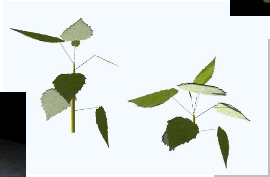
FSPM-P: A general FSPM prototype model

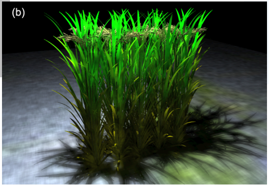
A first step towards a generic FSPM

Michael Henke, Gerhard Buck-Sorlin

2010-09-29

International Summer School
"Modelling and Simulation with GroIMP"
Göttingen





Initial situation

- Developer with:
  - No or little programming experience $\rightarrow$ challenge of programming
  - Little knowledge of biological systems $\rightarrow$ challenge of modelling
- Common way of modelling:
  - Ad hoc
    - Usually starting "from scratch"
    - (initially) no (clear) concept/design
    - Unsystematic
  - Extend/change existing models
    - Getting overview of code more difficult
- $\Longrightarrow$ "Reinventing the wheel"

But...

- Same components and recurring parts
- Subsystems can be re-used
- Benefit from former models

$\Longrightarrow$ Prototype

Advantages of a general FSPM-Prototype

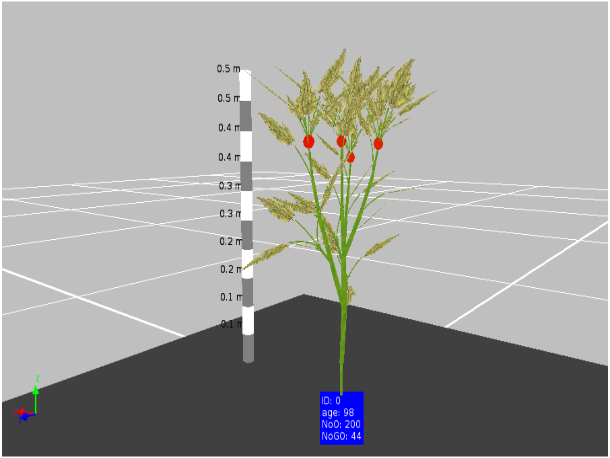
- Includes the (meta)knowledge of several models
- Predefined:
  - (Clear) proved design (software-technical)
  - Model concept: (init $\rightarrow$ control flow $\rightarrow$ output $\ldots$)
- Easy to parameterize, extend and use
- Rationalizes the development process and use of FSPMs
- Makes models comparable and combinable
- Facilitates communication between modeller, experimentator and programmers $\rightarrow$ can help make it a more accessible tool

FSPM-Prototype

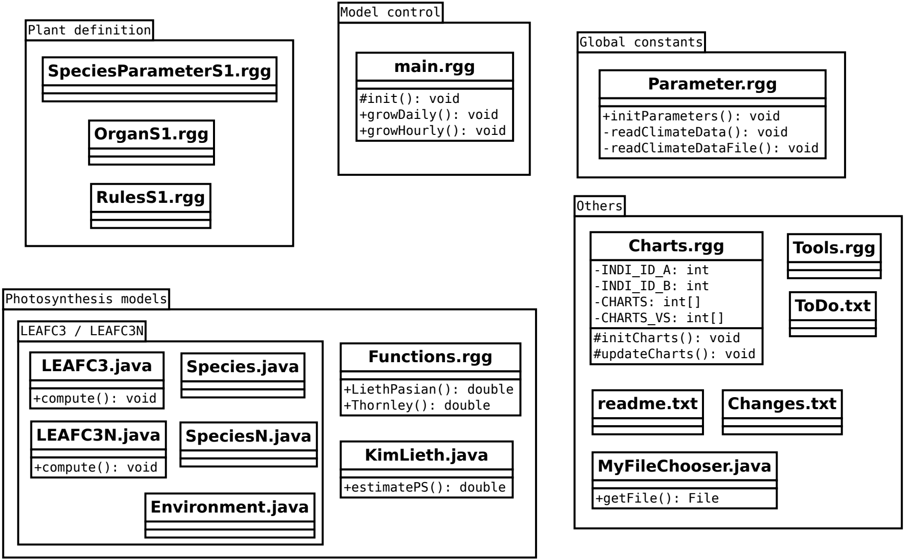
Since Nov. 2009:

- Base model: rapeseed model by C. Groer
- Reworking the concept and the design
  - Strictly object-oriented
  - Modular design
- Extending by several parts
  - Model control
  - Photosynthesis rate models (differing in complexity from simple light-response curves to biochemical Farquhar-type models)
  - Source-Sink Ratio for model regulation
- June 2010: FSPM-P V0.02

FSPM-P Structure



FSPM-P Design



Organ definitions

- Same organ interface for all organs
- Different hierarchical scales within the plant:
  - Organs: seed, root, bud, leaf, internode, flower, fruit, ect.
    - organ with predefined state variables and methods representing internal processes: photosynthesis, growth, maintenance and growth respiration
  - Organs aggregations: individual, shoot
    - containing summary functions based on XL-queries (e.g. for whole-plant photosynthesis)

Model work flow

- Initialisation
- Growth step (daily / hourly)
  1. Update sky and sun
  2. Run the light model
  3. Apply rules:
     - Update Organs (Functions, shape, etc.)
     - Morphology and Cut
     - Transport rules (currently not used but predefined)
  4. Update Output (Charts / Files)
- Summary / Final output
  - Harvest / Yield Chart

Model work flow

Main loop:

```
public void growDaily() {
  ...
  if (dayofyear<MAX_STEPS) {
    dayofyear++;

    Tools.INSTANCE.updateLight();
    RADIATION.compute();
    RulesS1.INSTANCE.applyRules();
    updateCharts();


    ...
  }
}
```

Model work flow

Rules:

```
protected void applyRules() {

  morphologyRules();
  cutRules();
  //transportRules();
  organUpdates();
  otherRules();

}
```

Model work flow

Morphology rules:

```
private void morphologyRules() [
  s:Seed, (s.isGerminateConditions()) ==>
    Root(s.getIndiID()) s Bud(1,1, s.getIndiID());

  b:Bud(rank, order, indiID), (b.isGrowingConditions()) ==>
    RV(-0.15)
    Internode(rank, order, indiID)
    [Leaf(rank, order, indiID)]
    if(b.isBranchingConditions()) (
      [RL(30) Shoot0(indiID) Bud(rank+1, order+1, indiID)]
    )
    Rotate(random(-5,5), random(-5,5), PHYLLOTAX + random(-5, 5))
    Bud(rank+1, order, indiID);
  ...
]
```

Model work flow

Growing Conditions:

```
public boolean isGrowingConditions() {
  ...
  return
    // architectural conditions
    rank<11 && order<=2 &&
    // absorbed sensed power
    absorbedSensedPower &&
    // average SSR as growth regulation
    (indi.getAverageSourceSinkRatio()>0.66) &&
    // plastochron
    plastochron<=0 ||
    // average SSR as growth regulation: building new sinks,
    // if avgSSR is to big and the bud is old enough
    (indi.getAverageSourceSinkRatio()>MAX_AVERAGE_SOURCE_SINK_RATIO
         && tempsum>200);
}
```

Carbon budget

- Source: a portfolio of photosynthesis models (Farquhar, Thornley, KimLieth, LiethPasian, . . .)
  - Collect produced carbon to a central pool CP in the individual (Partial softening of Central Pool concept: growth of leaves with local pool, remainder of local pool fed into the central pool.)
    $CP_t \ = \ CP_{t-1} + \Sigma(PS_{all\ growing\ organs})$
- Sink: Based on modified relative sink strength concept:
  - For each organ i:
    - Potential growth rate PGR_i (derivative of logistic or Beta distribution)
    - Relative sink strength $RSS \ = \ PGR_i/\Sigma(PGR_{all\ growing\ organs})$
    - Actual growth (rate) $AG_i \ = \ RSS * CP_{t-1}$
  - At the individual scale:
    - $CP_t = CP_{t-1} - \Sigma(AGR_{all\ growing\ organs})$

Regulation of processes

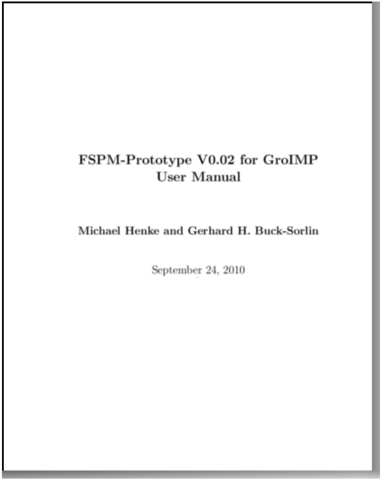
- $\Longrightarrow$ Observation: Source-sink ratio (SSR)[1]
- Dynamic average SSR, exhibits a range, depending on source or sink-limitation of 0.1 to 1.5
  - Processes regulation
  - If $avgSSR > 1.1$:
    - decrease source strength (via PS efficiency)
    - increase number of sinks (bud break)
    - increase organ PGR
  - < 0.9: vice versa

[1] Marcelis, L.F.M. 1996. Sink strength as a determinant of dry matter partitioning in the whole plant.

FSPM-P - Project

Features:

- FSPM-P Model
- User manual
  - Model description
  - Building A New Model
  - Experimental Settings
  - Measurement protocol
  - 2D Digital Measurements
  - Data processing
  - Results
  - Templates
  - ...



FSPM-Prototype V0.02 for GroIMP
User Manual

Michael Henke and Gerhard H. Buck-Sorlin

September 24, 2010

What can be modelled

- Individual plants
- Plant stands (canopies)
- Temperature-sensitive processes
- Variations in morphology under certain growth conditions
- ...

Application areas

- Efficient model development
- Intercropping
- Demonstration purpose
- Education and understanding
- Decision support; yield equation

Planned/Started Projects

- Rapeseed model:
  Tian Tian, G. Buck-Sorlin, M. Henke; 2010/11, Hangzhou, China
- Rice model:
  Wu Lingtong, M. Henke; 2010/11, Hangzhou, China
- Cotton model:
  G. Buck-Sorlin, Zhang Lizhen; 2010/11, Beijing, China
- Wheat/maize intercropping model:
  Zhu Junqi, G. Buck-Sorlin, 2010-14, Wageningen, NL

Next steps

Generally

- Fine tuning of parameters
- Implement a species specific model
- Extend and complete the user manual

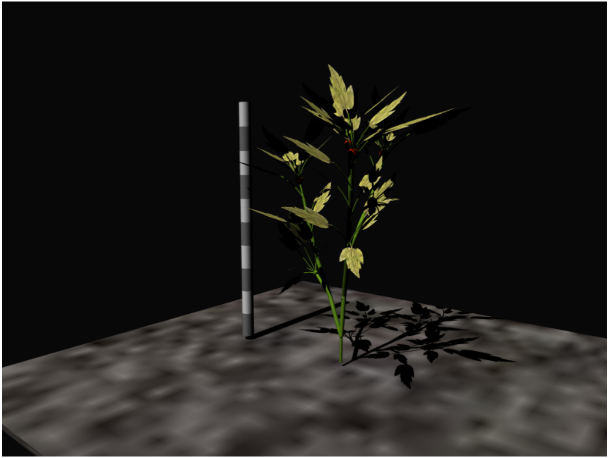
Improvements

- Modularize the photosynthesis models (Standardisation, identify submodels)

Outlook

Extensions

- Soil model ($\rightarrow$ Root model)
- QTL genotypes as model parameters
- Breeder (Genetic Algorithm)
- Transport phenomenons: water, hormones, signals ($\rightarrow$ water stress, control bud breaks,)
- Central carbon pool concept $\Longrightarrow$ local carbon pool and transport based concept
- Generalize rules



Thank you for your attention!

Ďakujem!

Dank je!

Danke!

Merci!

谢谢!