

GAVO DaCHS: DirectGrammars and Boosters

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The import architecture of DaCHS with grammars and rowmakers producing material suitable for SQL INSERT statements is designed to be flexible and as declarative as possible. Its one big drawback is that once you have to ingest more than a couple of million rows (or less rows with hundreds of columns) it tends to become slow, leading to ingestion times in excess of hours or even days.

To remedy this, DaCHS supports "boosters", programs that bypass both DaCHS' intestines and SQL INSERT statements, both of which are responsible for quite some overhead. Boosters, in contrast, use C code to fetch data and output binary COPY material to be dumped into the table. The net result are very significant speedups; a factor of 100 is easily attainable.

Of course, there are several downsides. One is that you have to write (and probably debug) C code, and schema changes will become fairly painful, requiring surgery in the C code (a notable exception are direct grammars reading from FITS binary tables; the latter contain sufficient metadata to allow fully automatic code generation in simple cases). Also, direct grammars can only operate on single tables; data descriptors containing more than one `make` cannot have direct grammars. As direct grammars talk to the database engine fairly directly, the table definition must have `onDisk="true"`.

Rowmakers given in `make` elements sitting behind direct grammars are ignored; any manipulations to the data coming in must be made within the C code. It is not an error for rowmakers to be present, though. This lets you test and debug with normal DaCHS grammars and then use a booster for the whole (potentially big) dataset by just commenting out the conventional grammar and commenting in the direct grammar. This is especially useful for table compares (e.g., using `gavo info`) to verify that the booster does the same thing as the conventional grammar/rowmaker combo.

A quick start on using boosters:

- 1) Replace your data element's grammar with the direct grammar spec, which would look somewhat like this:

```
<directGrammar id="fits" type="fits" cBooster="res/boosterfunc.c"/>
```

- 2) Generate the booster:

```
gavo mkboost your/rd#fits > res/boosterfunc.c
```

- 3) Edit res/boosterfunc.c (may be optional for fits boosters)

- 4) Import your data:

```
gavo imp your/rd
```

In the `directGrammar` element, the path in the `cBooster` attribute is interpreted relative to the RD's `resdir`. The `type` argument says roughly what kind of source you're parsing from. Values allowed here include:

- `col` (the default) – parse from stuff conventionally handled by a `columnGrammar`
- `bin` – parse from data that has fixed-length binary records (this is stuff that a `binaryGrammar` would grok)
- `split` – parse from files that have fields separated by some constant sequence of character (conventionally, these can be parsed by a `reGrammar`)
- `fits` – parse from FITS binary tables (that's what a `fitsTableGrammar` can read).

The `mkboost` subcommand receives a reference of to the `directGrammar` element – that is, the RD id, a hash, and the XML id of the grammar – as an argument.

Booster source code

Once you've generated the booster source, you're free to change it in whatever way you fancy. On schema updates, unfortunately, you'll have to merge in changes manually, as we've not found a sensible and general way to preserve arbitrary source changes when (re-)generating a booster. If you have a creative idea how better to separate generated and hand-made code, we're certainly interested. The way things are now, if you change the schema, you can re-run `gavo mkboost` but have to merge any changes manually.

The code generated starts somewhat like this:

```

#include <math.h>
#include <string.h>
#include "boosterskel.h"

#define QUERY_N_PARS 33

enum outputFields {
    fi_localid,          /* Identifier, text */
    fi_pmra,             /* PM (alpha), real */
    fi_pmde,             /* PM (delta), real */

```

The definition of `QUERY_N_PARS` (which is the number of columns in the table) is essential and must remain in this form, as the function building the booster greps it out of the source code to communicate this value to the booster boilerplate; this, however, means that you're free to change the concrete number if the number of table columns changes in the source file (you'd have to adjust the `outputFields` as well; this is typically going to be a cut-and-paste job from a repeated run of `gavo mkboost`). Again, `QUERY_N_PARS` must always be equal to the number of columns in the target table.

The code continues with an enumeration mapping symbolic names to the indices of the corresponding columns in the target table; the names are simple `fi_` and the field destination lowercased. If you only use these names to access fields, cutting and pasting on later schema changes should be fairly painless and safe.

While you shouldn't need to change any of this, you in general have to change the `getTuple` function. What it looks like strongly depends on the sort of booster you're generating for; this includes the prototype.

What's common is that `getTuple` needs to return a `Field` array. All boosters declare the return value like this:

```
static Field vals[QUERY_N_PARS];
```

– it needs to be static as a pointer to it is returned from the function; don't rely on anything in there to be stable across function calls, though, as the serialization to COPY material might mess around in that memory. The name `vals` is expected by, e.g., the `F` macro and must therefore not be changed.

`Field` is defined as follows:

```
typedef struct Field_s {
    valueType type;
    int length; /* ignored for anything but VAL_TEXT */
    union {
        char *c_ptr;

```

```

        double c_double;
        float c_float;
        int32_t c_int32;
        int8_t c_int8;
    } val;
} Field;

```

where `type` is one of:

```

typedef enum valType_e {
    VAL_NULL,
    VAL_BOOL,
    VAL_CHAR,
    VAL_SHORT,
    VAL_INT,
    VAL_BIGINT,
    VAL_FLOAT,
    VAL_DOUBLE,
    VAL_TEXT,
    VAL_JDATE, /* a julian year ("J2000.0"); this is stored as a simple double */
    VAL_DATE, /* date expressed as a time_t */
    VAL_DATETIME, /* date and time expressed as a time_t */
} valType;

```

JDATE is a julian day number to be dumped as a date (rather than a datetime). For other ways to represent dates and datetimes, see below.

You can, and frequently will, fill the stuff by hand. There are, however, a couple of functions that take care of some standard situations:

- `void linearTransform(Field *field, double offset, double factor)` -- changes `field` in place to `offset+factor*oldValue`. Handles NULL correctly, silently does nothing for anything non-numeric
- `void parseFloatWithMagicNULL(char *src, Field *field, int start, int len, char *magicVal)` -- parses a float from `src[start:start+len]` into `field`, writing NULL when `magicVal` is found in the field.
- `void parseDouble(char *src, Field *field, int start, int len)` -- parses a double from `src[start:start+len]` into `field`, writing NULL if it's whitespace only.
- `void parseInt(char *src, Field *field, int start, int len)` -- parses a 32-bit int from `src[start:start+len]` into `field`.
- `void parseShort(char *src, Field *field, int start, int len)` -- parses a 16-bit int from `src[start:start+len]` into `field`.

- `void parseBlankBoolean(char *src, Field *field, int srcInd)` -- parses a boolean such that field becomes true when `src[srcInd]` is nonempty.
- `void parseBigint(char *src, Field *field, int start, int len)` -- parses a 64-bit int from `src[start:start+len]` into field.
- `void parseString(char *src, Field *field, int start, int len, char *space)` -- copies len bytes starting at start from src into space (you are responsible for allocating that; usually, a static buffer should do, since the postgres input is generated before the next input line is parsed) and stuffs the whole thing into field.
- `void parseChar(char *src, Field *field, int srcInd)` -- guess.
- `MAKE_NULL(fi)` -- makes fi NULL
- `MAKE_DOUBLE(fi, value)` -- make fi a double with value
- `MAKE_BIGINT(fi, value)` -- make fi a double with value
- `MAKE_FLOAT(fi, value)` --
- `MAKE_SHORT(fi, value)` --
- `MAKE_CHAR(fi, value)` --
- `MAKE_JDATE(fi, value)` --
- `MAKE_TEXT(fi, value)` -- note that you must manage the memory of value yourself. In particular, it must not be automatic memory of `getTuple`, since that will not be valid when the tuple actually is built. Most commonly, you'll be using a static buffer here.
- `MAKE_CHAR_NULL(fi, value, nullvalue)` -- makes fi a char with value unless `value==nullvalue`; in that case, fi becomes a NULL
- `double mjdToJYear(mjd)` -- returns a julian year for mjd
- `AS2DEG(field)` -- turns a field value in arcsecs to degrees
- `MAS2DEG(field)` -- turns a field value in milli-arcsecs to degrees

Of course, you can also manually copy or delimit data and use `fieldscanf` as documented in [split boosters](#)

Boosters are linked together with `boosterskel.c` and must include `boosterskel.h`. If you're interested what these things do (or want to fix bugs, or whatever), you can get the files using:

```
gavo admin dumpDF src/boosterskel.c # or .h
```

Line-based boosters

These are boosters that read from a text file, line by line. Currently, the maximum line length is set to 4000 (`INPUT_LINE_MAX` in `boosterskel.c`). It is up to the parsing function to split and digest this text line.

Col boosters

For col boosters, the `getTuple` function looks somewhat like this:

```
Field *getTuple(char *inputLine)
{
    static Field vals[QUERY_N_PARS];

    parseWhatever(inputLine, F(fi_localid), start, len);
    parseFloat(inputLine, F(fi_pmra), start, len);
    parseFloat(inputLine, F(fi_pmde), start, len);
    parseFloat(inputLine, F(fi_raerr), start, len);
}
```

Here, it's your job to fill out `start` and `len` (at least; `start` is zero-based). `gavo mkboost` inserts `parseXXX` function calls according to the table metadata, which should be what you want in general. Add scaling or other processing as required.

Split boosters

When the input data comes as xSV (e.g., values separated by vertical bars, commas, or tabs), give a `splitChar` and set the `type` attribute to `split` in the `directGrammar`.

This then creates a source like:

```
char *curCont = strtok(inputLine, "\t");
fieldscanf(curCont, fi_objid, VAL_INT_64);
curCont = strtok(NULL, "\t");
fieldscanf(curCont, fi_run, VAL_SHORT);
```

etc. Thus, the input line is parsed using `strtok`, and each value is parsed using the `fieldscanf` function. This function takes the string containing the literal in the first argument, the field index in the second, and finally the type specifier. If the data comes in the sequence of the table columns, the generated source *might* just work.

Warning: C's standard `strtok` function merges adjacent separators, i.e., `foo|bar||baz` would just yield three tokens, `foo`, `bar`, and `baz`. With astronomical data, this is typically not what you want. Therefore, the generated booster function will have a line like:

```
#define strtok strtok_u
```

Delete it in case that you need the POSIX `strtok` behaviour. This would in particular apply if you have whitespace separated data with a variable number of blanks (which, however, would suggest that you're really looking at material for a col booster).

Bin boosters

When you get binary data of fixed record length, set the `recordSize` attribute on the `DirectGrammar` element:

```
<directGrammar type="bin" recordSize="300"...
```

Note that a `recordSize` larger than `INPUT_LINE_MAX` will cause a buffer overflow.

You are mainly on your own in terms of segmentation, but for entering values, you can use the `MAKE_*` discussed above.

For these in particular, use the the portable type specifiers for integral types, viz., `int8_t`, `int16_t`, `int32_t`, and `int64_t` and these names with a `u` in front.

In particular with binary boosters, it is essential you always properly cast what you read, e.g.,:

```
MAKE_DOUBLE(fi_dej2000, -90+*(int32_t*)(line+4)/1e6); /* SPD */
```

when a declination is given as mas of south polar distance.

FITS boosters

These read from FITS binary tables and are really a somewhat special beast. To build one of those, DaCHS inspects the first file matched by the parent data's `sources` element (which also means these won't work outside of a `data` element). DaCHS expects each table column to have a match (i.e., after lowercasing the name in the FITS table) in the FITS table. FITS table column without a match in the database table are ignored.

FITS binary tables are organized by columns rather than by rows, bearing witness to their FORTRAN heritage. The way the boosters are currently generated, all these columns are completely read into memory, which means you cannot ingest FITS binary tables that do not fit into your machine's memory. Fixing this would be fairly straightforward (patches are welcome, but we'll also fix this if you ask for it).

FITS boostes can automatically map column names for you. “<mapKeys> raj2000:RA, dej2000:DEC </mapKeys> will map column named RA in your sourcefile to column named raj2000 in your database table and analogously for DEC. If you don't do this, only column names from your DB table will be read and imported.

system-message

WARNING/2 in `booster.rstx`, line 333
[Inline literal start-string without end-string.](#)

If you need to postprocess the items, we recommend you do that again in the `getTuple` function (note how that gets passed the row index) for maintainability, rather than directly after reading the rows.

Attention: The system will not warn you if the type of a column in the table is not compatible with what you have in the database. If it is, the program will probably silently dump garbage into the db, though if you're lucky it'll crash. This is almost on purpose. It will let you do manual type conversions like, for example, making a 64 bit integer from a string as follows:

```
if (nulls[18][rowIndex]) {
    MAKE_NULL(fi_ppmx1);
} else {
    parseBigint(((char**)(data[18]))[rowIndex], F(fi_ppmx1), 0, 19);
}
return vals;
```

(we could admittedly warn you if this kind of thing becomes necessary, and we'll gladly accept patches for that).

Filling in data manually

The `F(index)` macro lets you access the field info directly. So, you could enter a fixed-length piece of memory into `fi_magic` like this:

```
static char bufForMagic[8];

memcpy(bufForMagic, inputLine+20, 8);
F(fi_magic)->type = VAL_TEXT;
F(fi_magic)->val.c_ptr = bufForMagic;
F(fi_magic)->length = 8;
```


Having static buffers in `getTuple` is usually ok since the COPY input is generated before `getTuple` is called again.

It is quite common to have to handle null values. In the example above, this could look like this if a NULL for magic were signified by a F in `inputLine[19]`:

```
static char bufForMagic[8];

if (inputLine[19]=='F') {
    F(fi_magic)->type = VAL_NULL;
} else {
    memcpy(bufForMagic, inputLine+20, 8);
    ...
}
```

Skipping a record

If you need to skip a record, do:

```
longjmp(ignoreRecord)
```

in `getTuple`. That works independently of the booster type.

Dates and times

The boosters treat "normal" dates and datetimes as `struct tm`'s. If you need a larger range, use `VAL_JDATE`, which lets you store julian dates in floats. Julian dates are serialized to dates rather than datetimes.

To parse `VAL_DATE` or `VAL_DATETIME`, you will write something like:

```
fieldscanf(curCont, fi_date, VAL_DATE, "%Y-%m-%d");
```

if parsing from date strings. If your input is something weird, figure out a way to generate a `struct tm` as defined in `time.h`. Then write:

```
struct tm timeParts;
timeParts.tm_sec = 12;
...
timeParts.tm_year = 1920;
F(fi_dt)->val.time = timeParts;
F(fi_dt).type = VAL_DATETIME;
```

(or `VAL_DATE`, as the case may be).

Having said all this, long experience has taught us it's usually best to have dates and such in the database as MJD or julian years. You can format those to ISO strings (or, really, anything else you want) on output by using display hints on `outputField` or even `column` itself.

MJDs are just so much easier to handle within ADQL queries. Support for timestamps, on the other hand, is extremely lousy.

Debugging

The source code generated by `gavo mkboost` typically is really mean. The preference is to make it coredump rather than give fancy errors, under the assumption that error messages from the booster would in general help less than the post-mortem dumps; this of course also means that you should not use direct grammars to parse from potentially malicious sources unless you substantially harden the generated code.

To figure out what's wrong if things go wrong, say:

```
ulimit -c unlimited # bash and friends
gavo imp q
gdb bin/booster core
where # that's for gdb
```

This should give you the line where things failed, and of course the full power of `gdb` to inspect how that happened.

As a short example, consider a `gdb` session where the author forgot to use the `mapKeys` in a FITS `directGrammar` for columns which are filled from the Binary table. This resulted in a segmentation fault, which made `gdb` say:

```
gdb:
Program terminated with signal 11, Segmentation fault.
#0 0x000000000406cde in getTuple (data=0x7fff592a41a0, nulls=0x7fff592a4250, rowIndex=0)
```

To figure out where the program crashed, say:

```
(gdb) where
#0 0x000000000406cde in getTuple (data=0x7fff592a41a0, nulls=0x7fff592a4250,
    rowIndex=0) at func.c:73
#1 0x000000000407784 in createDumpfile (argc=2, argv=0x7fff592a53c8)
    at func.c:296
#2 0x000000000406bdf in main (argc=2, argv=0x7fff592a53c8)
    at boosterskel.c:673
```

In the traceback, you can see the frame you're interested in and go there using up (or down, if you're too far up):

```
(gdb) up
#1 0x0000000000407784 in createDumpfile (argc=2, argv=0x7fff592a53c8)
    at func.c:296
296   in func.c
```

Incidentally, you could instruct gdb to use your boosterfunc.c file as the source file for func.c (that's the temporary name of that file when DaCHS built the binary in a sandbox). But it's probably as straightforward to just check the source code in your editor and figure out what variables you're interested in. In this case, this might be the number of the row where the crash happened (we are in the main row-reading loop of the booster):

```
(gdb) print i
$8 = 0
```

Voila, we crashed on the first row already. Let's go back into getTuple to figure out which column was bad:

```
(gdb) down
#0 0x0000000000406cde in getTuple (data=0x7fff592a41a0, nulls=0x7fff592a4250,
    rowIndex=0) at func.c:73
73   in func.c
```

Looking up line 73, there's (in this example) an access to `nulls[0][rowIndex]`. Could this dereference a null pointer? See for yourself:

```
(gdb) print nulls[0]
$9 = 0x0
```

Right – so that's where the trouble starts (in this case, the underlying reason was a DaCHS bug, as that array should never have been uninitialized).