OrthogonalizingBuildingFootprint

Right angles and parallel structures are generally the rule for actual buildings. When mapping building footprints, either working for an authoritative agency or in OpenStreetMap (OSM), many factors will affect the accuracy of the result (i.e. right angles and parallel structures are not exactly respected). Initially, this procedure was developed to orthogonalize building footprints made available by Canadian government agencies, in order to import them in OSM (with a compatible license). A description of the concepts behind orthogonalizing building footprints and the algorithm are detailed below.

Concepts Behind Orthogonalizing Building Footprints

First, not all sections of a building are necessarily orthogonal since some architectural features may impose different shapes.

Uncertainties on right angles.

For instance, let start with a simple building having a right triangle footprint (figure 1).

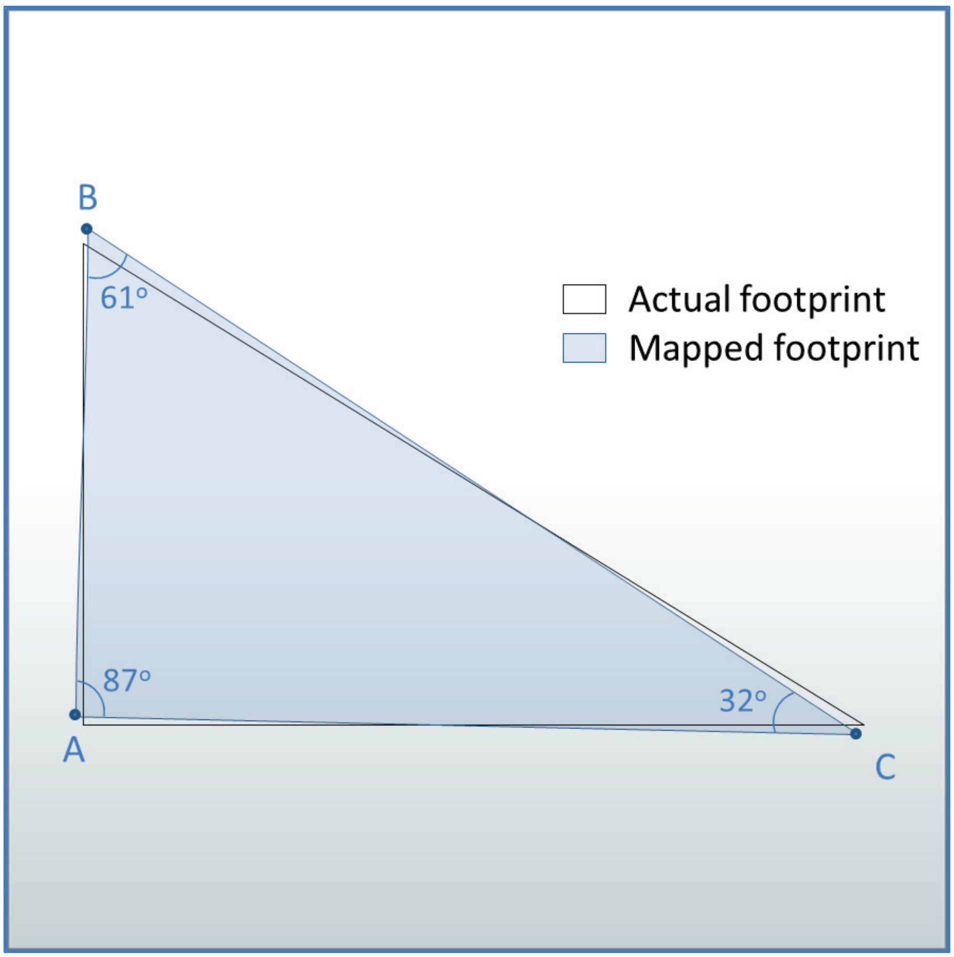

Figure 1 Right angle building

Mapped footprints often differ from the actual building shape. Here, mapped segments AB and AC show inaccuracies which make the angle A not orthogonal. At the same time, corners B and C do not have right angles and must not be orthogonalized. In order to differentiate orthogonal sections from those who are not, a parameter must define a maximum mapping error around right angles (figure 2).

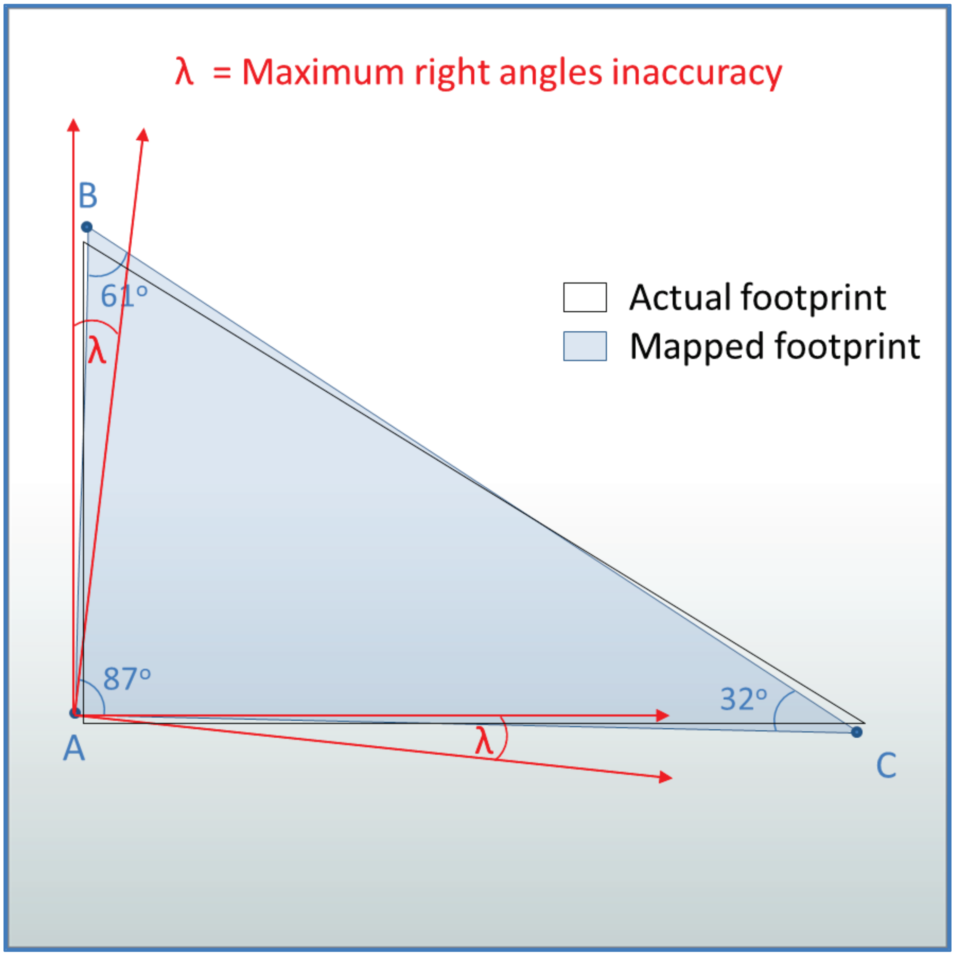

Figure 2 Maximum right angles inaccuracy

Below the threshold λ, angles must be orthogonalized, above they must not. A threshold λ of 10° defines that all segments linked with an angle of 90° ± 10 ° must be orthogonalized. In figure 2, angle A (i.e. segments AB and AC) must be orthogonalized while segment BC must not. The same rule applies for more complex buildings, creating sections of contiguous right angle segments and possibly sections of contiguous non-orthogonal segments.

Orthogonalizing a section of contiguous right angle segments consists of imposing the same slope to all parallel segments and an orthogonal slope to each adjacent segments (i.e. only two angles). When imposing the slope to a segment, segment centre coordinate is used to determine its new location.

Orthogonalizing Building Footprints Aggregate

In urban environment, buildings are often contiguous to each other, creating aggregates of building footprints. The same rule applies to aggregated building footprints. All contiguous sections of right angle building footprints must be imposed an orthogonal slope to each adjacent segments and the same slope to parallel segments. Doing so, adjacent segments that should be collinear may end-up as parallel because of the uncertainty on each segment. It is then necessary to impose a minimum distance ε on parallel segments to ensure that below this threshold, they will end up collinear and share the same coordinate at their edges (Figure 3).

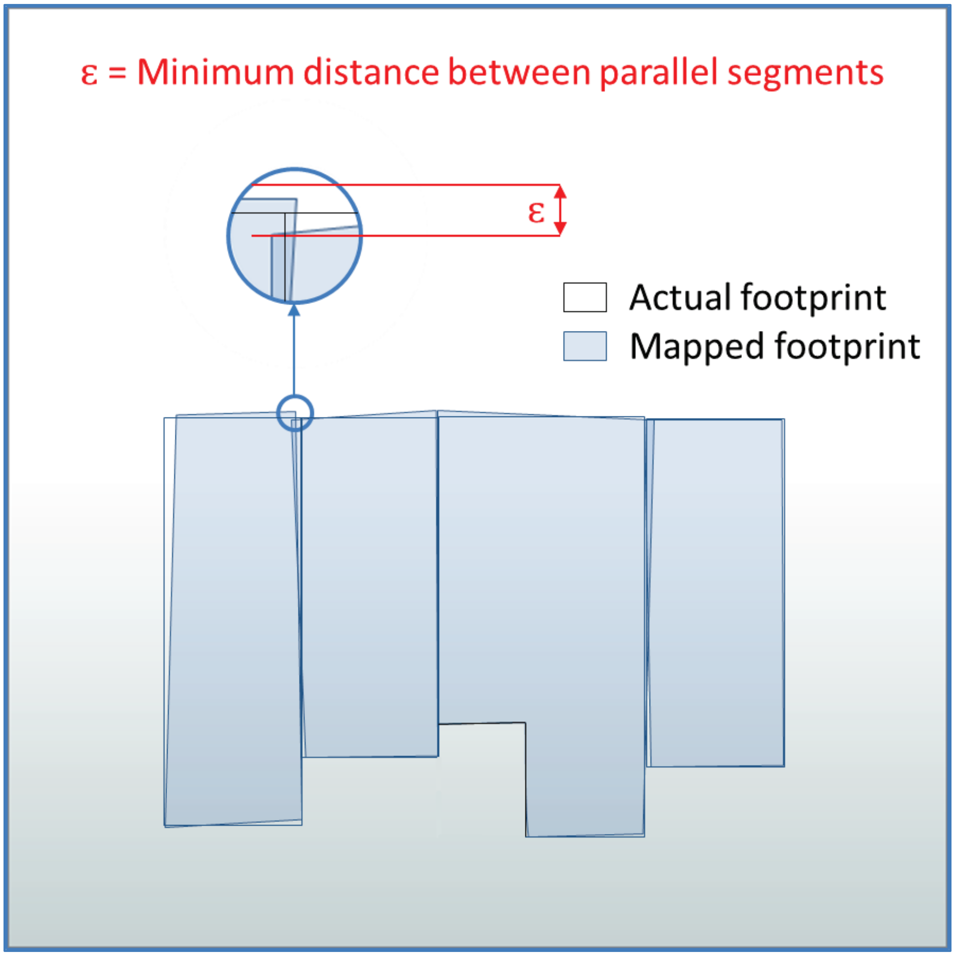

Figure 3 Minimum distance between parallel segments

A line equation of the general form Ax+By+C=0 is built for each line segment using the new common orthogonal slopes and each segment's centre coordinate. The line equations are adjusted to respect ε by rounding C by that value. Rounding C with ε makes collinear the segments of battlement shape buildings when the distance between segments' projection is smaller than ε.

Removing Collinear Vertices

Another characteristic of mapped footprints is the existence of unnecessary vertices (nodes) which may slightly alter the shape of the buildings (figure 4). Algorithms exist to remove these vertices based on the resulting line displacement after removing a given vertex (e.g. Douglas-Peucker). However, on building footprints, small segments (i.e. small displacement after removing vertices) may represent important building features and should not be removed. Fortunately, unnecessary vertices generate very small angles. One can define an angle threshold ϴ, below which removing a vertex as not significant impact on building footprint. A threshold ϴ smaller than the stroking tolerance of round buildings is advisable.

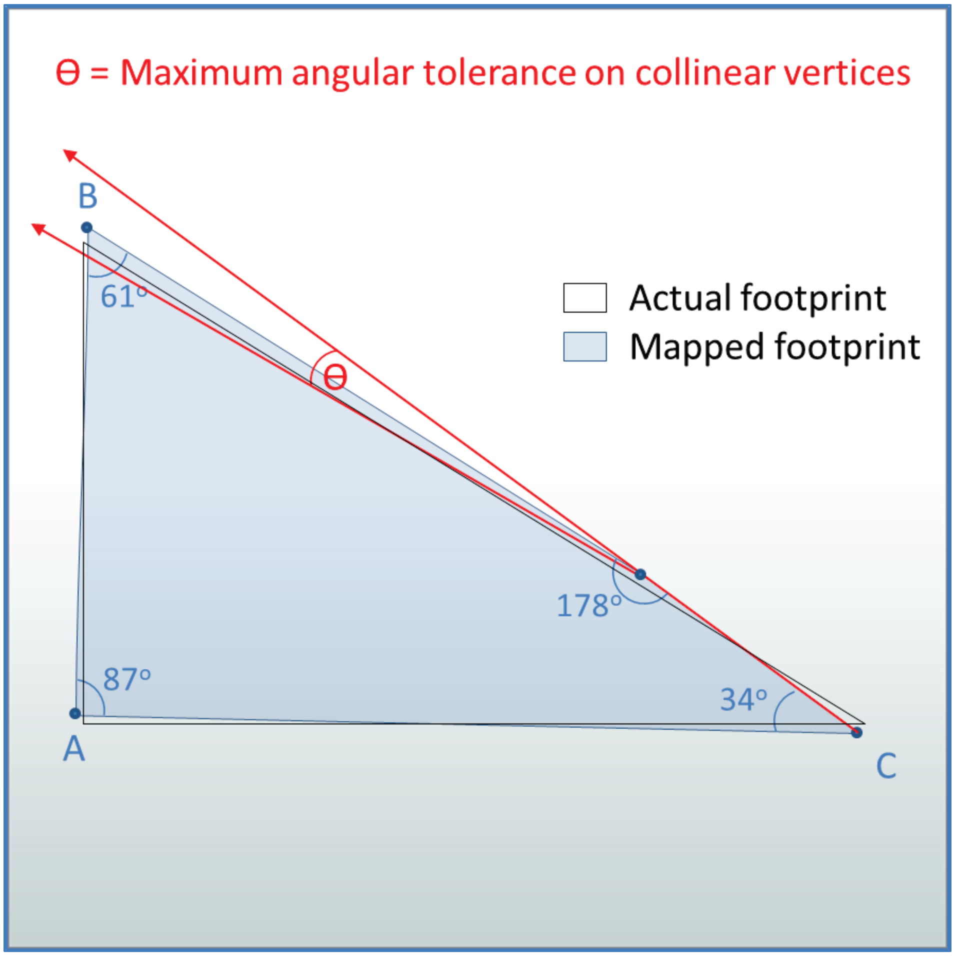

Figure 4 Maximum angular tolerance on collinear vertices

Summary

Not all sections of a building are necessarily orthogonal since some architectural features may impose different shapes. The junction of each line segment of a building footprint results in three angle types.

1. Non-significant angles are related to collinear or near-collinear vertices and are defined through the threshold ϴ (Figure 4). Vertices creating an angle smaller than that threshold are removed.
2. Orthogonal or near-orthogonal angles are defined by using a threshold λ (Figure 2) which defines the maximum angular error on right angles. When an angle differs from 90° by less than that threshold, the angle is considered to be orthogonal and the corresponding line segments are modified to unsure a right angle between them.

3. Between thresholds T and L are found non-orthogonal angles which should not be altered since there are no rules that define their expected values.

In order to modify the line segments that need to be orthogonalized, the line equation of each orthogonal or near-orthogonal segment is computed by using average segments' slope and centre coordinates. A distance threshold ε is used to ensure expected collinear segments will be created as such. Once new line equations are defined, the intersection between adjacent segments (new vertex coordinate) is computed using homogeneous coordinates. The details are found below.

Orthogonalizing Building Footprints Algorithm

Available soon.