HyperPath: a new journey planner for dynamic routing on transit networks

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Phenomena, ingredients and topics of the research

- Route choice of passengers on multimodal networks
  - strategies and hyperpaths
  - mixed schedule-based and frequency-based lines

- Dynamic aspects
  - within day / time dimension
  - real-time / on-line information
  - en-route adaptive route choice
  - performances and reliability / line headway distributions

- ITS to support passenger trips
  - avl for information besides operation
  - journey planners
  - point-to-point passenger navigation
Features and functionalities for a new journey planner

- Multimodal transit networks - a mixture of service types
  - scheduled based - reliable arrival times at stops of single runs
  - frequency based - passengers perceive line headway distribution at stops
  - continuous service connections
- Pedestrian network - different approach depending on available data
  - implicit connection based on geographic distance relation
  - fast pedestrians to reproduce access to main transit stops
  - topology explicitly introduced
- Transit travel times - different approach depending on available data
  - based on commercial speeds
  - based on the road travel time plus a dwelling time at stops
  - based on historic avl data that are time-varying for each section
  - based on the programmed schedule
Features and Functionalities for a new journey planner

- Regularity besides frequency
  - simulate the effect on waiting times of more regular headway distribution

- Fare structure
  - kilometric fees for each line
  - boarding fees for each line stop
  - zone based (origin-destination) matrix for more complex fares

- Passenger strategies
  - passenger at a transit stop board the first arriving carrier of an attractive line set
  - common (partially overlapping) lines
  - alternative paths (hyperpath)
Features and Functionalities for a new journey planner

- **Multiple modes**
  - link attributes stratified by mode (speeds, closures, tolls, costs)

- **Travelling preferences**
  - value of time, multiplier of walking and waiting times, additional costs for transfers and change of hierarchy
  - bundled in a user class, e.g. fast, simple, little walking, low cost
  - personalized for each route request
  - sensitivity analysis to look for alternative routes with a similar cost

- **Park and Ride**
  - optimal routing of intermodal trips through commuting terminal
  - time-varying delays and costs of each parking facility
Features and Functionalities of the software HyperPath

- Actual trip terminals and geocoding
  - origin and destination typed in a free text Google style; street addresses or point of interests
  - clicking a point on the map and apply reversed geocoding
  - street database and proprietary module or google api, for address disambiguation
- Precise connection to the transport network
  - implicit connection of actual origin and destination points to multiple nodes of the network
- Access and egress alternatives
  - with different speed and cost of travelling along implicit direct link
- Waypoints
  - set of intermediate points with the corresponding duration of the stops
Features and Functionalities of the software HyperPath

- Fast algorithm - computing times vary less than linearly with the number of nodes
  - flexible bucket list
  - A* like speed-up
  - parallel computation of different requests
  - real time computation using the most recent available information

- Dynamic shortest paths
  - dynamic link and line attribute piece-wise constant or linear
  - shortest hyperpath natively dynamic
  - estimated/forecasted performances that will occur at the actual time when the user will travel on each link of the network
  - requires to ask the user also for his/her arrival time to the destination
Features and Functionalities of the software HyperPath

- **Road network**
  - navigation details: turn prohibitions and access limitations, in addition to speed and intersection delay for each directional link, mode specific tolls and costs
  - truck routing attributes: tortuosity, steepness, bridges, tunnels, left and right turns at intersections, urban context, change of street hierarchy level, major roads

- **Import formats**
  - road network from Navteq or TeleAtlas
  - transit network from Google, Visum or Maior

- **Flexible map projections**
  - background images
  - network data (lines, stops)
  - proposed route
Features and Functionalities for a new journey planner

- Route description
  - textual format, as a sequence of actions
  - graphical format, as a sequence of polylines
  - link by link statistics

- Features of the graphical interface
  - bidirectional clicks from textual to graphical outputs
  - line offset on the map to avoid overlapping segments
  - attributes on the map, selected links as in a web gis
  - hierarchical text list of actions for hyperpaths
  - comprehensive log
  - multilanguage
Features and Functionalities for a new journey planner

- **System access**
  - web from computer
  - smart phones dedicated pages

- **Additional features**
  - OD matrix estimation using historic set of paths requested
  - traffic map with los as a background

- **Traffic events**
  - manually introduce road closures and speed reductions
  - events are taken into account in real-time
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Algorithm for mixed frequency and scheduled lines

function MIXL(m, o, d, τ, ν)
    ν = ν + 1
    x₀ = 0
    z₀ = τ
    s₀ = -1 \quad (-1 \text{ indicates that node } i \text{ is the destination})
    q₀ = 0
    y₀ = μ \cdot x₀ + γ \cdot VT_m \cdot L_{od} / VA_m \quad (VT_m \text{ value of time, } VA_m \text{ average speed})
    ν₀ = ν
    B = \{d\}
    j = d

do until j = o or B = ∅
    B = B - \{j\}
    for each α \in BS(j)
        i = TL(α)
        (t, c, k) = APF(α, m, q₀, z₀, ν₀)
        if α \in AB and ℓ(j) \in FB and ν_i = ν then c = 0
        if ν_i < ν or x_i > x_j + c then
            if α \in AB and ℓ(j) \in FB and ν_i = ν then
                x_i = x_j + c
                z_i = z_j / t
                H_i = 1 / (1 / H_j + 1 / t)
                x_i = x_i \cdot H_i
                z_i = z_i \cdot H_i
                s_i = -2 \quad (-2 \text{ indicates that the successive of node } i \text{ is a hyperarc})
            end if
        end if
    end for
    if α \in AB and ℓ(j) \in FB then
        H_i = t
        x_i = x_j + c
        z_i = z_j - t
        s_i = a
        ν_i = ν
    end if
    if i \in B then
        B = B - \{i\}
        y_i = μ \cdot x_i + γ \cdot VT_m \cdot L_{oi} / VA_m
        B = B + \{i\}
    end if
end do
next α
j = arg\min\{y_i : i \in B\}
loop
end function
Arc Performance Function
mode coefficients

Each mode $m$ is specified through its generalized cost coefficients:

- $VT_m$: value of time
- $VM_m$: value of money
- $VD_m$: value of distance
- $CR_m$: riding time coefficient
- $CP_m$: walking time coefficient
- $CW_m$: waiting time coefficient
- $VW_m$: walking speed
- $VA_m$: average speed
- $VL_m$: speed limit on connections
- $OF_m$: occupancy factor on connections
- $HD_m$: perceived delay for change of link hierarchy on connections
Let $\mathcal{F}$ be the set of transit lines. Each line is characterized by the following features:

- $f(i) \in \mathcal{F}$: line associated with line node $i \in \mathcal{N}$
- $R(a) \subseteq AR$: sequence of support arcs associated with on-board arc $a \in AO$
- $VC_t$: commercial speed of line $t \in \mathcal{F}$
- $KF_t$: kilometric fee of line $t \in \mathcal{F}$
- $BF_t$: boarding fee of line $t \in \mathcal{F}$
- $HW_t$: expected headway of line $t \in \mathcal{F}$
- $RG_t$: regularity of line $t \in \mathcal{F}$; $0$ means deterministic headway, $1$ means exponential, $> 1$ means higher regularity ($\infty$ means again deterministic headway)
- $NR_t$: number of runs of line $t \in \mathcal{F}$
- $ST_{ik}$: schedule time of the $k$-th run of line $f(i)$ at (stop) node $i \in \mathcal{N}$, $k \in [1, NR_{t(0)}]$
- $RV_{ik}$: validity (a set of days) of the $k$-th run of line $f(i)$ at (stop) node $i \in \mathcal{N}$, $k \in [1, NR_{t(0)}]$
- $PR_{ik} \in [0, NR_{t(0)}]$: index of the first run preceding time $\tau_h = h \cdot \Delta t$, with $h \in [0, n]$, for line $f(i)$ at stop node $i \in \mathcal{N}$; $0$ means no preceding run
- $SV_{i}$: validity (a set of days) of line node $i \in \mathcal{N}$
- $RT_a$: riding time of line $f(TL(a)) \in \mathcal{F}$ along arc $a \in AL$; $0$ means no riding time available
- $HM$: maximum headway (for all lines)
Arc Performance Function
road and connection arcs

\[
\text{function} \ (t, c, k) = \text{APF}(a, m, q, z) \\
\quad i = TL(a) \\
\quad j = HD(a) \\
\quad \text{if} \ a \in AR \ \text{then} \\
\quad \quad \text{if} \ VL_m > 0 \ \text{and} \ VL_m \leq 1 \ \text{then} \\
\quad \quad \quad t = L_a / (VL_m \cdot V_a) + \delta_a \\
\quad \quad \text{else if} \ VL_m > 1 \ \text{and} \ VL_m < V_a \ \text{then} \\
\quad \quad \quad t = L_a / VL_m + \delta_a \\
\quad \quad \text{else} \\
\quad \quad \quad t = L_a / V_a + \delta_a \\
\quad \text{end if} \\
\quad c = VT \cdot t + VM_m \cdot MTam / OF_m + VD_m \cdot L_a + OCam / OF_m \\
\quad \text{if} \ HC_a = 1 \ \text{then} \ c = c + VT \cdot HD_m \\
\quad k = 0 \\
\quad \text{else if} \ a \in AC \ \text{then} \\
\quad \quad \text{if} \ VL_m > 0 \ \text{and} \ VL_m \leq 1 \ \text{then} \\
\quad \quad \quad t = L_a / (VL_m \cdot V_a) + \delta_a \\
\quad \quad \text{else if} \ VL_m > 1 \ \text{and} \ VL_m < V_a \ \text{then} \\
\quad \quad \quad t = L_a / VL_m + \delta_a \\
\quad \quad \text{else} \\
\quad \quad \quad t = L_a / V_a + \delta_a \\
\quad \text{end if} \\
\quad c = VT \cdot t + VD_m \cdot L_a \\
\quad k = 0
\]
else if \( a \in AO \) then
  if \( q > 0 \) then
    \[ t = ST_{jq} - ST_{iq} \]
  else if \( RT_a > 0 \) then
    \[ t = RT_a \]
  else if \( VC_{t(i)} > 0 \) then
    \[ t = \sum_{b \in R(a)} L_b / VC_{t(i)} \]
  else
    \[ t = \sum_{b \in R(a)} L_b / V_b + \delta_b \]
end if

\[ c = VT_m \cdot CR_m \cdot t + VM_m \cdot \sum_{b \in R(a)} L_b \cdot KF_{t(i)} + VD_m \cdot \sum_{b \in R(a)} L_b + \sum_{b \in R(a)} L_b \cdot KC_{t(i)} \]
\[ k = q \]
else if \( a \in AB \) then
  if \( q > 0 \) then
    if \( \ell(j) \in SB \) then
      \( t = 0 \)
    else (if \( \ell(j) \in FB \) then)
      \( h = q + 1 \), do until \( \nu \in RV_{jh} \) or \( h > NR_{\ell(j)} \) : \( h = h + 1 \) loop
      if \( h > NR_{\ell(j)} \) then \( t = 0.5 \cdot HM \) else \( t = 0.5 \cdot (ST_{jh} - ST_{jq}) \)
    end if
  else
    \( t = 0.5 \cdot HW_{\ell(j)} \)
  end if
else
  \( t = 0.5 \cdot HW_{\ell(j)} \)
end if
if \( RG_{\ell(j)} > 0 \) then \( t = t \cdot (1 + 1 / RG_{\ell(j)}) \)
\( c = VT_m \cdot CW_m \cdot t \)
\( k = 0 \)
else if \( a \in AA \) then

\[ \text{if } NR_{\ell(i)} > 0 \text{ and } \nu \in SV_i \text{ then} \]

\[ h = 1 + z \Delta \tau \] (note the integer division “\( \backslash \)"")

\[ k = PR_{\ell(i)}, \text{ do until } (ST_{ik} \leq z \text{ and } \nu \in RV_{ik}) \text{ or } k = 0: k = k - 1 \text{ loop} \]

else

\[ k = 0 \]

end if

if \( k > 0 \) then

\[ t = z - ST_{ik} \]

if \( \ell(i) \in SB \) then

\[ c = VT_m \cdot CW_m \cdot t + VM_m \cdot BF_{\ell(i)} + BC_{\ell(i)} + TC_m \]

else (if \( \ell(i) \in FB \) then)

\[ c = VM_m \cdot BF_{\ell(i)} + BC_{\ell(i)} + TC_m \]

end if

else if \( \nu \notin SV_i \) or \( NR_{\ell(i)} > 0 \) then

\[ t = \infty \]

\[ c = \infty \]

else

\[ t = 0 \]

\[ c = VM_m \cdot BF_{\ell(i)} + BC_{\ell(i)} + TC_m \]

end if