Curve Matching: New Technologies for Personalized Predictors of Growth

Stef van Buuren (1,2)

1) Netherlands Organisation for Applied Scientific Research TNO, Leiden
2) Utrecht University

Note: for non-commercial purposes only
TNO Growth charts

Anthropometry
TNO Growth charts

Anthropometry
Tanner stages

Puberty Plot Anonymous 1

1% early
5% early
10% early

1% late
5% late
10% late
TNO Growth charts

 Anthropometry
 Tanner stages
 D-score, infant development
Figure 2 Weight (kg) distribution by age (years) for the EU-population. The lines correspond to the following centiles (from bottom to top): -2.5, -2, -1, 0 (median), +1, +2 and +2.5 SD.
TNO Growth charts

Anthropometry
Tanner stages
D-score, infant development
EFSA growth references
Preterm, 25-36 weeks
TNO Growth charts

Anthropometry
Tanner stages
D-score, infant development
EFSA growth references
Preterm, 25-36 weeks
Testis Volume, Ultrasound
Health professional

1. Given what I know of the child, how will it develop in the future?
2. How certain am I of the child’s future growth?
3. If I do not intervene, will development be normal?
4. If I do intervene, will the child’s growth be normal, or healthy?
Parent

1. Is the growth of my child normal?
2. What can be done to counter my child’s inhibited growth?
3. What is the prognosis if we do nothing?
4. How certain is this prognosis?
Wish list

› Method to predict individual child growth that
  › Is easy to use, and correct
  › Builds on familiar tools
  › Uses existing data to improve health
  › Portrays uncertainty in a natural way
  › Visualizes the effect of possible treatments
Curve matching

› Observe the target child’s growth trajectory
› Plot the trajectory of the child, up to “now”

› Search for other children similar to the target child
› Plot trajectories of matched children

› Summarize matched trajectories into prediction

Obtaining appropriate matches

- Modeling choices
  - Outcome: future growth (at 14 months)
  - Predictors: current growth, previous growth (by broken stick model)
  - Exact matches: sex and/or gestational age

- Methodology (variation on **predictive mean matching**, per outcome)
  - Calculate predicted value for all potential donor children + the target child by linear model
  - Select subset of donor children that matches exactly on sex and/or gestational age
  - Within this group, find \( m \) matches whose predicted value are closest to target child
  - Plot the bundle of realized growth curves of the \( m \) matches
  - Individual prediction: Average of the full-trajectory broken stick estimates of the \( m \) matches
Broken stick model

The *broken stick model* describes individual growth curves by a linear mixed model using first order linear B-splines.

The model can be used to

• smooth growth curves by a series of connected straight lines;
• align irregularly observed curves to a common age grid;
• create synthetic curves at a user-specified set of break ages;
• estimate the time-to-time correlation matrix;
• predict future observations.
Broken stick model
Broken stick model
Broken stick model
Broken stick model

\[ R^2 = 0.755 \]
Broken stick model
Broken stick model

$R^2 = 0.911$
What about development?

<table>
<thead>
<tr>
<th>Visit</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 weeks</td>
<td>Fixates eyes</td>
</tr>
<tr>
<td></td>
<td>Reacts to speech</td>
</tr>
<tr>
<td></td>
<td>Moves both arms as much</td>
</tr>
<tr>
<td></td>
<td>Moves both legs as much</td>
</tr>
<tr>
<td></td>
<td>Lifts chin</td>
</tr>
<tr>
<td>8 weeks</td>
<td>Smiles back</td>
</tr>
<tr>
<td></td>
<td>Follows with eyes and head</td>
</tr>
</tbody>
</table>
Current state

1. D-score for infants 0-2 years fairly well established
   1. Independent of ethnic background (within Netherlands)
   2. D-score 2 years predicts IQ 5 years
   3. D-score identifies children who later go to special education

D-score not yet implemented in online growth predictor
Ideas yet to explore

› Extend to higher ages
› Extend to assist in screening
› Extend to individual causal effects
› Extend to find optimal treatment choices
› Extend to developmental scores
Want to try it?

› http://vps.stefvanbuuren.nl:3838/growthpredictor/