Sketch Map Analysis Preparation: Digitization of Maps. Based on the research question that shall be answered, the experiment has to decide what information they want to extract from the sketch maps, i.e. which landmarks and streets the participants are expected to recall in a "perfect" (i.e., best possible) sketch map.The experimenter digitises the base map of the experimental area and the sketch maps collected throughout the experiment.

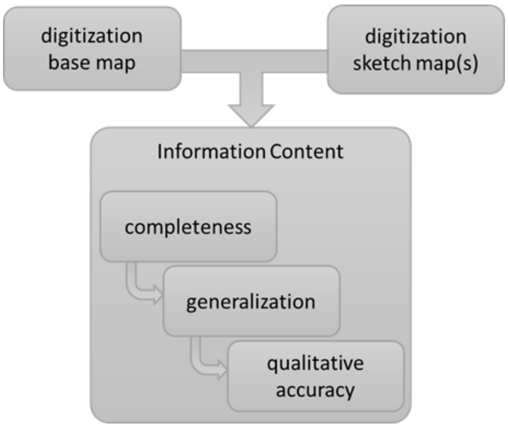

Figure 3: Procedure of the SketchMapia software: To evaluate the information content of a sketch map, we need to compare it to a base map

Further, we distinguish between analysing its information content and the type of the map: The information content is analysed in a sequential order with respect to the completeness of the sketch map, the degree of generalisation of sketched features and with respect to the qualitative accuracy.

Sketch Map Analysis Step 1: Completeness. The sketch map's completeness tells about the ratio of features captured in the sketch map with respect to all base map features. We identify all features that have not been sketched. All other features – independently of whether they are drawn at the same level of generalisation or in an accurate way, are counted for the number of drawn objects. We interpret the amount of recalled features as an indicator for more or for less comprehensive spatial knowledge acquisition.

Sketch map completeness is the first step of the analysis process, because it determines the set of features in the base map that need to be aligned to (generalised or non-generalized) features in the sketch map.

Sketch Map Analysis Step 2: Generalisation. The degree of abstraction, respectively the detailedness, is considered as an indicator for the level of abstraction of spatial knowledge. Generalisation is the second step of the sketch map analysis process in which we establish alignment between features: This may be a one-to-one alignment (i.e. no generalisation involved). If generalisation is involved, we distinguish between group-to-one alignment and group-to-group alignment. In the first case, several detailed features in the base map are aligned with one abstract feature in the sketch map. In the latter case, several objects are drawn in the sketch map to indicate a particular pattern but not concrete features. The alignment is established at a generalised level, e.g. the houses at the side of a street are represented by a set of houses in the sketch map while not every single sketched house can be aligned to a particular house in the base map.

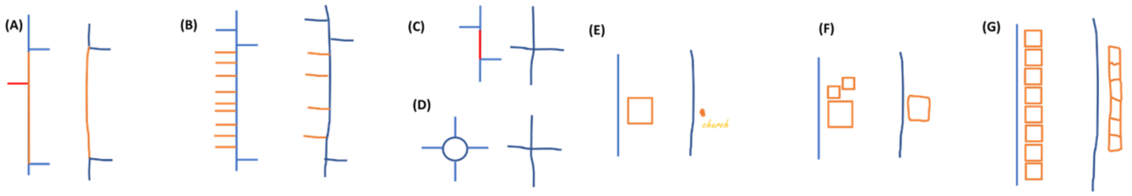

Figure 4: Seven generalisation types: geometric merging for streets (A), abstraction to show existence for streets (B), junction merge (C), roundabout collapse (D), collapse for buildings (E), amalgamation for buildings (F), abstraction to show existence for buildings (G)

Figure 4 visualises the different generalisation types that we proposed in [11] based on an extensive analysis of sketch maps. Generalisation type (A) and type (C) are a result of an incompletely drawn sketch map. In generalisation type (A), a side street was left out and thus two street segments are merged into one. In generalisation type (C), the missing street leads to a junction merge which eventually also affects the spatial accuracy of the street segments, because a new street pattern occurs.

Generalisation type (B) and (G) are examples of group-to-group alignments. While in the base map each feature matches one feature in the reality, the set of side streets respectively the set of houses don't refer to a concrete street or house in reality, but indicate only the existence of a set of streets respectively houses. In generalisation type (D) and (E), the extended feature in the base map is represented by a feature of lower dimensionality: The junction is collapsed into a junction and the polygon representing the footprint of a building is collapsed into a point (see also Figure 2 for examples of buildings represented as polygons vs as points on a sketch map). Generalisation type (F) amalgamates a multi-complex building to one single building.

The procedure of highlighting missing and generalised objects in a base and a sketch map was tested in .... Five raters received annotated the same set of 30 sketch maps which systematically differed in their degree of generalisation and completeness. Out of the total of 416 features coded by the 5 participants, 53 features were generalised, 275 features were non-generalized, 82 features were not drawn (out of which 24 resulted in merging of segments due to omission of streets). Once the colour-coded data was ready, we used the Light'sKappa index [5] of the irr package [7] in R to calculate the agreement. The overall agreement score among the participants was kappa = 0.889 with a significant value of p = 0.056.

Sketch Map Analysis Step 3: Spatial Accuracy. The third step aims to determine spatial accuracy of a sketch map. It operates on the generalised feature alignments, i.e. in case a feature is generalised, the detailed features are replaced by the generalised one and the spatial relations are calculated based on the generalised one. Since sketch maps are distorted and schematized due to the cognitive processes underlying the formation of a cognitive map, we strongly believe that a quantitative regression measure has only limited meaning. In our previous work [34, 27] we have investigated invariant aspects in sketch maps, i.e. (qualitative) spatial relations among sketched objects which are typically not distorted in the sketch map.

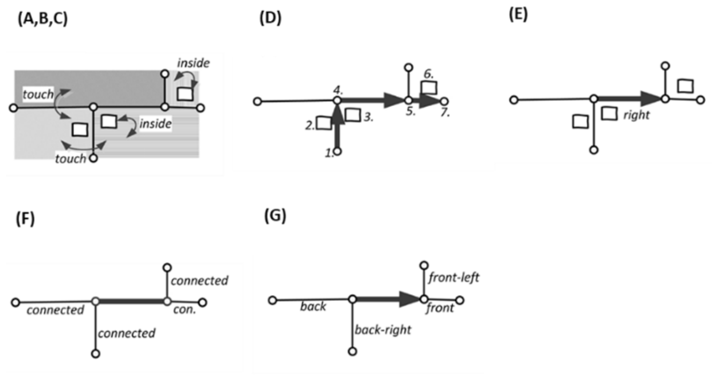

Figure 5: Seven sketch aspects to determine the qualitative correctness: [27]: topological relations between landmarks (A), regions (B), and between street segments (C), linear order of features along the route (D), left/right relation of landmarks with respect to the street €, connectivity of street segments (F), and orientation of street segments (G).

Figure 5 illustrates the six sketch aspects taken into account for calculating the qualitative accuracy. The first sketch aspects refer to topological relations: In our implementation, we calculate topological relations jointly for landmarks and regions (A, B), and separately the topological relations between street segments and landmark/regions (C). Sketch aspect (D) describes the linear ordering of landmarks and junctions along a route. A route is defined as connected street segments. Sketch aspect (E) describes whether the landmark is left or right located with respect to its nearby oriented street segments. Sketch aspect (F) describes whether two street segments are connected to each other. Sketch aspect (G) describes the binary directional relations of two street segments that coincide in at least one junction point.

In various studies [9, 10] we investigated the reliability of these sketch aspects in alignment scenarios to determine at which level topological relations, ordering relations and direction relations should be distinguished to provide a reliably and accurate measurement.