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# Generation of test data for Scheduled Paratransit Transport Systems

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## Lab Report, 2013-05

# 1 Introduction

In this report we describe the creation of random test data for the case of Scheduled Paratransit Transport Systems (SPTS). SPTS focus on flexible public transport services that address the needs of the elderly, as well as of people with a disability. In this flexible transport services a bus operating in a public transport route may diverge from its nominal path to pick-up passengers with limited mobility and drop them off at their destination. The generator described in this report aims to create appropriate test instances that simulate practical problems within three distinct environments: a) Urban, b) Suburban, and c) Rural. The data generator uses special techniques to produce test instances that incorporate the characteristics of each of the three aforementioned environments.

# 2 Random Test Data Generator for SPTS

The data generator for SPTS deals with four main aspects: a) the locations of the regular bus stops, b) the locations of the pick-up and delivery requests, c) the latest time of arrival at each regular bus top, and d) the earliest and latest drop-off times of the paratransit requests. The processes that address aspects (a), (c) and (d) are the same for all environments, while the procedure for aspect (b) differs depending on the type of environment. The generator constructs problem instances given the following parameters (inputs):

a) $m$ the number of regular bus stops
b) $k$ the number of the scheduled bus trips
c) $n$ the number of paratransit requests
d) $\rho$ the average distance between two sequential regular bus stops
e) $u$ the average vehicle speed
f) $f$ the time period between two consecutive bus trips (headway)
g) $d$ the coefficient of the allowed delay w.r.t. the nominal bus trip at each bus stop
h) $\xi$ the width of the drop-off time windows for the paratransit requests

**Regular Bus stop locations:** The location of a regular bus stop is defined w.r.t. the location of the previous regular bus stop. The coordinates from this latter origin are the distance $r$ and the angle $\theta$, where $r$ is randomly generated in the interval $[\frac{4}{5}\rho, \frac{6}{5}\rho]$ and $\theta$ is randomly generated in the interval $[-60^o, +60^o]$. Figure 1 shows the region for the location of bus stop $i+1$ with respect to location of bus stop $i$. The location of the first bust stop is considered to be known.

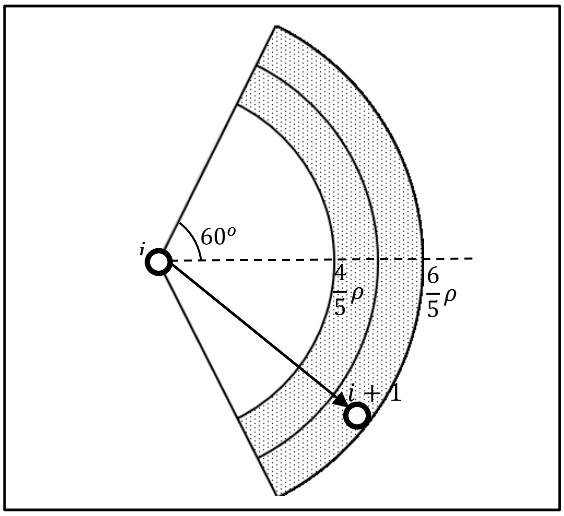


**Figure 1: Area for the locating bus stop $i + 1$ w.r.t.to bus stop $i$**

**Pick-up and drop-off locations of paratransit requests in the Urban environment:** The allowable regions in which the pick-up and drop off locations lie are ellipses. Each ellipsis has as foci two sequential regular bus stops and its longest diameter (major axis) is equal to $\omega$. The related construction procedure for the generating a pick up location is the following:

a) A regular bus stop $h$ is selected uniformly from $\{1, \ldots, m-1\}$, where $m$ is the last regular bus stop of the sequence
b) The ellipse is created using the locations of regular bus stops $h$ and $h+1$ as foci points, and
c) The pick-up location is selected randomly from the area of the ellipse using a uniform distribution

The drop-off locations are created by the same procedure, but in this case the reference bus stop $g$ is selected randomly from the set $\{h+1, \ldots, m\}$. Figure 2 illustrates the geometry of the above procedure.

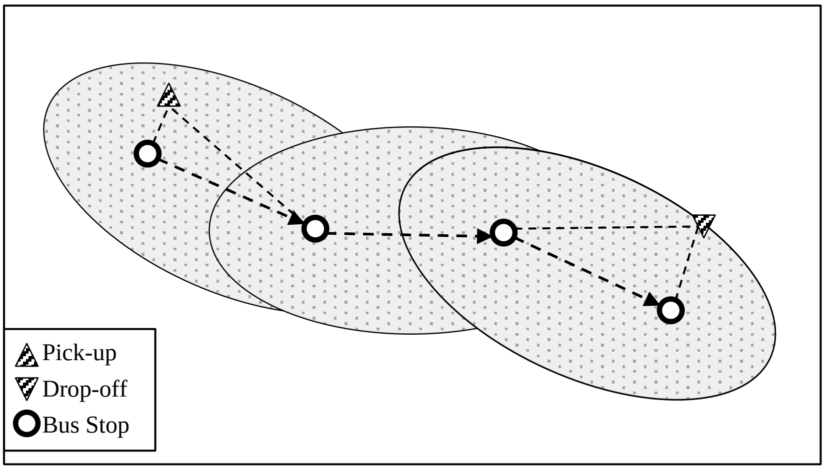


**Figure 2: Creation of a pick-up and a drop-off location in urban environment**

**Pick-up and drop-off locations of paratransit requests in a Suburban environment:** A procedure similar to the one above is followed. However, in this case the selection of the reference bus stops $h$ and $g$ is different; $h$ is selected from $\{1, \dots, m-2\}$ considering that the probability of selecting points $\left\{1, \dots, \left\lceil\frac{m}{4}\right\rceil\right\} \cup \left\{\left\lceil\frac{2m}{4}\right\rceil, \dots, \left\lceil\frac{3m}{4}\right\rceil\right\}$ is two times the probability of selecting the remaining points in the set. $g$ is selected randomly with respect to the reference bus stop $h$ as follows:

- If the reference bus stop $h$ is in the first half of the route ($h < \left\lceil\frac{m}{2}\right\rceil$), then $g$ is selected from the set $\{h+1, \dots, \left\lceil\frac{m}{2}\right\rceil\}$, considering that the probability of selecting points $\{\left\lceil\frac{m}{4}\right\rceil, \dots, \left\lceil\frac{2m}{4}\right\rceil\}$ is two times the probability of selecting the remaining points in the set
- If the reference bus stops $h$ is in the second half of the route ($h \geq \left\lceil\frac{m}{2}\right\rceil$), then $g$ is selected from the set $\{h+1, \dots, m-1\}$, considering that the probability of selecting points $\{\left\lceil\frac{3m}{4}\right\rceil, \dots, m-1\}$ is two times the probability of selecting the remaining points in the set

This attempts to model the behavior of passengers that travel from a sub-urban area to the center of the city (the first half of the route) or vice versa (the second half of the route). Figure 3 illustrates the geometry of the regular bus stops, the pick-up and drop-off locations, and the ellipse areas for the suburban environment.

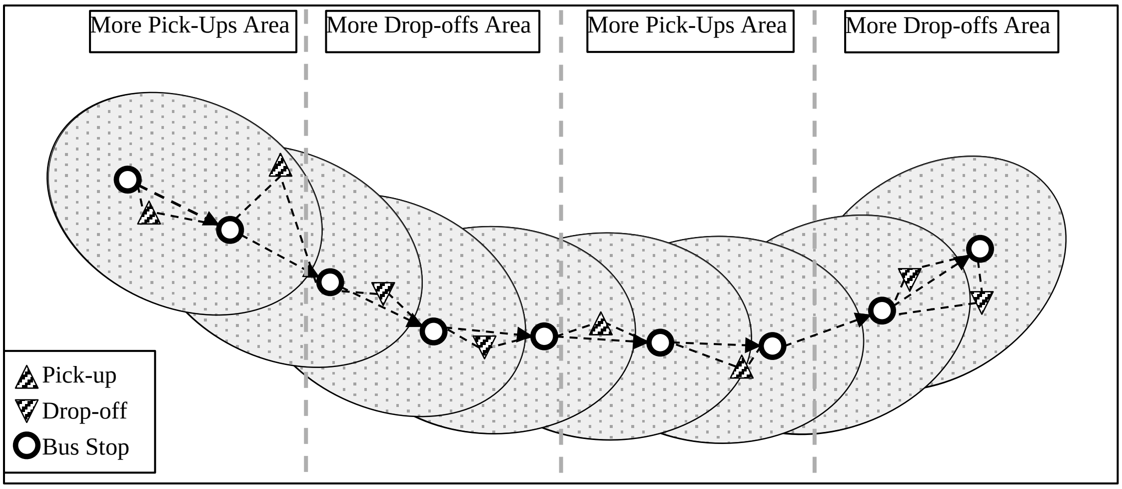


**Figure 3: Creation of a pick-up and a drop-off location for a suburban environment**

**Pick-up and drop-off locations of paratransit requests in a Rural environment:** The selection process for the reference bus stops $h$ and $g$ is similar to the one used for the Urban environment. The difference lies in the allowable regions, which, in this case, are circles of radius $\overline{\omega}$ centered at the locations of the reference bus-stops, respectively. This construction procedure attempts to model the fact that residences in rural areas tend to be distributed around the center of the communities. Figure 4 illustrates this process.

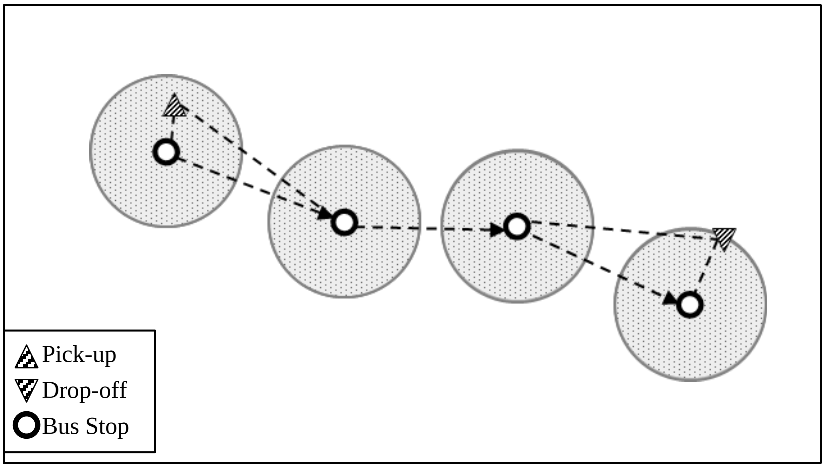


**Figure 4: Creation of a pick-up and a drop-off location in rural environment**

**Earliest and latest times of arrival at a regular bus stop:** The earliest time of arrival to a regular bus stop is the minimum time to travel from the route origin (first regular bus stop) to the one under consideration. The latest time of arrival is determined by adding to this earliest time the time required to travel an additional distance $d \times \rho$, where $\rho$ is the average distance between two sequential regular bus stops. Hence, $d$ determines the service level for the regular bus line passengers.

**Earliest and latest drop-off times of the paratransit requests:** In the formulation of Section 2, only the earliest and latest drop-off times are defined, since the pick-up time is a decision variable related to the ride time. Thus, in the test cases of Section 4 the latest drop-off time is defined as follows:

- a random bus trip is selected, e.g. $\tau$
- the minimum time to travel from the first regular bus stop to the bus stop that is closer to the drop off location through the respective pick-up location is calculated, e.g. $\zeta$
- the time from the latter bus stop to the drop-off location itself, e.g. $\varphi$
- then, the actual latest drop-off time will be equal to $\tau \cdot f + \zeta + 2 \cdot \varphi$, where $f$ is the headway between consecutive trips

The earliest drop off time is defined as the difference of the latest drop-off time minus a service parameter $\xi$. This parameter defines the maximum allowable time to drop off a paratransit customer before her/his requested time.