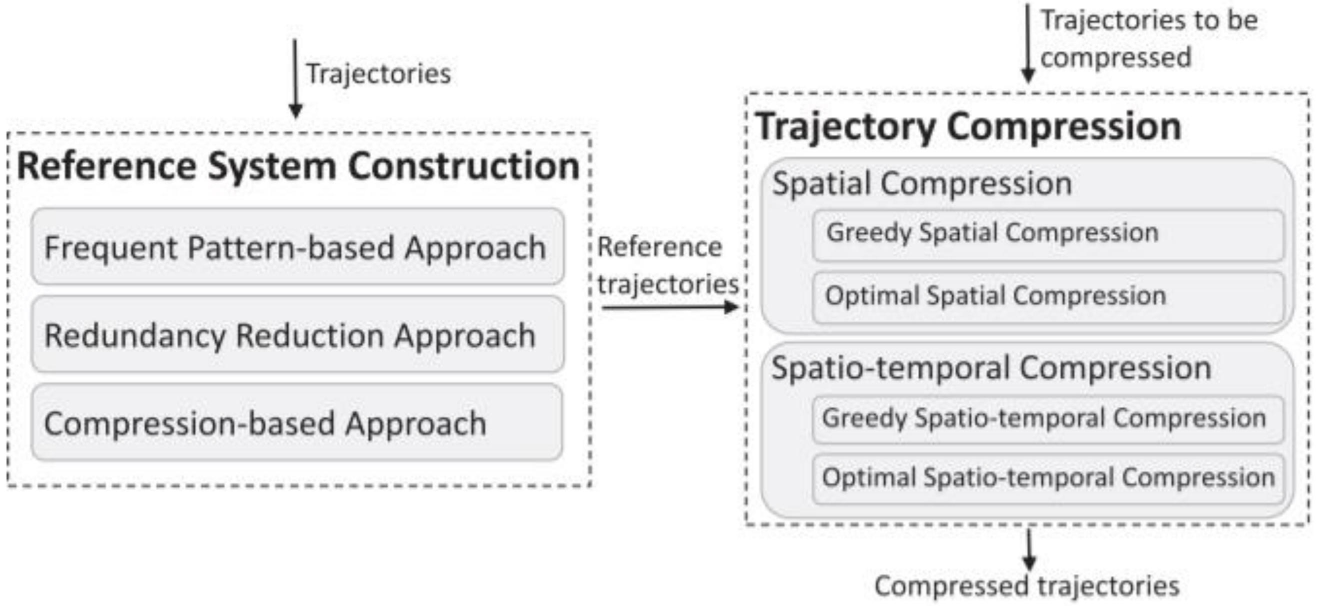
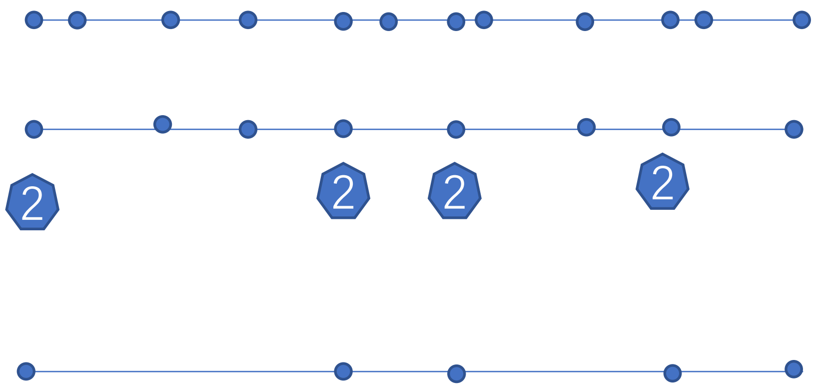
(2020IEEE TRANS)Reference-Based Framework for Spatio-Temporal Trajectory Compression and Query Processing



REFERENCE SET CONSTRUCTION

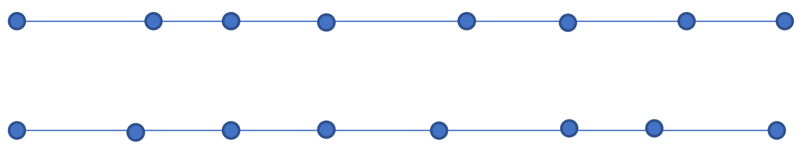
Frequent Pattern-Based Approach (FPA)



REFERENCE SET CONSTRUCTION

Redundancy Reduction Approach

Segment Redundancy Reduction (SRR)



$$d_{max} = \max_{0 \le k \le m} d(T_a.p_{i+k}, T_b.p_{j+k}) \le \epsilon_s.$$

Trajectory Redundancy Reduction (TRR)

$$L(T,R) = \frac{|p \in T | \exists q \in R, d(p,q) \le \epsilon_s|}{|T|} > \theta. \qquad (1)$$

SPATIAL COMPRESSION

Matchable Reference Trajectory

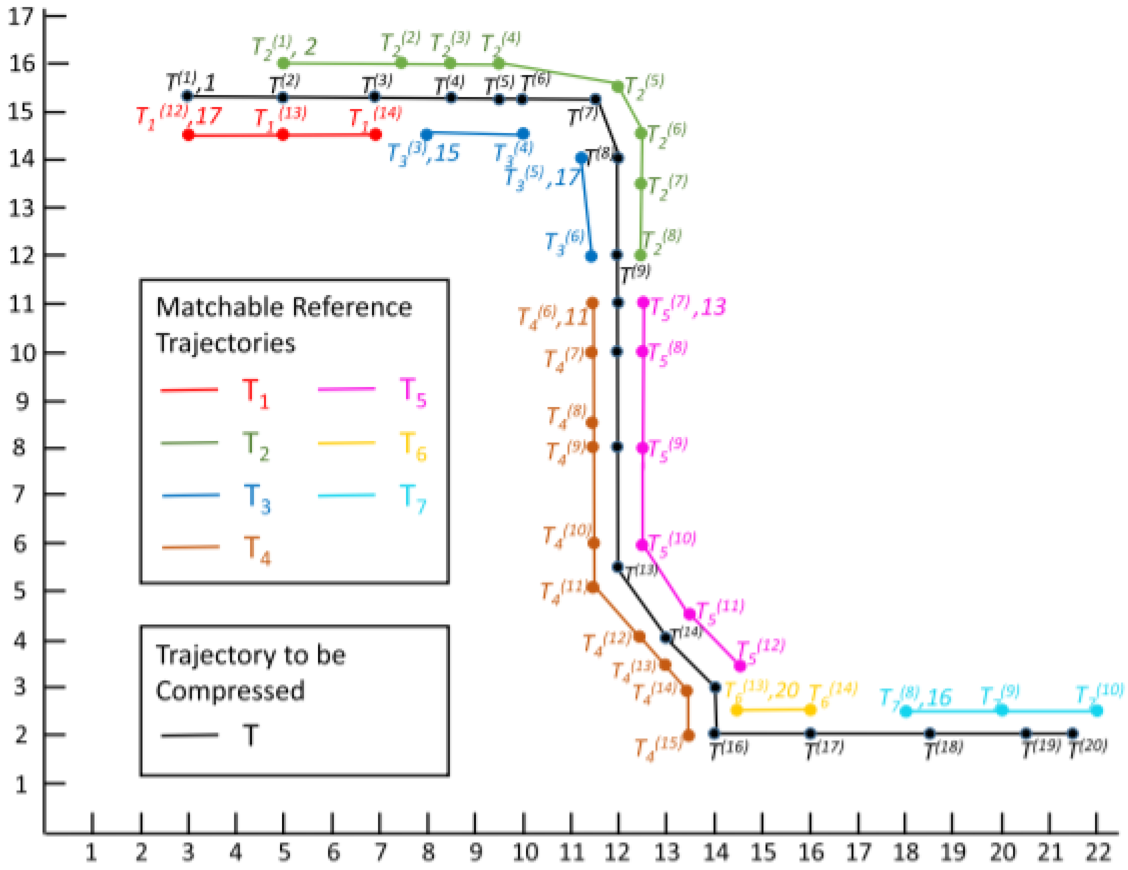
$$M(T^{(i,j)}) = \Big\{ \mathbb{T}^{(k,g)} \Big| \mathbb{T} \in R, 1 \leq k \leq g \leq |\mathbb{T}|, \\ MaxDTW(T^{(i,j)}, \mathbb{T}^{(k,g)}) \leq \epsilon_s \Big\}. \tag{2}$$

Algorithm 1. Matchable Reference Trajectory Search

Input: T, R, ϵ_s
Output: M
for *each* $T^{(i,i+1)} \in T$ **do**
  $M(T^{(i,i+1)}) \leftarrow$ MRT set for segment $T^{(i,i+1)}$;
for $n \leftarrow 3$ to $|T|$ **do**
  for *each length-n sub-trajectory* $T^{(i,j)} \in T$ **do**
    for $\mathbb{T}_a^{(m,n)}, \mathbb{T}_b^{(s,t)} \in M(T^{(i,j-1)}), M(T^{(j-1,j)})$ **do**
      if $MaxDTW(T^{(i,j)}, \mathbb{T}_a^{(m,n)}) \leq \epsilon_s$ **then**
        Add $\mathbb{T}_a^{(m,n)}$ into $M(T^{(i,j)})$;
      if $MaxDTW(T^{(i,j)}, \mathbb{T}_b^{(s,t)}) \leq \epsilon_s$ **then**
        Add $\mathbb{T}_b^{(s,t)}$ into $M(T^{(i,j)})$;
      if $a = b$ and $n = s$ **then**
        Add $\mathbb{T}_a^{(m,t)}$ into $M(T^{(i,j)})$;
  if *no length-n sub-trajectory has MRT* **then**
    Break;
return M;

Optimal Spatial Compression

$$F_T[i] = \begin{cases} 0 & \text{if } i = 0 \\ \min_{1 \leq j \leq i \wedge M(T^{(j,i)}) \neq \emptyset} \{F_T[j-1] + 8\} & \text{otherwise} \end{cases}, \quad (3)$$

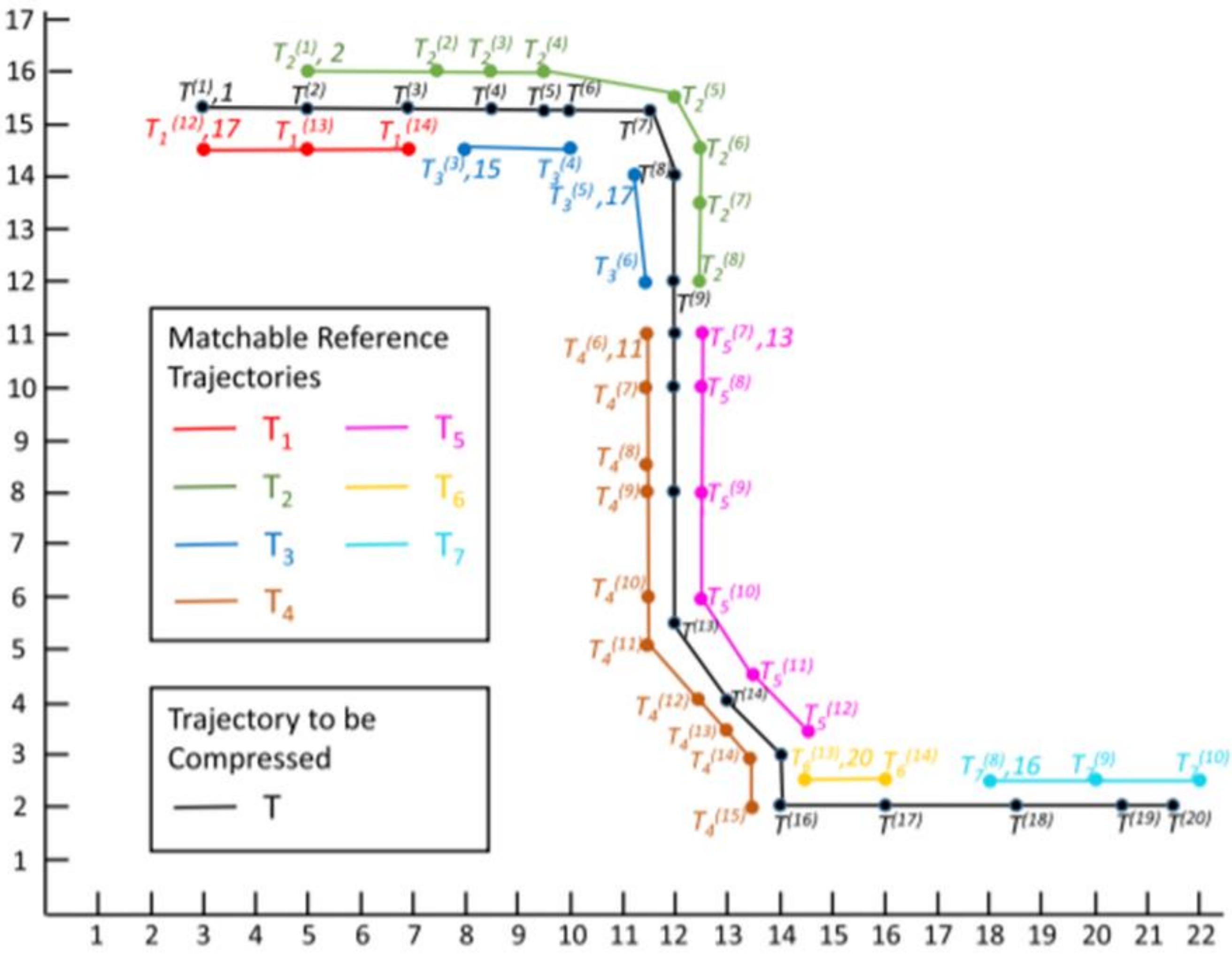


Optimal Spatial Compression

Algorithm 2. Optimal Spatial Compression

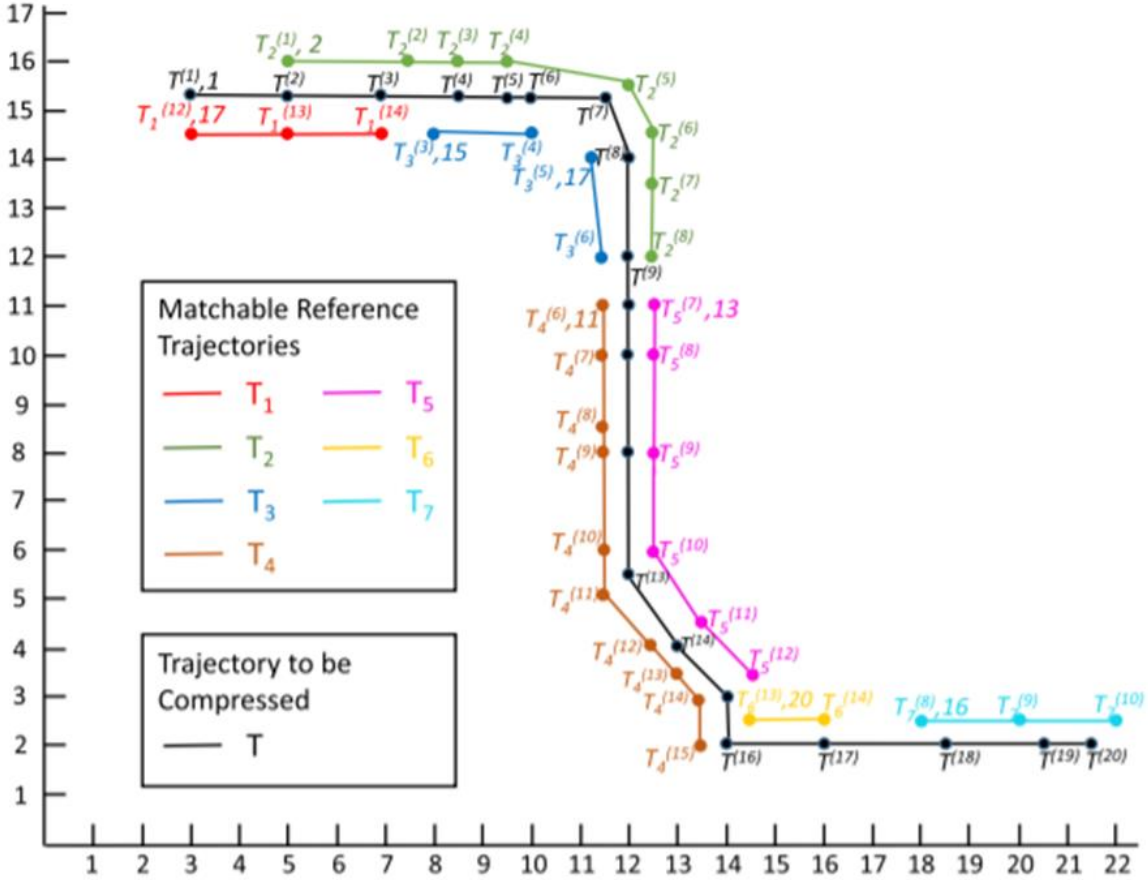
Input: T, $M(T)$
Output: T'

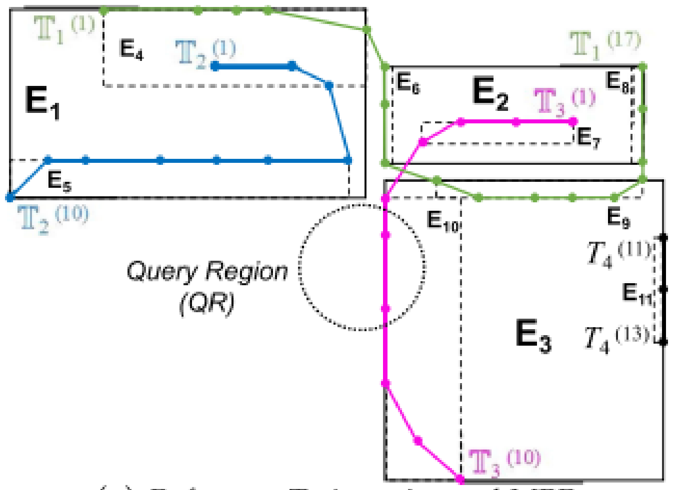
$T' \leftarrow null$;
$F_T[0] \leftarrow 0$;
for $i \leftarrow 1$ to $|T|$ **do**
  $min \leftarrow 8|T|$;
  for $j \leftarrow 1$ to i **do**
    if $M(T^{(j,i)}) \neq \emptyset$ *and* $F_T[j-1] + 8 < min$ **then**
      $min \leftarrow F_T[j-1] + 8$;
      $pre[i] \leftarrow j - 1$;
  $F_T[i] \leftarrow min$;
$i \leftarrow |T|$;
while $0 < i \leq |T|$ **do**
  if $pre[i] \leftarrow i - 1$ **then**
    Add p_i into T';
    $i \leftarrow i - 1$;
  else
    Add arbitrary $\mathbb{T}^{(k,g)} \in M(T^{(pre[i]+1,i)})$ into T';
    $i \leftarrow pre[i]$;
return T';



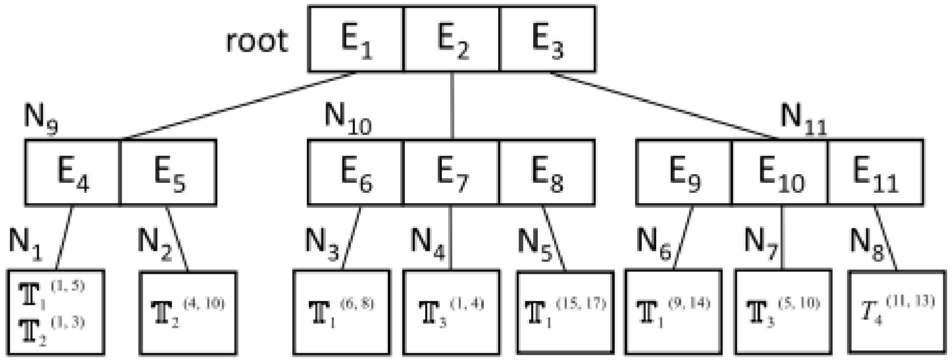
Optimal Spatio-Temporal Compression

$$F_T[i] = \begin{cases} 0 & \text{if } i = 0 \\ \min\Big\{F_T[i-1] + 12, \min\limits_{1 \leq j < i \wedge M(T^{(j,i)}) \neq \emptyset} \\ \{F_T[j-1] + C_{T^{(j,i)}}(M_{opt}(T^{(j,i)}))\} + 8\Big\} & \text{otherwise} \end{cases},$$





(a) Reference Trajectories and MBRs



(b) R-tree for Reference Trajectories

N_1: $\mathbb{T}_1$, $\mathbb{T}_2$: (raw trajectory, start time, end time)	N_2: $\mathbb{T}_2$: (raw trajectory, start time, end time)	N_3: $\mathbb{T}_1$: (raw trajectory, start time, end time)	N_4: $\mathbb{T}_3$: (raw trajectory, start time, end time)	N_5: $\mathbb{T}_1$: (raw trajectory, start time, end time)
$\mathbb{T}_1^{(1,5)}$: $(T_1^{(1,4)}, 4, 7)$, $(T_3^{(1,4)}, 4, 7)$ $\mathbb{T}_2^{(1,3)}$: $(T_1^{(5,6)}, 8, 9)$	$\mathbb{T}_2^{(4,10)}$: $(T_2^{(1,6)}, 1, 6)$, $(T_1^{(7)}, 10, 10)$	$\mathbb{T}_1^{(6,8)}$: $(T_2^{(7)}, 7, 7)$, $(T_3^{(5,7)}, 8, 10)$	$\mathbb{T}_3^{(1,4)}$: $(T_4^{(1,4)}, 5, 8)$	$\mathbb{T}_1^{(15,17)}$: NULL

N_6: $\mathbb{T}_1$: (raw trajectory, start time, end time)	N_7: $\mathbb{T}_3$: (raw trajectory, start time, end time)	N_8: T_4: (raw trajectory, start time, end time)	N_9	N_{10}	N_{11}	root
$\mathbb{T}_1^{(9,14)}$: $(T_4^{(5,10)},9,14)$	$\mathbb{T}_3^{(5,10)}$: $(T_2^{(8,13)},8,13)$, $(T_1^{(8,11)},11,14)$, $(T_3^{(8,12)}, 11,15)$	$T_4^{(11,13)}$: $(T_4^{(11,13)},15,17)$	$\mathbb{T}_1$: N_1 $\mathbb{T}_2$: N_1, N_2	$\mathbb{T}_1$: N_3, N_5 $\mathbb{T}_3$: N_4	$\mathbb{T}_1$: N_6 $\mathbb{T}_3$: N_7	$\mathbb{T}_1$: N_8, N_9, N_{10} $\mathbb{T}_2$: N_8 $\mathbb{T}_3$: N_9, N_{10}

(c) Data Structure of Each Node