URBTREE : A TREE GROWTH MODEL FOR THE URBAN ENVIRONMENT

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ABSTRACT :

The Boom en Beeld project aims at developing a methodology for change detection of tree objects in urban areas using imagery. This paper focuses on one aspect of this methodology, the prediction of the size of tree objects at a given time in the future. The most important factor is the prediction of the tree growth which estimates the future size of the tree. In the urban area, tree growth is strongly influenced by man made objects and activities. The developed tree growth model uses species specific tree characteristics like shape (column, round or ellipse), size classification (big, regular, small), growth speed (slow, regular or fast growing tree), life phase (young, mature, old) in combination with influences caused by the stand characteristics of the nearby surface coverings (paved, open or vegetated). The UrbTree model is a spatial driven growth model and can model differences in tree growth caused by the nature of the surface covering of the neighbouring area of the location of the trees by using spatial analyses techniques. The quality of the available geodata is an important factor in the modelling process, especially the amount of sealing imposed by the different kinds of paving must be taken into account. The amount of tree growth that can be calculated using the model over a five year period is still close to the bandwidth with which the actual tree growth can be detected on the separate images from two different time steps.

1. INTRODUCTION

The UrbTree model is a tree growth model that is used to predict the growth of trees within the urban environment. The model is developed in the scope of the Boom en Beeld (Tree and Image). The Boom en Beeld project aims at developing a methodology for monitoring tree objects in urban areas using imagery to provide up-to-date information about urban green to organisations who are involved with the management of urban green. The expected update cycle for information concerning urban green is somewhere between two and five years. This time span is also the goal for the UrbTree model to predict the tree growth. The input for the UrbTree model is existing information on tree objects, usually available from databases from municipalities. The output of the UrbTree model are the predicted tree crown dimensions for all these tree objects. In the Boom en Beeld workflow (Van der Sande, 2010) tree crowns are also extracted on up-to-date imagery using object based classification techniques (Bijker et al., 2010). These modelled and extracted tree crowns are then analysed to identify differences like “removed” or “to small”. This is used as a signal for further inspection to identify the reason for the detected anomaly, either by manual on-screen interpretation of the imagery or inspection in the field.

The UrbTree model is a spatial driven growth model. It uses general growth parameters depending on tree species. It focuses mainly on how the tree growth is influenced by man-imposed factors in the urban environment. In this, the UrbTree model differs from other plant growth models which use physiological processes involved in growth (Fourcaud, 2008; Hemmerling et al., 2008). The impact of man-imposed factors on tree growth is described in literature (Atsma, 1999) and also became clear during a case study for the redesign of an existing road in an urban renewal area (Kramer, 2010). The study area involved consists of a dual carriage road with five lanes of sycamore trees. All trees were planted at the same moment and have grown for around thirty years under the same climatological circumstances. However, the size of the trees (both the tree crown and trunk) differs significantly. The trees that were situated in a penetrable surface have grown into big trees with a tree crown of about 13 meters in diameter. The trees that were situated in a impervious surface only grew into trees with a tree crown of about 6 meters in diameter. The bigger trees are situated in a grass field with only a foot- and bicycle path nearby. The smaller trees are situated in the middle of the dual carriage road, with only a strip of about two meters of grass. This study area also shows the differences in tree crown growth depending on the existence of trees in the direct vicinity. All trees can be found in groups of three. The crowns of the bigger trees touch each other which results in a smaller crown size of the tree in the middle. This is not the case for tree groups where the crowns do not touch each other, the crowns of these trees are similar in diameter. This indicates that the tree growth is also influenced by neighbouring trees. The UrbTree model will be used to model tree growth within an area where factors as temperature and rainfall can be considered as homogeneous. Also soil is not used as a variable in the model. When planting trees in an urban environment, usually soil improvement measures are taken to ensure a suitable habitat for trees to grow. For a specific location, the general growth parameters should be calibrated from field measurements.

2. THE URBTREE MODEL

The UrbTree model depends on geographical processing techniques for the modelling of the tree growth. The model is implemented in the Python programming language and uses the ArcGIS geoprocessing toolkit to perform the geographical processing. ArcGIS is not compulsory, the model can be implemented in any toolkit that allows spatial analysis.

2.1 Input data requirements

The main part of the model is the UrbTree classification scheme that defines the growth reduction parameters based on tree species. Many varieties and sub-varieties of trees do exist and each variety has its own typical way of growing. To be able to model tree growth without the necessity to specify the tree growth for each specific (sub)varierity a tree classification scheme is created. This scheme reflects specific aspects of the way the tree grows. A specific tree variety can be classified as a small or a big tree. Also basic shapes of trees can be distinguished; a column shaped tree will grow differently than a round shaped tree. Some varieties are fast growing, others slow growing. And a young tree will grow differently than a mature or old tree. Table 1 shows the classification scheme, this scheme is based on the book 'Stadsbomen vademecum deel 4' (Janson, 1997). Each subclass in the scheme will yield a factor by which the average tree growth is influenced.

main classes	**subclasses**
size class (size of full grown tree)	small (< 8 meters high) regular (8 – 15 meters high) big (> 15 meters high)
shape class	column (height >> width)
	vertical ellipse (height > width)
	round (height ≈ width)
	horizontal ellipse (height < width)
growth type	slow regular fast
life phase	young mature old

Table 1. UrbTree classification scheme

The actual factors for each subclass will be derived from variety descriptions in literature available from tree nurseries (Lappen, 2009) and when possible from field measurements.

The model requires two types of input data, the tree database containing the trees for the area to be modelled, and the topographic data (geodata) for this area . The tree database contains for every tree the location (x- and y-coordinate), the size of the tree crown (height and width) and the division into subclasses from the classification scheme. The geodata must at least contain the classes buildings, roads, grass, open surface (bare soil or vegetated) and water. This should be available in a detailed scale, 1 : 500 or 1 : 1000, otherwise the geographic accuracy of the data will hamper the spatial analyses used in the modelling process. For The Netherlands, this kind of geodata is available at the municipalities.

2.2 Process model

Figure 1 shows the schematic representation of the UrbTree process model.

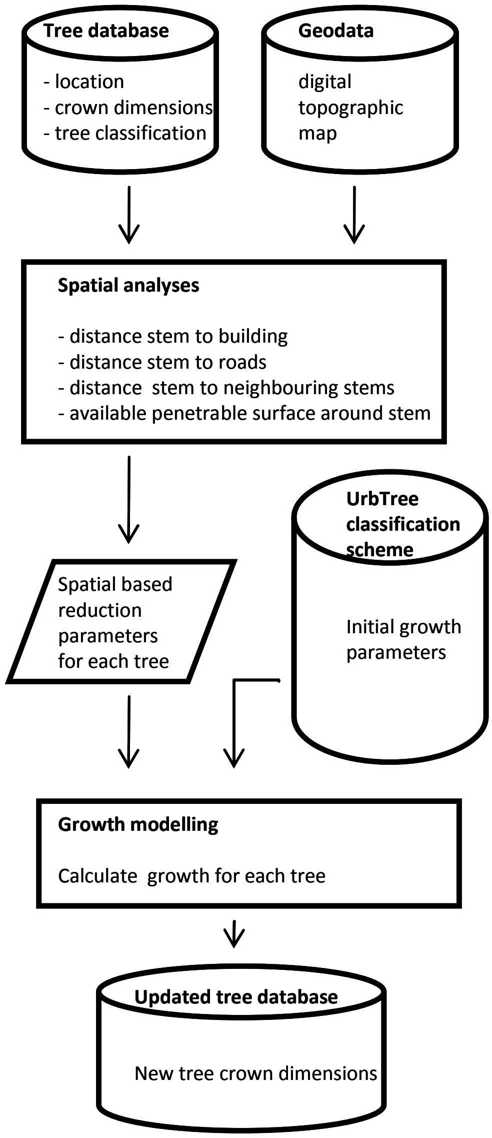


Figure 1. UrbTree process model

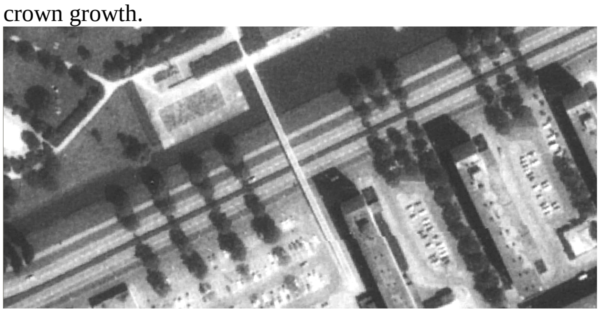
In the spatial analyses process step, the growth reduction factors are calculated for each tree. The distance to nearby buildings and roads is analysed to calculate the reduction factors caused by these topographic objects. Also the distance to nearby trees is analysed. Both the vertical and horizontal growth of the tree crown is affected when tree crowns connect with each other. The horizontal growth will be reduced whereas the vertical growth height will be increased. The last factor to be analysed is the penetrability of the surface in the direct vicinity of the tree crown. The growth of the tree is reduced when water can not reach the roots of the tree or the amount of water the reaches the roots is reduced by partial openness of the surface around the tree stem. The input area for this spatial analyses is a circle with a diameter of the tree crown width, it will yield are reduction factor based on the percentage of open area within the tree crown circle.

The reduction parameters from the spatial analyses, combined with the growth parameters from the UrbTree classification scheme are used to calculate the dimensions of the tree crown over the desired time period. This process is iterative performed per year, the yearly growth of the tree crowns will alter the reduction factors from the spatial

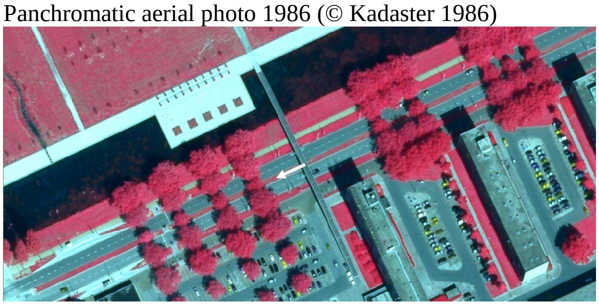
analysis every year. For each yearly run, the calculated dimensions of each tree crown are used as the input dimensions for the next run.
It is also possible that the geodata will change during the desired time period. A redesign of the area to be modelled, either a change of infrastructure, buildings or coverings, will alter the reduction factors calculated by the spatial analysis process. It is important to update the geodata used by the model at the correct point of time.

3. STUDY AREA

For this study material is used for an area located in a suburb of the municipality of Arnhem. The study area consists of a dual carriage road with five lanes of sycamore trees. All trees are planted around 1980 and show significant differences in growth caused by differences in the nature of the cover of the immediate vicinity. Figure 2 shows the area for the Arnhem case study in 1986 and 2008, showing the difference is tree crown growth.



Panchromatic aerial photo 1986 (© Kadaster 1986)



Colour-Infrared aerial photo 2008 (© Eurosense B.V. 2008)

Figure 2. Aerial photo's for case study area Arnhem

Figure 3 shows the sycamore trees in 2008, the location and direction for this photo is indicted by the white arrow on the colour-infrared photo in figure 2. The differences in tree size for the different tree lanes and the differences in surface type are clearly visible.

Figure 3. Oblique photo showing sycamore trees at study area.

4. DATA

Figure 4 shows the geodata for the area. This geodata was digitized from the areal photo, water is a part of the class 'grass / open surface'

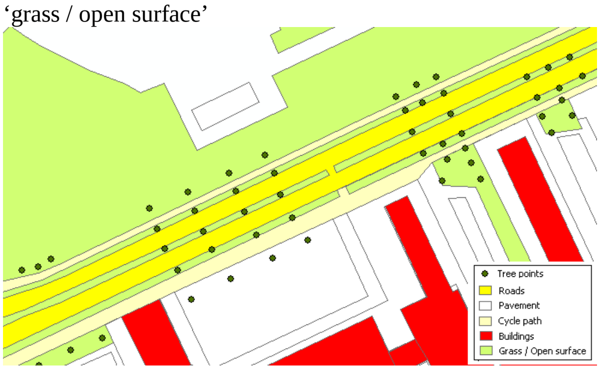


Figure 4. Geodata

The tree crowns for 1986 were digitized on the areal photo (figure 5). The tree crowns do not show clearly on the black and white photo, tree crowns, grass and shadows are all depicted in dark shades of grey but a reasonable estimation can be made .

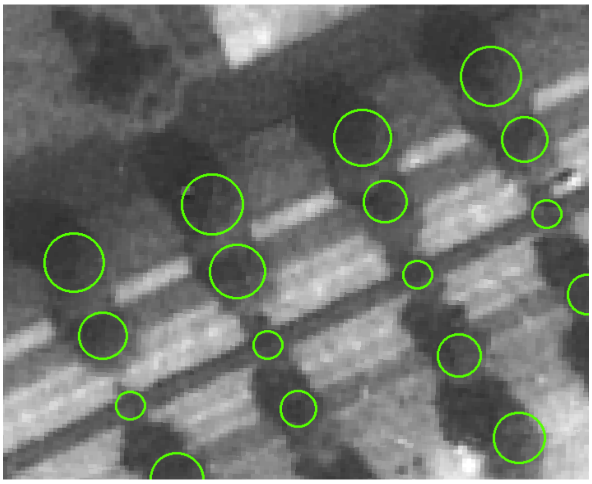


Figure 5. Digitized tree crowns for 1986

The crowns were digitized by different people to get an impression on how accurate the tree crowns can be digitized on this type of imagery. This test did show an average difference of about half a meter in crown width, with peaks up to one meter. The tree crowns were also digitized on the colour-infrared photo from 2008. In this photo, the tree crowns are clear to see and easier to digitize. But still, when the crowns are digitized by different people, an average difference in crown width of about half a meter do occur, again with peaks up to one meter.
An estimation for the yearly growth of the trees is derived from measurement made in 2008. Both height and width of the tree is measured and the age estimated for several sycamore trees that have a place with open surface coverage.

5. RESULTS AND DISCUSSION

The implementation of all aspects of the UrbTree model is not finished yet. The first calibration test does provide valuable information on the applicability and limitations of the UrbTree model.

The intended method to calibrate the model is to make use of the measurements for the trees in lane 1 in 1986 (figure 6) and 2008 (figure 7). The growth for these trees is not influenced by the surface coverings near the trees since all trees are located in a grass area. The dimensions of the trees in lane 3 can be used to initialize the growth reduction factors caused by the influence of the surface coverings.

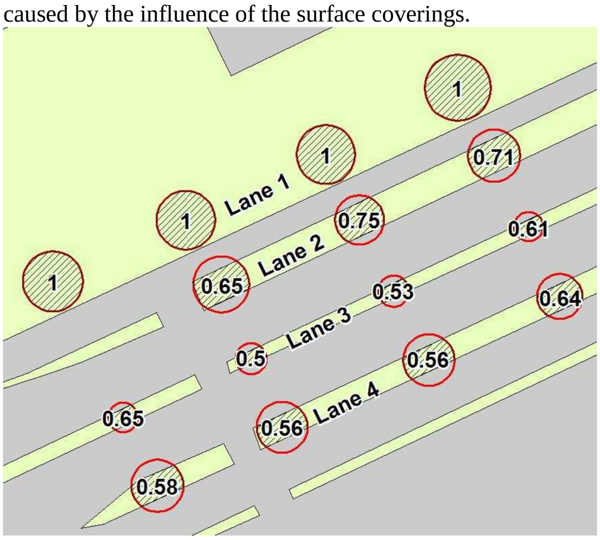


Figure 6. Tree crowns from 1986 with areal percentage in open coverage (hatched area)

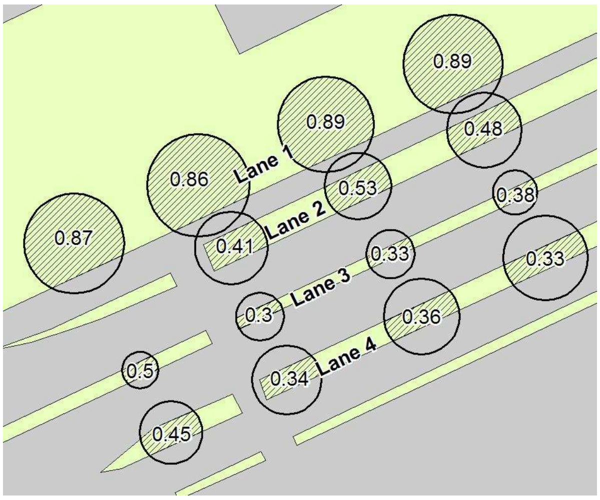


Figure 7. Tree crowns from 2008 with areal percentage in open coverage (hatched area)

From the measurements of the fifteen trees the average growth and the average growth per year for each lane are calculated (table 2). Also the available open coverage is calculated for both years.

	Average Measured growth 1986 – 2008 (meters)	Average growth per year (meters/year)	Average percentage open coverage in	
			1986	2008
Lane 1	7.6	0.35	100	88
Lane 2	4.2	0.19	70	47
Lane 3	3.5	0.16	57	38
Lane 4	5.8	0.27	59	37

Table 2. Growth measurements

The growth of the trees in lane 3 and 4 is only limited by the available open coverage for each tree. The growth of the trees in lane 2 is also limited by the neighbouring bigger trees in lane 1. The results in table 3 show that the modelled growth based on the difference in available open coverage does match the measured growth for both lane 2 and 3 but does not match for lane 4.

	Measured growth (MeG (meters)	Mean open coverage (%)	Modelled growth (MoG) (meters)	Difference between MeG and MoG (meters
Lane 2	4.2	58.5	4.4	0.2
Lane 3	3.5	47.5	3.6	0.1
Lane 4	5.8	48	3.6	-2.2

Table 3. Modelled growth and differences

The accuracy for digitizing the tree crowns is about half a meter. This implies that the accuracy for measuring the tree growth between two time steps is up to one meter. The differences between the measured and modelled growth for lane 2 and 3 are well within the limits caused by the digitization of the tree crowns. The difference for lane 4 exceeds this limit, this implies the occurrence of another influence on the tree growth. This could be caused by a difference in nature of the road surface. The secondary road south of lane 4 is a brick-paved road whereas the dual carriage way between lanes 2, 3 and 4 is covered with asphalt. The brick-paved roadway is more open than the asphalt covered roadway and makes it possible for surface water to penetrate into the ground. This can explain the extra measured growth, the differences in the nature of road coverage is not used in this model run. The nature of the road coverage must be recorded in the geodata that is used as input for the model.

The model is intended to be used to monitor the tree growth over a period of two to five years and detect differences between the modelled and observed tree growth. Based on the average yearly tree growth in table 2, the amount of observed tree growth in five years is between one meter for trees with restricted growth and almost two meters for trees without growth restrictions. When monitoring over a five year period, the amount of modelled three growth is still close to the bandwidth with which the actual tree growth can be detected on the separate images from two different time steps. The implication of this for the monitoring approach should be further investigated.

6. CONCLUSIONS

The UrbTree model can model differences in tree growth caused by the nature of the surface covering of the neighbouring area of the location of the trees. The limitation of the tree growth can be calculated by using spatial analyses techniques. The quality of the available geodata is an important factor in the modelling process, especially the amount of sealing imposed by the different kinds of paving must be taken into account.

The amount of tree growth that can be calculated using the model over a five year period is still close to the bandwidth with which the actual tree growth can be detected on the separate images from two different time steps. The implication of this for the monitoring approach should be further investigated.

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