Writing Vesta Bridges

An Introduction to Integrating New Tools and Tool Flows into Vesta Builds

Tools under Vesta

- Tools run during a Vesta build have their context defined by an SDL program
  - The command line
  - The complete filesystem (see `chroot(2)`)
  - The environment variables
  - The standard input
- All these details are parameters to the SDL `_run_tool` primitive function

Tools under Vesta

- Setting up the context for a tool can be complicated
  - Tool executable file (for the right platform)
  - Run-time libraries, config files, etc. the tool needs
  - Placing the input files
- Vesta enforces precision (which is good)
- But users aren't interested in the details

Bridge = Abstraction

- A *bridge* is a collection of SDL functions that simplify running one more tools
  - “Bridges the gap” between the operation the user is interested in and the low-level details needed to carry it out
- Usually multiple bridges are gathered together into a *build environment*
  - A collection of different operations the user might need

Good Bridge Design

- Don't assume the filesystem is set up by the caller
  - Bridge function that runs a tool should add any files it needs (e.g. executable, run-time libraries, etc.)
  - For efficiency it's sometimes best to set up the filesystem once then run the tool multiple times
- Primary inputs should be parameters to bridge functions
  - Input files
  - Type of output/processing

Good Bridge Design

- Separate the SDL code from platform-specific files (executables, run-time libraries, etc.)
  - Possible to share bridge code across multiple platforms (e.g. x86 Linux, x86-64 Linux, Solaris)
  - Upgrade tool versions and change bridge code independently
  - Requires additional abstraction: bridge gets *specialized* to a particular platform with parameters by the build environment

Good Bridge Design

- Provide abstract *bridge options* for choices the user may want to make less often
  - Choices that affect multiple things
  - Anything likely to change between platforms
- Provide a way for the user to add arbitrary command-line switches to a tool
  - Handles situations the bridge writer didn't consider
  - Sufficient in many cases (e.g. "`-DMACRO`" for C/C++)

`grep` Bridge

- As an example, we'll write a bridge for a relatively simple tool: `grep`
- We'll use 3 Vesta packages for:
  1. The platform-specific files (the `grep` executable)
  2. The SDL bridge code
  3. An example of how to use the bridge

Getting the Executable

- Most modern operating systems use a *packaging system* to manage installed components
  - RedHat Linux uses the RedHat Package Manager (or RPM)
  - Debian Linux uses a different package manager
- Each installed *OS component package* is made up of some set of files
- *Package files* (`.rpm`/`.deb`) contain the files and all information needed to install a package

Getting the Executable

- To see the files in the `grep` package installed on Linux:
  - RedHat: `rpm -ql grep`
  - Debian: `dpkg -L grep`
- To get the files in the `grep` package into Vesta, we use the `pkg2vesta.pl` script
  - See: `/vesta/vestasys.org/vesta/extras/pkg2vesta`

Running `pkg2vesta.pl`

```
pkg2vesta.pl  --from-installed \
  --package-root /vesta/example.com \
  grep
```

- Creates the correct directory, package, branch
- Checks out the branch
- Fills the working copy with the files from the installed package plus SDL files and information about what was done

- If you have a package file (.rpm/.deb), don't use `--from-installed`

What `pkg2vesta.pl` Made

- `root`
  - Partial filesystem with all files from this package
- `root.ves`
  - Returns the filesystem
- `build.ves`
  - Returns the OS component ready for use
- `README`
  - What was imported, command-line options

If you Don't Have a `.rpm`/`.deb`

- You may not have a piece of software packaged for your OS:
  - It's being locally developed
  - It's only provided as source code for compilation
  - It was provided from a vendor in another form
- If you only have binaries, consider imitating the structure `pkg2vesta.pl` creates
- If you have source, consider compiling on demand under Vesta

Simple Bridge

```
{
  // Search for pattern in file
  grep(pattern: text, file: text): text
  {
    // Add the root for the tool and an empty working directory
    . += [ root = [.WD=[]] + ./build_root(<"grep">) ];

    // Build a command line
    cmd = <"grep", pattern>;

    // Run the tool
    r = _run_tool(./target_platform, cmd,
                  // Pass file as standard input
                  file,
                  // Capture standard output as a value
                  "value");

    return (if r == ERR || r/signal != 0 then ERR
            else r/stdout);
  };

  // The bridge model returns this binding.
  return [ grep = [ grep ] ];
}
```

Simple Bridge Details

```
grep(pattern: text, file: text): text
```

- Defines a function named “`grep`”
- First argument “`pattern`” will be the pattern to search for
- Second argument “`file`” will be the text to search
- The function result will be the output of grep: the lines in “`file`” containing “`pattern`”
- Both arguments and the result are type `text`
- Like all SDL functions, this has a final implicit argument named “`.`”

Simple Bridge Details

```
. += [ root = [.WD=[]] + ./build_root(<"grep">) ];
```

- Augments the value of "`.`" with the binding overlay assignment operator (`+=`)
- Replaces "`./root`" with a new binding made by combining two bindings with the overlay operator (`+`)

`[.WD=[]]`

- An empty binding (i.e. directory) named "`.WD`"
- This is the default working directory when running a tool.

Simple Bridge Details

`./build_root(<"grep">)`

- Calls the function "`./build_root`" passing a list with a single element: the text string `"grep"`
- `./build_root` is a convention used by build environments to make it easier to construct a root filesystem out of several OS component packages
- We just want the "`grep`" component we imported with `pkg2vesta.pl`, so that's all we ask for

Simple Bridge Details

```
cmd = <"grep", pattern>;
```

- Create a two element list holding:
  - The text string `"grep"`
  - The value of the “`pattern`” argument
- Store it in a variable named “`cmd`”
- This will be the command line we execute as a tool

Simple Bridge Details

```
r = _run_tool(./target_platform, cmd, file, "value");
```

- This is where we actually run the tool
- The first parameter to `_run_tool` is the system type to run the tool on. We pass `./target_platform`.
- The second argument is the command line from our variable `cmd`
- The third argument is the standard input stream from the argument `file`
- The fourth argument is what to do with the standard output. We ask for it to be captured as a value.

Simple Bridge Details

- How is the filesystem passed?
  - In `./root`
  - Like other functions, `_run_tool` takes "`.`" as a final parameter, automatically from the calling context
  - We don't explicitly pass the filesystem, but `_run_tool` gets the value of "`.`" implicitly, including the `./root` we set earlier

Simple Bridge Details

- How are the environment variables passed?
  - In `./envVars`
  - Just like the filesystem, environment variables are passed through "`.`"
  - We didn't set any here, but there might be some passed in as part of "`.`" from the caller of our `grep` function

Simple Bridge Details

```
return (if r == ERR || r/signal != 0 then ERR
  else r/stdout);
```

- After `_run_tool` finishes, we want to return the standard output of the tool
- First we check for a couple possible error cases indicating that the tool failed and return ERR if it did
- If all seems well, we return “`r/stdout`”

Simple Bridge Details

```
return [ grep = [ grep ] ];
```

- The result of the bridge model is a binding meant to be made part of the "`.`" used by client models
- The binding contains the name "`grep`" with a binding value
- The `grep` sub-binding contains our `grep` function with its own name
  - Remember "`[x]`" is equivalent to "`[x=x]`"
- So users will get our function with `./grep/grep`

Simple Bridge Usage Example

```
files
  // Sample text file to grep
  sample;
{
  // Find any lines containing the letter "a" in
  // sample.  Put the result in a file named
  // "sample.out"
  return [
    sample.out = ./grep/grep("a", sample)
  ];
}
```

Putting The Pieces Together

- We now have several different pieces:
  - A package containing the `grep` binary we imported with `pkg2vesta.pl`
  - A package containing our bridge `build.ves`
  - A package containing our example usage `build.ves`
- To put them together, we need a platform-specific top-level model: `linux_i386.main.ves`

linux_i386.main.ves

```
import
  self = build.ves;
from /vesta/vestasys.org/platforms/linux/redhat/i386 import
  std_env/9;
from /vesta/example.com/platforms/linux/redhat/i386/components import
  grep/"2.4.2-5"/1; // Our grep binary package
from /vesta/example.com/bridge_intro import
  grep_bridge/1; // Our grep bridge
{
  // Build the basic environment.
  . = std_env()/env_build([]);

  // Add the grep OS component package
  . ++= [ components = grep() ];

  // Add the grep bridge
  . ++= grep_bridge();

  return self();
}
```

Top-level Model Details

```
import
   self = build.ves;
```

- The top-level model is in the same package as our example `build.ves` which calls `./grep/grep`
- This imports the example `build.ves`, putting it in a variable named "`self`"
- We'll call it once we've set up everything we need for the example to work

Top-level Model Details

```
from /vesta/vestasys.org/platforms/linux/redhat/i386 import
  std_env/9;
```

- This gets the basic build environment for i386 Linux
  - It's based on RedHat 7.1, essentially a "lowest common denominator" environment
- It imports it into a variable named `std_env`
  - When an import doesn't contain "`=`", the variable name is the first path component
- We'll use this for some basic things (`./build_root` among others) and augment it

Top-level Model Details

```
from /vesta/example.com/platforms/linux/redhat/i386/components import
  grep/"2.4.2-5"/1; // Our grep binary package
```

- This gets the binary package we created with `pkg2vesta.pl`
- It imports into a variable named "`grep`"
- We need to quote the path component with the grep version number, because it contains "`-`"
  - Any path components containing characters other than letters, numbers, "`.`" and "_" must be quoted
  - Also, any path components matching reserved words must be quoted

Top-level Model Details

```
from /vesta/example.com/bridge_intro import
  grep_bridge/1; // Our grep bridge
```

- This gets the build.ves for our grep bridge
- It imports it into a variable named "`grep_bridge`"

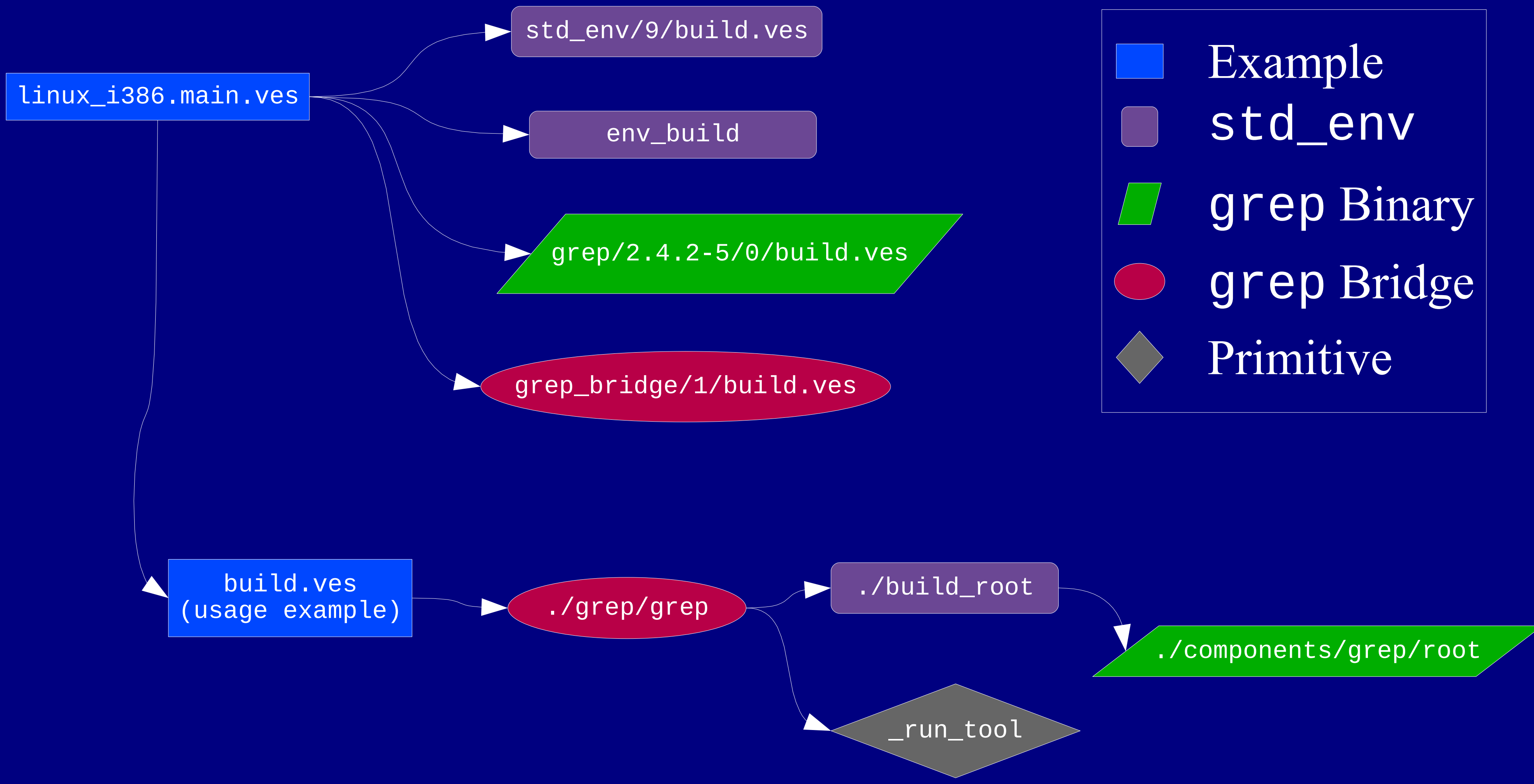
```
. = std_env()/env_build([]);
```

- This creates the basic build environment
  - Calls the `std_env` model
  - Looks up the name `env_build` in its result and calls it as a function
  - Puts the result in "`.`"

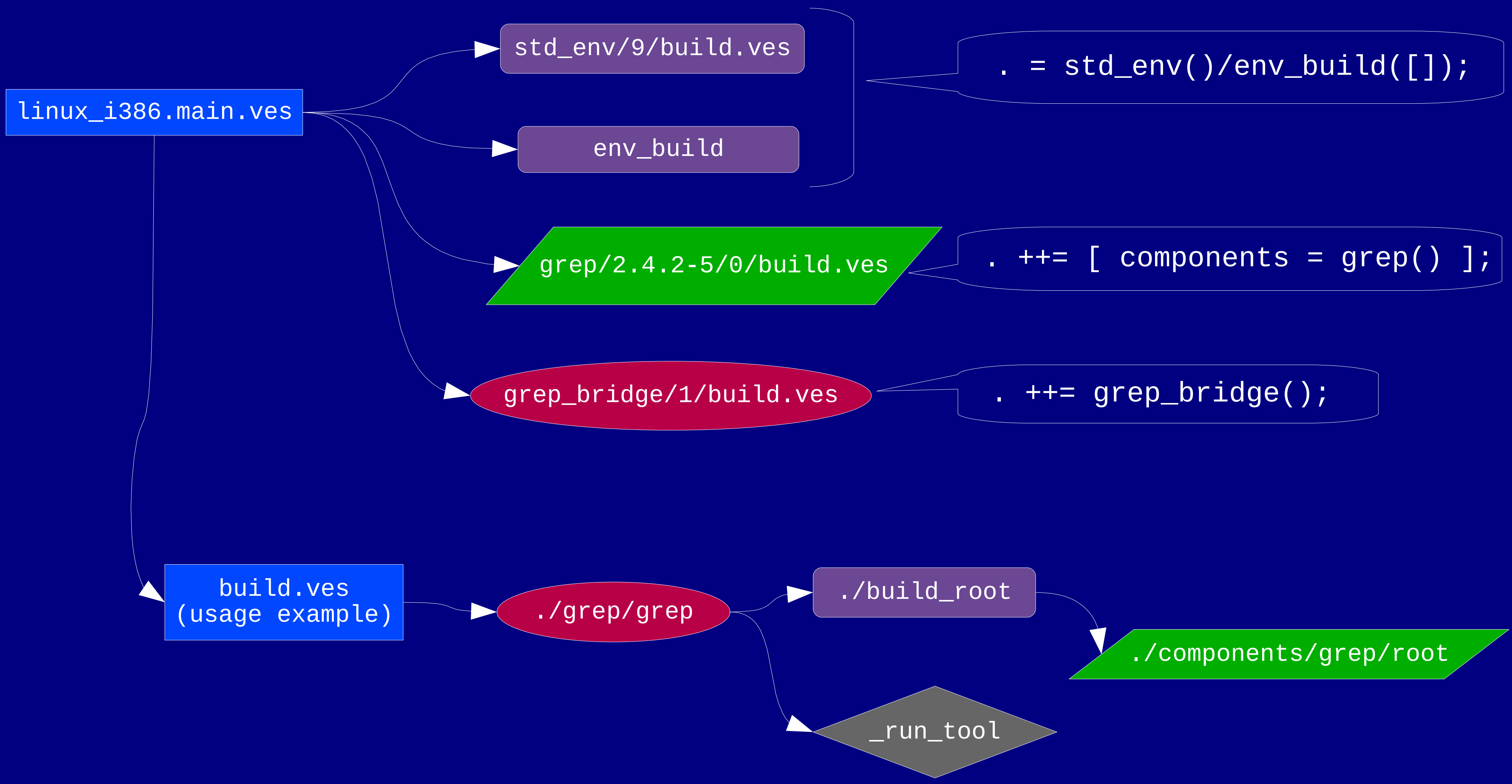
Top-level Model Details

- `. ++= [ components = grep() ];`
  - This adds our grep binary to the set of OS component packages stored in `./components`
  - After this, `./build_root` will be able to build a filesystem including the grep OS component
- `. ++= grep_bridge();`
  - This adds our grep bridge to “`.`”
- `return self();`
  - Now that everything is set, call our example

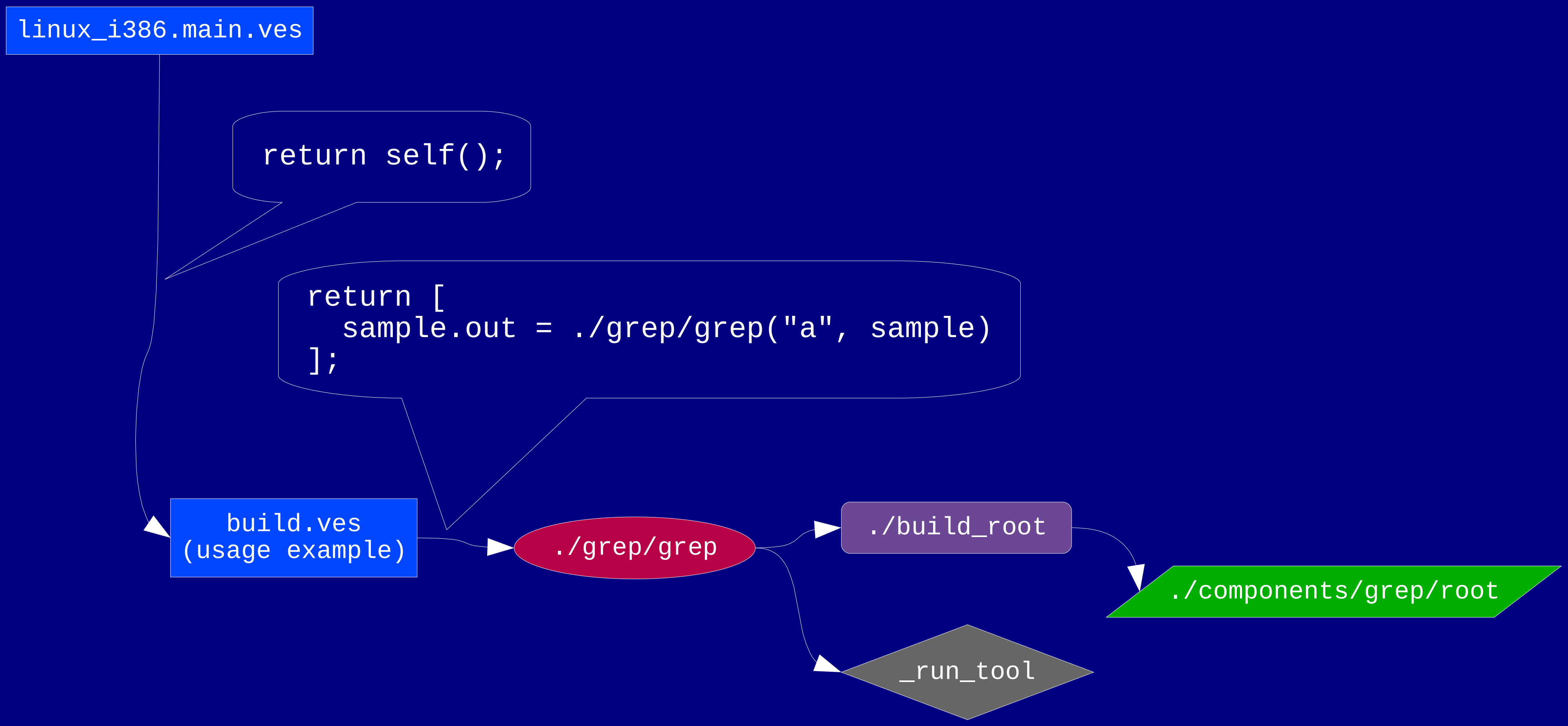
Call Graph of Example



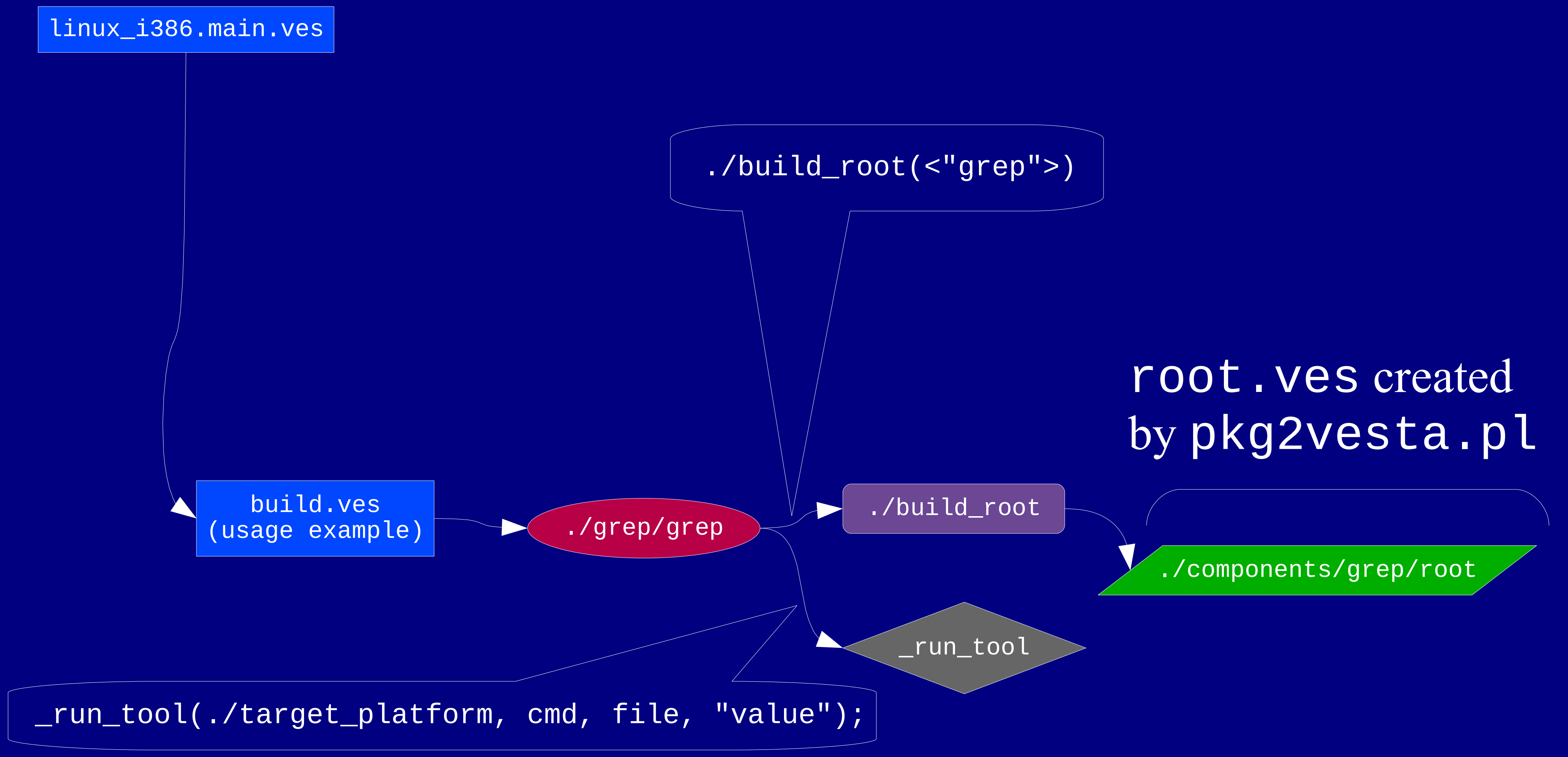
Call Graph of Example



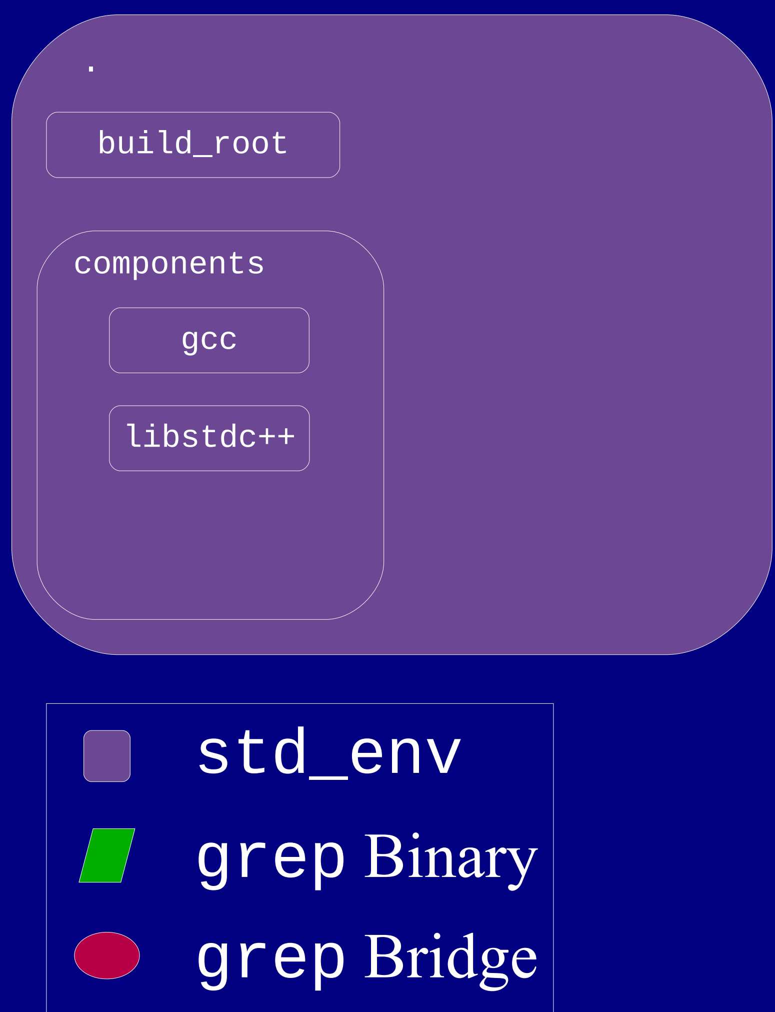
Call Graph of Example



Call Graph of Example



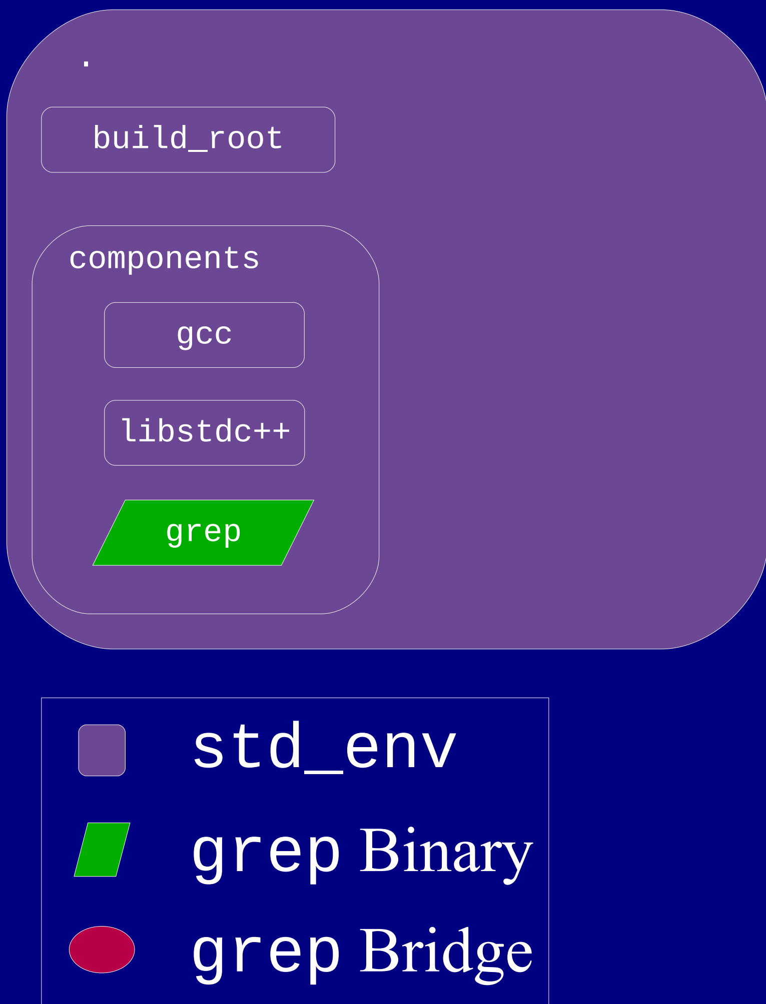
Construction of Dot (.)



1. Basic . comes from `std_env`

```
. = std_env()/env_build([]);
```

Construction of Dot (.)



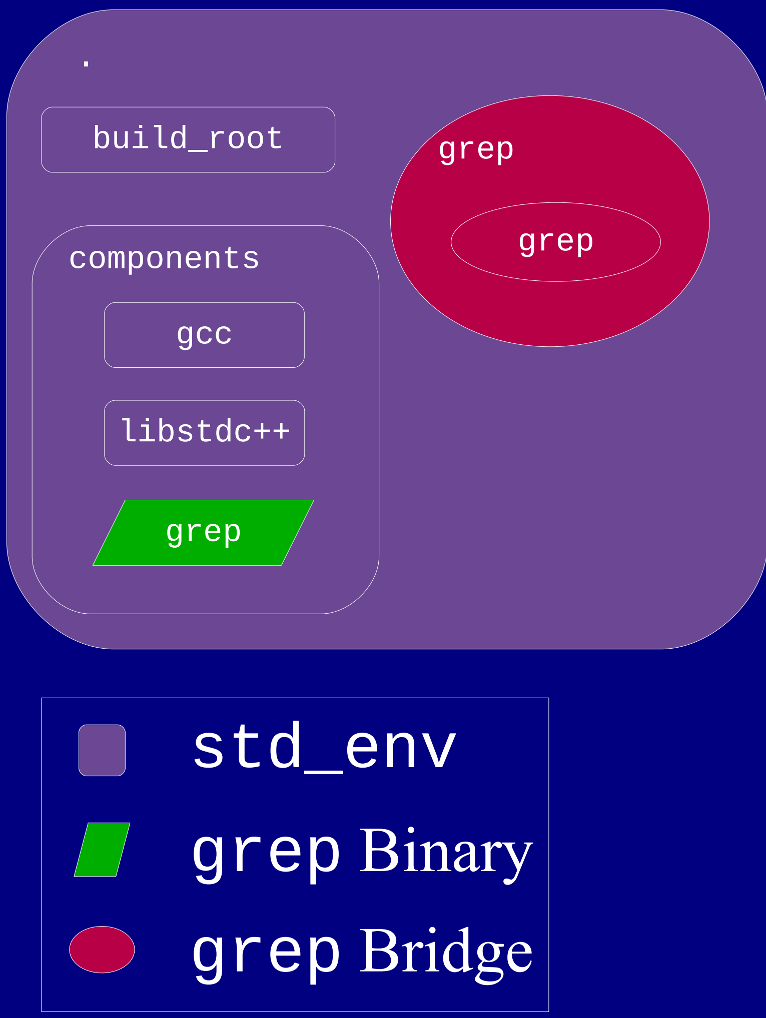
1. Basic . comes from `std_env`

```
. = std_env()/env_build([]);
```

2. We add our `grep` OS component

```
. ++= [ components = grep() ];
```

Construction of Dot (.)



1. Basic . comes from `std_env`

   ```
   . = std_env()/env_build([]);
   ```

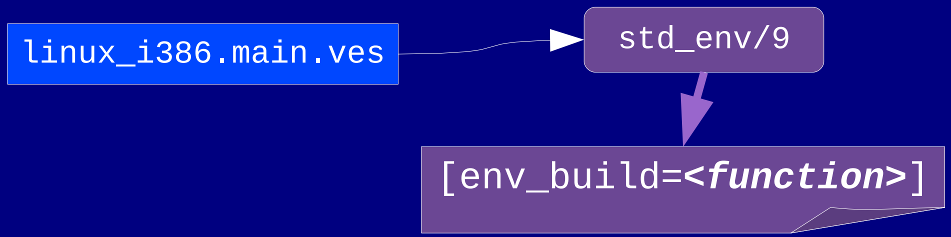
2. We add our `grep` OS component

   ```
   . ++= [ components = grep() ];
   ```

3. We add our `grep` bridge

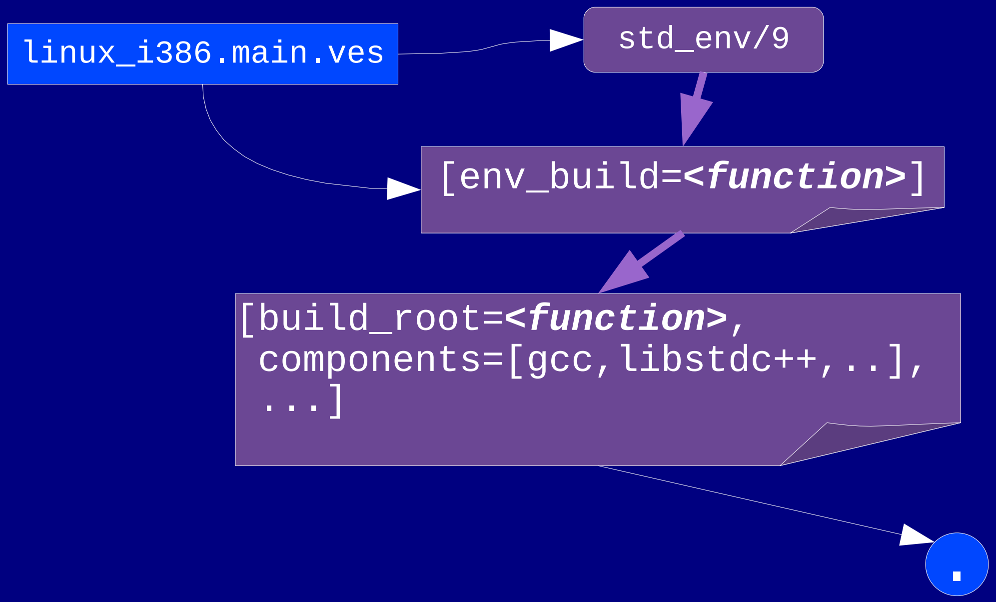
   ```
   . ++= grep_bridge();
   ```

Data Flow in `linux_i386.main.ves`



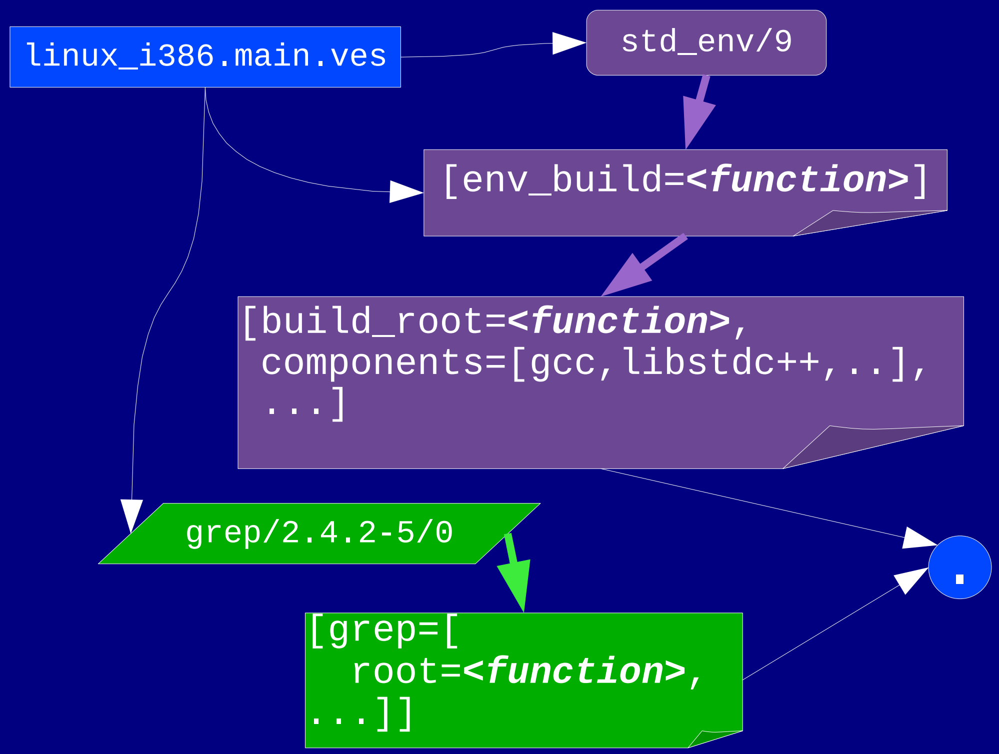
1. `std_env` returns `env_build`

Data Flow in `linux_i386.main.ves`



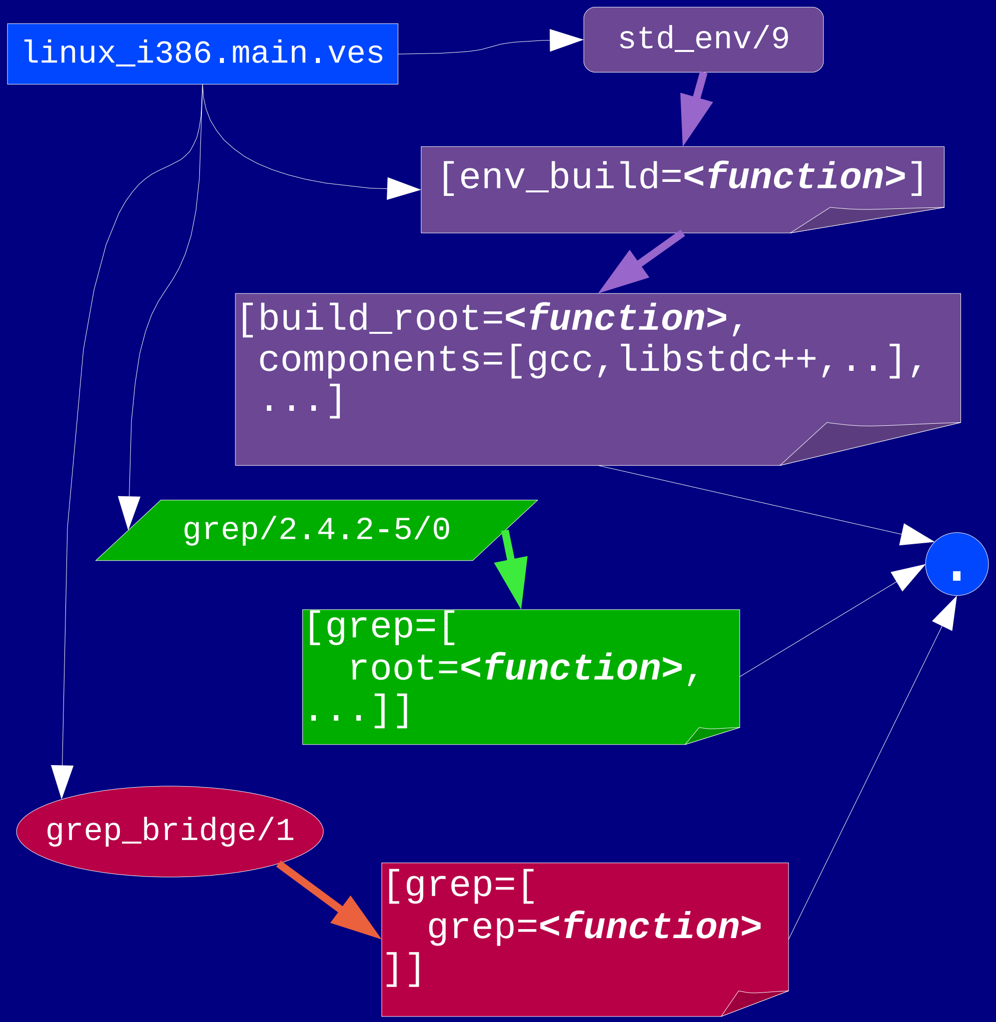
1. `std_env` returns `env_build`
2. `env_build` returns initial dot

Data Flow in `linux_i386.main.ves`



1. `std_env` returns `env_build`
2. `env_build` returns initial dot
3. `grep` OS component model returns OS component (added to `./components`)

Data Flow in `linux_i386.main.ves`



1. `std_env` returns `env_build`
2. `env_build` returns initial dot
3. `grep` OS component model returns OS component (added to `./components`)
4. `grep` bridge returns bridge binding containing bridge function (added to dot)

Evaluating The Example

- When we try to evaluate our example, something seems to be wrong:

```
% vmake
Advancing to /vesta/example.com/bridge_intro/grep_example/checkout/1/1
Vesta evaluator, version release/12.pre13/5

0/hostname: grep a
0/Error: invoking _run_tool:   /usr/sbin/tool_launcher: Execve failure, No such
   file or directory (errno = 2)
  Possible cause: perhaps tool pathname is invalid or file system is
   incomplete?

One error was reported.
Vesta evaluation failed.
```

- Now we'll need to investigate
  - This is often part of writing a new bridge

Investigating The Problem

- We'll start by adding -fsdeps to the vmake command line:

```
% vmake -fsdeps
[...]
0/hostname: grep a
FS dependency: !/./root/.WD/grep
FS dependency: N/./root/bin/grep
FS dependency: !/./root/lib
FS dependency: !/./root/usr
0/Error: invoking _run_tool: [...]
```

- This tells us that the tool is looking for some paths which don't exist:
  - `/lib`
  - `/usr`

Investigating The Problem

- Why dont't `/lib` and `/usr` exist when the tool is running?
  - We specified its complete filesystem in `./root` before calling `_run_tool`
  - We only asked `./build_root` for the `grep` OS component
  - Perhaps the `grep` OS component with imported with `pkg2vesta.pl` doesn't have these directories?

Investigating The Problem

- Let's see what we imported:

```
% ls -lR /vesta/example.com/platforms/linux/redhat/i386/components/grep/2.4.2-5/1/root
/vesta/example.com/platforms/linux/redhat/i386/components/grep/2.4.2-5/1/root:
total 1
dr-xr-xr-x  1 ken root 512 May 27 14:43 bin

/vesta/example.com/platforms/linux/redhat/i386/components/grep/2.4.2-5/1/root/bin:
total 156
-r-xr-xr-x  1 ken root 49244 May 27 14:43 egrep
-r-xr-xr-x  1 ken root 49244 May 27 14:43 fgrep
-r-xr-xr-x  1 ken root 49244 May 27 14:43 grep
```

- Sure enough, no `/lib` or `/usr`

Investigating The Problem

- The `/lib` and `/usr` directories are probably not enough by themselves
  - The tool was probably looking for something inside one of those directories
  - Unfortunately, we don't know what
  - We could add empty `/usr` and `/lib` directories and run with `-fdeps` again to get more information
- Since it's looking for `/lib`, it's a good bet that it's a missing run-time library

Investigating The Problem

- Let's see what shared libraries our imported `grep` needs:

```
% cd /vesta/example.com/platforms/linux/redhat/i386/components/grep/2.4.2-5/1/root
% ldd bin/grep
        libc.so.6 => /lib/libc.so.6 (0x40025000)
        /lib/ld-linux.so.2 => /lib/ld-linux.so.2 (0x40000000)
```

- `grep` must be looking for the C run-time library (`libc.so`)
  - Most programs need this to run
  - We need to ask `./build_root` to include this for us when we call it

Fixing The Problem

- The name of the component with `libc.so` is "`glibc`"
  - This name is specific to the OS packaging system's naming convention, and may be different for other platforms
- To fix the problem, we'll change this:
  - `./build_root(<"grep">)`
- To this:
  - `./build_root(<"grep", "glibc">)`

Switches

- Suppose the caller wants to pass additional command-line flags to grep
  - `-v` to invert the match
  - `-i` for case-insensitive
  - `-n` to show line numbers
- Let's add code to allow users to add command-line switches to our grep invocation

Switches

- Define a place for users to supply switches as part of the bridge result:

```
// Optional command-line switches
switches = [];

// The bridge model returns this binding.
return [ grep = [ grep, switches ] ];
```

- This is similar to other standard bridges
- Users will add switches like:

```
. ++= [ grep/switches/invert = "-v" ];
```

Switches

- Inside the grep function, we'll incorporate the switches into the command line:

```
// Build a command line
cmd = (<"grep"> +
    ./generic/binding_values(./grep/switches) +
    <pattern>);
```

- This uses a function from:

`/vesta/vestasys.org/bridges/generics`

Usage Example with Switches

- Let's use a switch in `build.ves`:

```
files
  // Sample text file to grep
  sample;
{
  // Ignore case when using grep
  . ++= [ grep/switches/nocase = "-i" ];

  // Find any lines containing the letter "a" or "A"
  // in sample.  Put the result in a file named
  // "sample.out"
  return [
    sample.out = ./grep/grep("a", sample)
  ];
}
```

Switches vs. Abstract Options

- We could instead create boolean options for these different grep capabilities:

```
. ++= [ grep/options/nocase = TRUE ];
. ++= [ grep/options/invert = TRUE ];
```

- We'd translate these *abstract options* into *concrete switches* in the bridge code
- This would be a good idea for complex options or options which use different command-line switches on different platforms

Multiple Files

- What if we have multiple input files?
  - The user could call `./grep/grep` multiple times
  - The bridge could support multiple files
- Let's add support for multiple input files
  - The input will be a binding rather than a single text value
  - We'll use the `_par_map` primitive function to process the inputs

Handling Multiple Files

```
grep(pattern: text, /**pk**/inputs: NamedFiles): text
{
  // Add the root for the tool and an empty working directory
  . += [ root = [.WD=[]] + ./build_root(<"grep", "glibc">) ];

  // Build a command line
  cmd = (<"grep"> +
         ./generic/binding_values(./grep/switches) +
         <pattern>);

  /**nocache**/
  grep_one(name, file)
  // Inner function that runs the tool for a single input file.
  {
    // Run the tool
    r = _run_tool(./target_platform, cmd,
                  // Pass file as standard input
                  file,
                  // Capture standard output as a value
                  "value");

    return (if r == ERR || r/signal != 0 then ERR
            else [$name = r/stdout]);
  };

  return _par_map(grep_one, inputs);
};
```

Details of Handling Multiple Files

```
grep(pattern: text, /**pk**/inputs: NamedFiles): text
```

- The second argument is marked with "`/**pk**/`" to tell the evaluator that the function's result will always depend on the complete value of this argument
  - This helps make caching more efficient
- The type "`NamedFiles`" means a binding whose values are all of type text
  - In other words, a directory that contains files but no subdirectories
  - See the vtypes(5) man page

Details of Handling Multiple Files

```
// Add the root for the tool and an empty working directory
. += [ root = [.WD=[]] + ./build_root(<"grep", "glibc">) ];

// Build a command line
cmd = (<"grep"> +
       ./generic/binding_values(./grep/switches) +
       <pattern>);
```

- We set up the filesystem and command line once, sharing it across all the individual grep runs
- Note that “`cmd`” gets captured from the definition context of the inner function, but the new value of “.” gets passed as a parameter (through `_par_map`)

Details of Handling Multiple Files

```
/**nocache**/
grep_one(name, file)
```

- We define an inner function which will run grep once for each input file
- It must take two arguments (a name and a value) since we're going to use it with `_par_map` over a binding
- We mark this function with "`/**nocache**/`" to suppress caching it
  - `_run_tool` is always cached, and this function doesn't do much besides call `_run_tool`, so there's no point in caching it

Usage Example with Multiple Files

- We changed the parameters to our function, so we need to update our `build.ves`:

```
files
  // Sample text files to grep
  inputs = [ sample1, sample2 ];
{
  // Find any lines containing the letter "a" in
  // our input files.  (The bridge puts the results
  // in files with the same names as the inputs.)
  return ./grep/grep("a", inputs);
}
```

Finishing Touches: Generalization

- There are several things hard-coded in our bridge:
  - The command name ("`grep`")
  - The method for getting the root filesystem
  - The bridge name in the result ("`grep`")
- What if we wanted separate bridges for `fgrep` and `egrep`?
- Let's add *bridge specialization parameters* to remove these hard-coded parts

Bridge Parameters

- At the beginning of the bridge model, we'll add code which saves parameters from the value of ". " when the bridge model is called

```
// The command to invoke.  (Optional parameter; defaults to "grep".)
command = if .!command then ./command else "grep";

// The root filesystem to use for this platform (which must include
// the executable named by "command").
root = ./root;

// The name of this bridge.  (Optional parameter; defaults to
// "grep".)
bridge_name = if .!bridge_name then ./bridge_name else "grep";
```

Bridge Parameters

- The value of "`.`" must be a binding containing the named parameters
- We have default values for `command` and `bridge_name`, using them if the caller didn't supply them
- The variables created here will be used below
  - Note that the definition of our function will capture these variables so they can be used when it is called

Bridge Parameters

- Inside our grep function, we'll use the `command` and `root` variables:

```
// Add the root for the tool and an empty working directory
. += [ root = [.WD=[]] + root() ];

// Build a command line
cmd = <command, pattern>;
```

- This assumes that:
  - `root` is a function which will return the root filesystem
  - `command` is a text value

Bridge Parameters

- At the end of the bridge model, we'll use `bridge_name` to change the name used in the binding returned:

```
// The bridge model returns this binding.
return [ $bridge_name = [ grep, switches ] ];
```

- This assumes that `bridge_name` is a text value

New linux_i386.main.ves

```
import
  self = build.ves;
from /vesta/vestasys.org/platforms/linux/redhat/i386 import
  std_env/9;
from /vesta/example.com/platforms/linux/redhat/i386/components import
  grep/"2.4.2-5"/1; // Our grep binary package
from /vesta/example.com/bridge_intro import
  grep_bridge/1; // Our grep bridge
{
  // Build the basic environment.
  . = std_env()/env_build([]);

  // Add the grep OS component package
  . ++= [ components = grep() ];

  // Add the grep bridge
  bridge_args = [ command = "grep", bridge_name = "grep",
                  root = ./build_root_delayed(<"grep", "glibc">) ];
  . ++= grep_bridge(bridge_args);

  return self();
}
```

Top-level Model Changes

```
bridge_args = [ command = "grep", bridge_name = "grep",
                root = ./build_root_delayed(<"grep", "glibc">) ];
```

- This sets up the bridge specialization arguments
- `./build_root_delayed` is like `./build_root`, but it returns a function which will build the root filesystem later

```
. ++= grep_bridge(bridge_args)
```

- This passes the arguments to the bridge model as "."
  - Remember: imported models have one implicit argument which is "."

Learning More

- Examples from this presentation can be found in:
  - `/vesta/vestasys.org/examples/bridge_intro`
  - See the `README` file for some suggested exercises
- The `lex` bridge dissection in the SDL reference is another document which can help you learn about bridge writing:

  `http://www.vestasys.org/doc/sdl-ref/bridge-dissection.html`

Learning More

- The full documentation of the `_run_tool` primitive function describes capabilities not covered here:

  http://www.vestasys.org/doc/sdl-ref/primitive-functions/_run_tool.html

- Read the code of `std_env` and other bridges
  - There's no special magic: it's all just a library of SDL code for calling `_run_tool`, and now you've seen how it works