Methodology In this chapter, a brief description of the Data and the definition of the Registration Problem will be
Data The CityGML models are public data in some states in Germany, for example, in Nordrhein-Westfalen [?]. O
Besides the representation of the building, CityGML models provide other interesting information about the buildi
The point cloud data is collected and provided by the A-DRZ project partners that develop and operate the actual
fig:initial$_{f}ront_{m}odelandfig: initial_{b}ack_{m}odelshowaCityGMLmodelanditscorrespondingpointcloudbeforebeingreg$
Unfortunately, there is no ground truth for the registration of the data available. Therefore, the results are evaluate
[htp] 1 [scale=0.2]images/solution$_{i}mages/initial_{f}ront_{m}odel.pngFrontview.$
Setup The main setup is depicted in fig:system$_{d}iagram.TheinputofthesystemisaCityGMLmodelanditscorrespond$
Registration Problem in 3D In general, the registration task consists of finding the transformation that aligns the i
More specifically, given a source point set $P = \{p_i\}_{i=1}^{N}$, where $p_i \in R^4$, and a target point set $Q = \{q_j\}_{j=1}^{M}$, where q

where $d(Tp_i, q_j)$ is the Euclidian distance between Tp_i and q_j. The points p_i and q_j are points in homogeneous coo
In this case, the point set P corresponds to the point cloud, while the point set Q corresponds to the CityGML mo
The difficulty of this task is to find correspondences between P and Q that minimizes eq:lossfunction. If the corres
Registration Problem in 2D To simplify the problem, one can transform the 3D registration problem into a 2D regi
The registration problem in 2D remains the same as in 3D, but $p_i \in R^3$, $q_j \in R^3$, and $T \in SE(2)$. As in the 3D reg
Registration Problem as a Mixed Integer Linear Program The 3D registration problem defined in section:Registrati
There is a matrix $X \in R^{N\times M}$ that represents the correspondences between P and Q. That means that $x_{ij} = 1$ if t
Then, there should be a homogeneous transformation T that transforms the point p_i into the point q_j, for all i, j w
More formally, the objective of the Mixed Integer Linear Program is to maximize:

subject to:

eq:subject$_{s}um_{r}owsandeq: subject_{s}um_{c}olumnsconstrainttoonethenumberofcorrespondencesthatapointcanhave, i.$
eq:subject$_{t}ransformation_{0}, eq: subject_{t}ransformation_{n}egative_{0}, eq: subject_{t}ransformation_{1}, andeq: subject_{t}ra$
eq:subject$_{l}ines_{p}reservationisusedtopreservelinesbetweenpointsafterthetransformation.If \mid d(p_i, p_k) - d(q_j, q_l) \mid \geq$
The elements of T are constrained by lower (δ_1^-, δ_2^-, t_x^-, and t_y^-) and upper (δ_1^+, δ_2^+, t_x^+, and t_y^+) boundaries in eq:s