論文の内容の要旨
Dissertation Abstract

論文題目 Dissertation Title	Constrained Optimization Approaches to Customizing Layout and Annotation for Metro Maps （地下鉄路線図のためのデザインと注釈ラベル配置をカスタマイズする制約付き最適化手法）
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Metro maps are common media for providing information about public transportation means, and usually available in every major city to help travelers make full use of the corresponding transportation systems. Generating aesthetic layout of such metro maps will significantly improve their readability, and thus is important also from a practical viewpoint. Indeed, Harry Beck invented schematic representation of London Underground map by introducing several aesthetic criteria for rearranging the layout of the metro network. His criteria have been commonly employed by contemporary map illustrators when they draw schematic representations of metro maps, for example, in travel guidebooks.

On the other hand, annotating metro maps with text and image labels can provide supplemental information, and thus can facilitates travelers to effectively find sites of interest and their associated routes over the metro network. Actually, map illustrators often seek aesthetic layouts of both the metro network and large annotation labels, and successfully arranged their positions to increase the space coverage over the map domain. However, as a computational problem, optimal placement of such large annotation labels has been explored independently of the layout of metro networks. Automatically tailoring the aesthetic layout of a metro network and its associated annotation labels together is still a challenging task, due to not only the computational complexity of each individual layout problem but also that for finding a plausible compromise between these two problems.

This thesis presents a novel approach to customizing annotated metro maps by solving this hybrid problem of metro map layout and annotation. The contribution of this thesis is three-fold (see Figure 1). We first tackle the metro map annotation problem by developing a zone-based approach for placing annotation labels while keeping the original layout of a metro network unchanged. This is accomplished by tightly enclosing the metro network to maximally utilizing available labeling space around it. For placing annotation labels while minimizing the total leader lengths, we incorporated evolutions algorithms so that we can embed labeling boxes into specific zones according to their types. We then pursue the metro map layout problem by introducing travel-route-centered design of metro maps. This allows us to aesthetically deform the map layout by elongating a specific route over the metro network to be straight along the centerline of the map domain. Annotation labels are constrained to be placed at the top and bottom of the map domain in this approach for annotating all the stations along the specified route. Finally, we compose a hybrid approach for solving both the metro map layout and annotation problems by seeking maximum space efficiency of the map contents. Indeed, with this approach we try to place annotation labels as compactly as possible while keeping the aesthetic layout of the metro network. The associated computational complexity has been significantly reduced by a newly developed three-step algorithm, where we can also select the stations to be annotated while adjusting the size of the corresponding annotation labels.

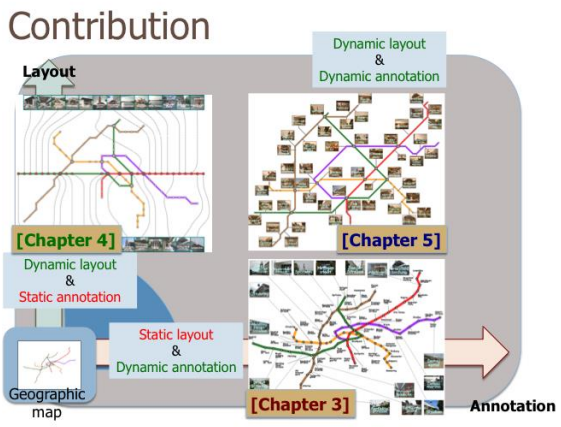

Figure 1: Organization of this thesis. In Chapter 3, we tackled the label placement problem. In Chapter 4, we tackled the label rearrangement problem. In Chapter 5, we tackled the hybrid problem of the above two.

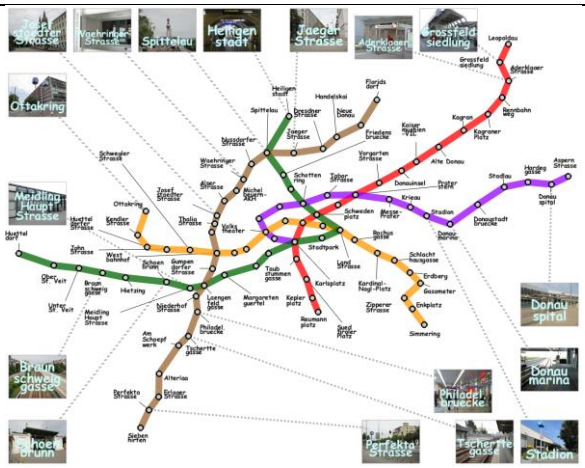

Figure 2: The result of our zone-based approach to annotating image annotation on geographic metro layout.

The idea behind our approach is to formulate the aesthetic criteria for designing metro map layout and annotation as constraints imposed on the metro network, and solve the associated map composition problem as a constrained optimization problem. Our computational tools for solving such constrained optimization problems are genetic-based formulation, minimum-cost maximum-flow problem formulation, and mixed-integer programming formulation. The genetic-based formulation allows us to embed annotation labels within the available labeling space around the metro network while avoiding mutual intersections between labeling boxes and leaders (Figure 2). The minimum-cost maximum-flow problem formulation makes it possible to explore the curved leader shapes between stations on the straight centerline route and boundary labels while maximally reducing the number of intersections between the label leaders and the underlying metro line segments (Figure 3). The mixed-integer programming formulation searches for octilinear layouts of the metro network together with well-balanced distribution of annotation labels around it (Figure 4). Our contribution lies in the new formulation of such constrained optimization problems for aesthetic design of annotated metro maps together with implementation of computational algorithms for solving them. Several design examples are also presented to demonstrate the feasibility of this approach, which is followed by user studies and discussion on the limitations of the present formulation.

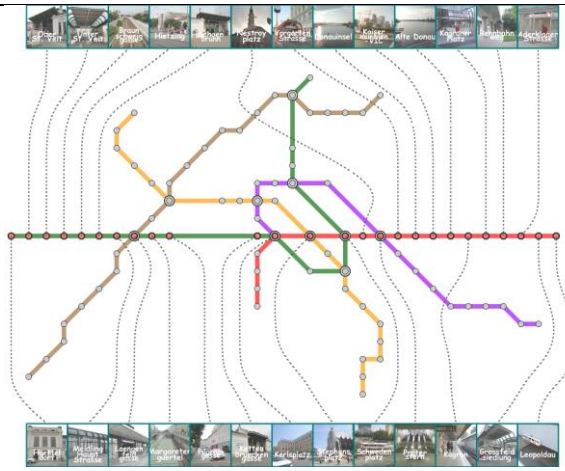

Figure 3: The result of our approach to designing annotated travel-route-centered metro map.

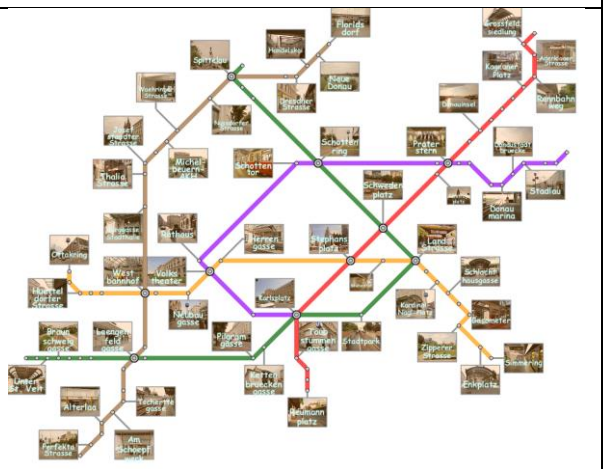

Figure 4: The result of our approach for spatially efficient design of annotated metro maps.