FETCH_INPUT -- method -- checking parameters and database activity
  - RUN -- method -- main functionality, ideally mute
  - WRITE_OUTPUT -- method -- mostly writing into databases, dataflow
  - [POST_CLEANUP] -- method -- mostly memory cleanup
  - DONE -- this is how they all should be
  - [FAILED] -- if exhausted all attempts
  - [PASSED_ON] -- if garbage-collected from a killed Worker

- A Runnable can redefine some of the following “virtual” methods:

  - param_defaults() -- a hash of the lowest level defaults in parameter precedence
  - pre_cleanup()
  - fetch_input()
  - run()
  - write_output()
  - post_cleanup()

Writing your own Runnable. Available API

- To get access to all the API available to the Runnable, it has to inherit from Process, directly or indirectly:

```
use base ('Bio::EnsEMBL::Hive::Process');      # or your group's subclass
```

- The main cohesive material of the Hive system is the API that deals with parameter retrieval, storage and propagation. It is closely linked with dataflow mechanism.

  - my $alpha = $self->param('alpha'); # getter
  - my $alpha = $self->param_required('alpha'); # strict getter
  - $self->param('beta', $beta); # setter
  - if ($self->param_is_defined('gamma')) { … } # check
  - $self->dataflow_output_id({ 'alpha' => 1.5, 'gamma' => 5 }, 3); # send event
  - $self->warning('I got a strange feeling I am in an infinite loop…'); # not warn
  - die 'all gone wrong'; # record this message in log_message
  - $self->throw(); # or any other die-based reporter
  - $self->input_job->incomplete(0 | 1);
  - $self->input_job->transient_error(0 | 1);
  - $self->input_job->lethal_for_worker(0 | 1);

Writing your own Runnable. Exercise

- Please study the LongMult example Runnables, they are always up to date with the development

- Exercise: write a Runnable that takes in an array of LONG numbers and adds them all together. It may need its own “driver” PipeConfig.

- Prove that (A1+A2+A3+...+An)*B == A1*B+A2*B+A3*B+...+An*B by adding your new Runnable to LongMultSt_conf.

Questions?

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SEVENTH FRAMEWORK PROGRAMME

Quantomics

From Sequence to Consequence : Tools for the Exploitation of Livestock Genomes

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