1. Background

According to Bielecka [1], 80% of the data used in public administration has its spatial reference and the best way to present this kind of data are maps. These statistics come from a decade ago, but we can assume that nowadays the percentage is even higher. In spite of lower artistic value than paper maps, digital maps are more commonly used in the 21st century. This is because they can be edited in a more efficient way, but above all it is possible to generate them automatically or semi-automatically. The main task in that case is to use appropriate generalization algorithms that will allow developing a readable digital map. The above is a difficult task while generating regular maps, but it gets even more complicated when it comes to generating tactile maps.

Most of the maps are read by the sense of sight, which is the natural, best way to receive them. Unfortunately, disabled people who perceive the world with different senses cannot use this data, which means that they are deprived of the benefits coming from the Information Age. This group of people includes the blind and visually impaired. According to World Health Organization there are 253 million people living with vision impairment of whom 36 million are blind and 217 million have moderate to severe vision impairment [2]. This is why there is a need to present spatial data in a form that is suitable for these people. One way of achieving that is to produce tactile maps—raised, specially-adapted tactile representations of the phenomenon in question with its spatial reference that are read with the sense of touch or, to a limited extent, with eyes [3].

The overall aim of this work is to provide an objective summary of the current state of research concerning automated map generation in general, with particular emphasis on tactile maps. Systematic literature reviews are not popular in earth and technical sciences but there are some related to GIScience. However, none of them refer to automatic map generation. Fortunately, numerous articles and publications that deal with this topic exist and many of them focus on tactile maps specifically. Our aim was to answer the following research questions based on the literature review:

- RQ1: What are the generalization methods and models for automatic tactile/thematic/background map generation?
- RQ2: What are the existing systems and solutions allowing automatic (tactile) map generation?
- RQ3: How to properly design spatial databases for automatic map generation?

Answering these questions might be very useful later as the main goal of the author’s Ph.D. project is to design a platform for automatic tactile map generation.

2. Study Selection Criteria (Inclusion/Exclusion)

Inclusion criteria:

- Only journal articles, conference proceedings, reports and book chapters originating peer-reviewed sources (although grey literature will be considered);
Primary studies selected from sources published in the last 10 years (2008–2017, including those already published in 2018);

Papers should be written in English, German or Spanish.

Exclusion criteria:

Duplicate content—studies written by the same authors with just slight differences and minor extensions or those that are based on the same data.

Papers not mentioning at least one of the following topics:

- Generalization algorithms;
- Spatial data sources for tactile map generation;
- Good practices regarding tactile map design;
- Spatial data sources for automatic map generation;
- Methods for automatic map generation.

These criteria will be first applied to a pilot subset of primary studies to check whether they are appropriate. If the results are satisfactory, these criteria will be implemented, and all identified references will be screened independently by two reviewers: Jakub Wabiński and Albina Mościcka. In the first iteration we will be reviewing titles, keywords and abstracts. Disagreements among the assessors will be resolved through brainstorming during common meetings.

The process of selecting studies will be similar to the one proposed in Cochrane Handbook for Systematic Reviews of Interventions with some minor changes [4]:

1. Keyword-based search in selected data libraries;
2. Applying inclusion/exclusion criteria (apart from the one regarding the paper’s topic);
3. Merging search results with use of Mendeley software and automatic removal of duplicate content;
4. Examining titles, authors and abstracts to remove obviously irrelevant papers and another iteration of duplicate check—papers will be given an appropriate tag regarding their topics;
5. Retrieving full texts of the selected studies;
6. Full text examination, study quality assessment and data extraction;
7. Exclusion of papers that do not match the criteria of study quality assessment;
8. Backward reference search;
9. Comparison of the results with other reviewers (only selected papers);
10. Final decisions regarding the chosen primary studies.

The final review will explain the reasons for the exclusion of primary studies. As readers might plausibly expect to find some of the excluded studies within the review, a list of the excluded studies can be provided upon request. Listing such studies as excluded and stating the main reason for exclusion (tags), can show the consideration that has been given to them by the authors.

3. Search Strategy

The search process will be carried out taking into account all of the previously mentioned inclusion and exclusion criteria. Firstly, several electronic literature sources will be chosen to perform the automatic predefined keyword search. The choice of online libraries was based on experiences of other researchers who performed SLRs in the field of GIScience [5,6]: Google Scholar, IEEE Library, Scopus, Springer Web of Science, Willey Online Library and FreeFullPDF. During the process we will be using ResearchGate to search for unofficial papers and use help of the Scientific Information Center of XXX. We also keep gathering relevant articles suggested by scientific newsletters—personalized suggestions from Mendeley, ResearchGate and Tandfonline. All the selected primary studies are going to be stored and managed within the Mendeley Reference Management Software.

The most suitable set of keywords to be used will be determined with use of the iterative approach proposed by Kitchenham [7]. A primary set of keywords will be used to find the relevant papers. Then these papers and their metadata will be semantically analyzed looking for new keywords. All the alternative spellings, synonyms and abbreviations of the main keywords will also be used in the final search. An approach based on bibliographic operators is considered (e.g., “*”
operator for alternative endings of the same word in British and American English. The main keywords to be used in the first step are as follows:

- tactile map
- automatic map generation
- map generalization
- generalization methods
- spatial data sources
- blind

The automatic search will also include Boolean operators: AND, OR, as well as other searching operators such as quotation marks. It is possible that the predefined list of keywords may contain some buzzwords (the term blind and visually impaired might be one of these) that will have to be excluded in the future. An example of search string to be used in Scopus:

“TITLE-ABS-KEY(“tactile map*” OR "tactual map*" OR "touch map*" OR "map for blind" OR "3D tactile model*" OR “haptic map*” OR “multisensory map*” OR “inclusive cartography”) AND (cartograph* OR earth OR globe) AND PUBYEAR > 2007 AND NOT DBCOLL(medl)”

Additionally, references and keywords of the primary studies identified in the first step will be examined in order to find new potential sources of primary studies. The authors also consider consulting experts in the field of this particular review regarding unpublished materials and their thoughts about the existing ones in case of any doubts. Besides, a manual search will be carried out so that additional sources of primary studies, not listed in online libraries, might be identified. Main Polish GIScience journals from recent years are going to be browsed to find suitable primary studies in this field. These include: ‘Geodeta’ and ‘Przegląd Geodezyjny’ as well as conference proceedings, e.g., International Cartographic Conference Proceedings or International Conference on Cartography and GIS Proceedings.

Discussions and consultations with librarians of the National Library of XXX, XXX Main Library and other academic libraries are planned to be held to make the search process as fast and efficacious as possible.

The title, keywords and abstract of every material identified during the search process will be then analyzed by two independent reviewers. This will allow us to decide whether the materials match the inclusion/exclusion criteria and to remove obviously irrelevant studies. If the entries do not have an abstract, the paper will be scanned briefly. Besides, the accepted studies will be assigned tags defining the research questions that they might potentially answer. These tags will help to group materials and conduct quantitative analysis:

- RQ1: gen;
- RQ2: sys;
- RQ3: data.

The same applies to the excluded materials. They will be assigned their tags too, explaining the reason for exclusion:

- Papers not mentioning any of the topics of interest → 1;
- Papers not falling in the search range 2008–2018 → 2;
- Papers written in the language that none of the reviewers know → 3;
- Duplicate content not detected by the automatic tool within Mendeley → 4.

4. Study Quality Assessment

All the selected primary studies will have to go through the quality checklist (Table 1). This is going to be performed with use of one of the data extractors.

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. Are the aims/research questions clearly stated?
2. Are there any generalization methods/algorithms/models mentioned?
3. Are there any existing automatic map generation systems/solutions mentioned?
4. Are there any examples given of existing databases used for automatic map generation?
5. Is the study anyhow related with visually impaired people?
6. Are there any related works mentioned (from the past)?
7. Were any techniques of additive manufacturing mentioned (3d printing)?
8. Is there any information related to the costs of map production?
9. Did untoward events occur during the study?
10. Is practical significance discussed?
11. Are there any negative findings/limitations presented?
12. Are any future research projects mentioned? (or is the work completed?)
13. Are any project results presented? (tool/platform/method/prototype/final product)
14. Do the numbers add up across different tables and subgroups?
15. Have all study questions been answered, or has the research goal been achieved?

This is a straight-forward assessment considering yes/no questions. A paper will be accepted if its score is eight points or more. These papers must match the inclusion/exclusion criteria. Points are granted for positive answers to the mentioned questions. A weighted scale will be used as some of the questions are more important than the others.

- Two points for positive answer to questions: 1–6 and 12–15.
- One point for positive answer to questions: 7–11.

5. Data Extraction

A data collection form will be used to extract all the essential data from the selected primary studies. Apart from including all the questions needed to answer the review questions and quality evaluation criteria, the data collection form will provide the following basic information about the papers:

1. Score obtained during quality assessment;
2. Name of the reviewer and additional checker of the review;
3. Date of data extraction;
4. Basic information about the paper itself: title, authors, journal, publication date, funding;
5. Space for additional notes;
6. Papers identified during backward reference search.

The data extraction will be handled in a digital form. Data collection forms will be stored as Excel files with respect to the predefined scheme. In order to ensure the appropriate quality of data extraction, in every case at least two independent researchers should complete the data collection form. Later, they will be compared and any disagreements should be solved then. In the event if it is impossible due to lack of time, the supervisor may perform data extraction on a random sample of the primary studies and compare the results with the main reviewer. The data collection form is presented in Table 2:

<table>
<thead>
<tr>
<th>Data Item</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality assessment score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data extractor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data checker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary study metadata</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category of paper</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Data generalization

What data generalization methods, algorithms, and models, if any, were used?

What were the parameters of the generalization algorithm?

Are these methods automatic, semi-automatic, or manual?

What tools, software, and programming language were used to perform generalization?

Is there any information available about the accuracy of the process? How was it measured?

### Automatic map generation

Is the study anyhow related to the automation of map production?

What types of maps are tested?

Is automation described in terms of: costs, time, and accuracy?

Was the automation successful?

Name the systems and solutions presented in the paper.

### Data sources

What type of data was used? (vector/raster, analogue…)

Are any spatial data sources mentioned?

How detailed was the data used?

What was the data extent on a map (scale, range)?

Describe the database used.

### Various

If the study is related with the visually impaired, what is it about?

(tactile mapping, tactile graphics, navigation/orientation issues, other)

If 3D printing was used, name the technique and material.

Were any tests with users carried out?

What was the sample size?

Were the users blind or visually impaired?

Highlight any new findings/conclusions after paper-screening

Papers identified during backward reference search

Other remarks

### 6. Synthesis

The results obtained from different primary studies will be sorted in tables to highlight the similarities and differences between them. The main emphasis will be laid on potential differences in the results of automatic map generalization. It is expected that different studies will present various answers to the questions: whether full automation of this process is possible or not and what restrictions/problems were faced. Are the resulting products useful? What sources were used to perform generalization?

It is planned to conduct a quantitative synthesis wherever applicable, i.e., for quantitative data related to research questions. This data will be grouped and presented on graphs, charts and in tables. All clearly irrelevant results, i.e., papers that do not address any aspect of the research questions, will be discarded.

### 7. Reporting and Schedule
The Systematic Literature Review is going to be published in one of the major journals regarding cartography and GIScience in the year 2019. The goal is to have it published in Transactions in GIS in which the most relevant systematic literature reviews have been published so far (in the field of GIScience and cartography).

The results will also be propagated at some upcoming conferences in the field of GIScience and Cartography. This kind of dissemination of the results might turn out helpful in terms of promoting the idea of systematic literature reviews that is not very popular among researchers working in GIScience and cartography. Moreover, this type of literature review is not very popular in XXX, especially in technical and earth sciences.

Results of this Systematic Literature Review are going to be included in the PhD dissertation of the main author, forming a chapter related to literature review.

### Table 3. Review schedule.

<table>
<thead>
<tr>
<th>Name of the Task</th>
<th>Start Date</th>
<th>End Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Preparing the Review Protocol</td>
<td>1 April 2018</td>
<td>31 May 2018</td>
</tr>
<tr>
<td>2 Literature query</td>
<td>1 June 2018</td>
<td>31 July 2018</td>
</tr>
<tr>
<td>3 Title–Abstract–Keyword scanning</td>
<td>1 August 2018</td>
<td>31 August 2018</td>
</tr>
<tr>
<td>4 Full paper screening and data extraction</td>
<td>1 September 2018</td>
<td>30 November 2018</td>
</tr>
<tr>
<td>5 Synthesis</td>
<td>1 December 2018</td>
<td>31 January 2019</td>
</tr>
<tr>
<td>6 Writing the article</td>
<td>1 February 2019</td>
<td>31 March 2019</td>
</tr>
</tbody>
</table>

8. References