Gadget3: An Evolution of the Gadget Modelling Framework

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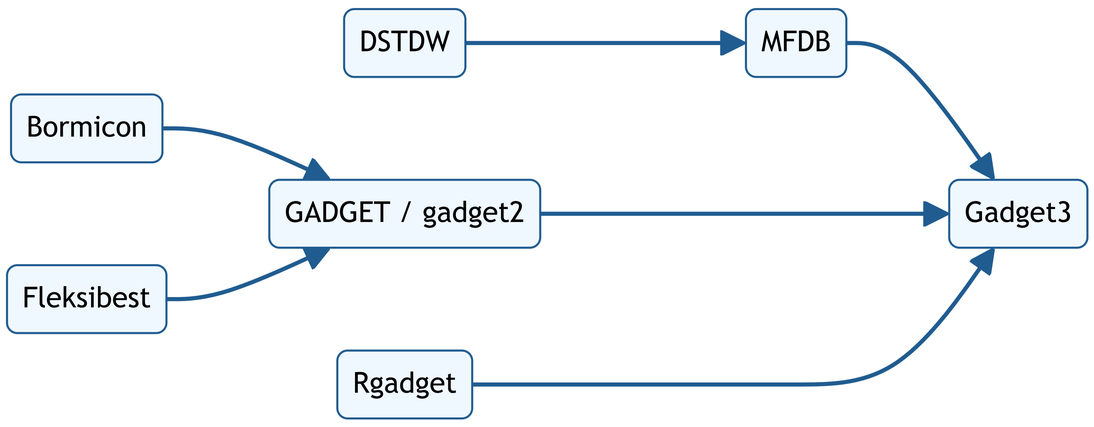
What is gadget3?

- **An R package to build marine ecosystem models**
- **It is not a model** in itself, it's a **toolbox of complimentary parts** to assemble
- **Your model is defined entirely within R**, with no input file formats to generate
- **Batteries included**: Processes for implementing single or multi-species and/or multi-fleet models are available to be plugged into your model as you need them
- **Everything can be customised**, to the point of implementing your own processes from scratch

Gadget family history



The original GADGET (Begley and Howell (2004)), now called gadget2, is a fork of Bormicon combining improvements made in Fleksibest. This was further enhanced by RGadget to programmatically configure and run gadget2 from R.

The DSTDW and MFDB packages are data warehousing tools to assist in aggregating data for incorporation into models, designed to compliment gadget2.

Gadget3 is a reimplementation of gadget2, combining ideas from all previous packages. Whilst a new system, all gadget2 concepts have a 1:1 mapping to gadget3, and should be instantly familiar.

Why did we make gadget3?

Whereas gadget2 implements it's own optimisers, gadget3 uses Template Model Builder (TMB). As well as vastly improving convergence speed, we gain access to other TMB features such as random effects.

gadget3 aims to be a superset of gadget2, and to be "next-gen" (Punt et al. (2020)):

- **Minimal complexity**: There is no minimal set of configuration. Models can start out as single-species, single-fleet and grow as required.
- **Flexible parameterisation**: gadget2's parameterisation was restricted & could not do age-based selectivity, for example. gadget3 can use any simply by using a formula with appropriate terms.
- **Extensibility**: Adding an extra process or variant in gadget2 requires modifications to the C++ code. gadget3 processes can be customised or entirely new processes added with R code, without having to modify the gadget3 package.
- Gadget3 models aren't a black box
  - Model code has minimal dependencies and can be re-run at any point
  - The generated code is designed to be read / vetted if necessary
  - Can be saved and used to prove the model hasn't changed

Actions, stocks & substocks

The heart of a gadget3 model is a list of **actions**. Actions define interactions between **stock** objects, which store the state of actors within the model.

Stocks can represent portions of a fish stock (substocks), or fleets:

```
ling_immature <- g3_stock(c('ling', 'immature'), 30:100) |> g3s_age(0, 5)
ling_mature <- g3_stock(c('ling', 'mature'), 30:100) |> g3s_age(3, 15)
stock_fleet_surv <- g3_fleet("surv")
```

We then build a list of actions that should happen in our model:

```
actions <- list(
    g3a_time(1990, 1994),
    g3a_initialconditions_normalcv(ling_immature),
    g3a_initialconditions_normalcv(ling_mature),
    g3a_renewal_normalparam(ling_immature),
    g3a_age(ling_immature, output_stocks = list(ling_mature)),
    g3a_age(ling_mature),
    g3a_predate(stock_fleet_surv, list(ling_immature, ling_mature),
        suitabilities = g3_suitability_exponentiall50(),
        catchability_f = g3a_predate_catchability_totalfleet(1e6) ))
```

And convert to an R function, or a TMB objective function ready to be optimised:

```
model_fn <- g3_to_r(actions)
obj.fn <- g3_tmb_adfun(g3_to_tmb(actions))
```

Customisation & novel processes

gadget3 actions are **composable**, the mechanics of each action is defined by providing R formulas, which themselves can accept formulas. Instead of providing a constant catch rate above we could provide landings data with:

```
g3a_predate_catchability_totalfleet(g3_timeareadata('landings', landings_df))
```

We are not limited to supplied formulas. The variant of Beverton-Holt from SS3 (Methot and Wetzel (2013)) has recently been added into gadget3. But we could have done this before by supplying our own formula:

```
spawn_action <- g3a_spawn(ling_mature, output_stocks = list( ling_immature ), list(
    s = g3_formula( sum(stock_ss(stock__wgt) * stock_ss(stock__spawningnum)) ),
    r = g3_formula(
        4 * h * s * R / (B0 * (1 - h) + s * (5 * h - 1)),
        h = g3_parameterized('srr.h'),
        R = g3_parameterized('srr.R', by_year = TRUE,
            exponentiate = TRUE, scale = "srr.R0"),
        B0 = g3_parameterized('srr.B0') )))
```

Where do I get it?

Stable releases on CRAN: `install.packages("gadget3")`

Development on GitHub: https://github.com/gadget-framework/gadget3

Where do I learn more?

Documentation site, and the getting started vignette:

https://gadget-framework.github.io/gadget3/

Acknowledgements

Gadget3 has received funding from:

- Innviðasjóður Icelandic infrastructure grant #191774-0031
- Under One Cod #206740-051
- NORSUSTAIN project funded by the joint Danish, Greenlandic, and Faroese Presidency of the Nordic Council of Ministers
- Formas Swedish Research Council for Sustainable Development #2021-00826

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Keywords: stock assessment, gadget, population model, statistical model, integrated analysis