The SCOOT Urban Traffic Control System
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What is SCOOT?

- The Split Cycle Offset Optimization Technique (SCOOT), is an online signal timing optimizer.
- It was developed in 1973 by the Transport Research Laboratory in the United Kingdom.
- It has been implemented into real-world application since 1979.
Development of SCOOT

- Early work - developed off-line software (TRANSYT) to calculate optimum signal settings for a signal network.
- Based on TRANSYT, SCOOT has been continuously developed as an on-line signal control system at early 1980’s.
- Version 3.1 included bus priority, database facilities and incident detection.
- Version 4.2 added estimates of the emission of pollutants.
- Version 4.5 enabled the bus priority to differentiate between different buses. (e.g. : to give more priority to late buses.)
- MC3 has enabled the Kernel software to safely use data supplied by packet switched communications systems, provided a congestion supervisor and increased the priority available to buses by allowing state skipping where it is appropriate.
Introduction

- **SCOOT**: it is designed for general application within a computerized Urban Traffic Control System.

- **Methodology**: it is a method of coordination that adjusts the signal timings in frequent, small increments to match the latest traffic situation.

- **Traffic Model**: data from vehicle detectors are analyzed by an on-line computer which contains programs that calculate traffic flows, predicted queues.

- **Optimisers**: three optimizers which are adapting – the amount of green for each approach (Split), the time between adjacent signals (Offset), and the time allowed for all approaches (Cycle Length).
System Architecture
How the SCOOT Works?

- **Upstream Detectors**
- **On-line Traffic Model**
- **Up-stream Cycle Flow Profile**
- **Down stream Predict Requirement**
- **Signal Optimiser**
- **Signal Timing Plan**
- **Local Controller**
Both SCOOT and TRANSYT employ the traffic model to predict the delay and stops caused by particular signal settings;

In the case of TRANSYT, the model is off-line and it predicts the average delays that resulted from specified average flows;

The SCOOT model is on-line that the predictions of delay are re-calculated every few seconds from the latest measurements of traffic behaviors.
SCOOT Traffic Model

1. Vehicle Detection
2. Cycle Flow Profile
3. Prediction of Queues
4. Congestion
5. Measurement of Travel Behavior
Vehicle Detections

- The vehicle detectors are placed at the upstream of the stop-line;
- The detectors are located as far upstream as possible from the stop-line;
- Normally, the distance between detector and stop-line is larger than the maximum potential queue length;
- If the actual queue length is larger than the distance, then the system would get the warning of congestion, and the corresponding function would be effective;
- For the specific bus priority control, a set of bus detectors should be installed.
Cyclic Flow Profiles (CFP)

- The data from detectors are stored in the SCOOT system as the form of “Cyclic Flow Profiles”.

- The profile patterns tend to be repeated and coupled with new data in a cyclic sequence to avoid large random fluctuation in the profile.

- The cycle flow profiles contain the information needed to decide how best to coordinate adjacent pair of signals and cause the signal optimiser to search for a new best timing.
Profile A shows that most of the traffic crosses the detector as a dense “platoon” during the first half of the signal cycle time;

Without other considerations, a good progression could be achieved by ensuring that the downstream signals remain green while the platoon crosses the stop-line.
Profile B shows no marked tendency for traffic to travel in platoons;

Profile C shows that traffic has formed two distinct platoons within each signal cycle. In this case, the green time at the downstream may be arranged to give progression to either the first or second platoon.
Prediction of Queues

- The cruise time is used to predict when the vehicle flows that are recorded in the profile are likely to reach the stop line.

- Vehicle arrivals at the stop line during the red time are added onto the back of queue, which usually continuous to grow in the next green time until the queue clear.

- Vehicle discharges from the front of the queue at the specified saturation rate
Prediction of Queue

Flow adds to the back of the queue

Actual queue

Detector Data

Current CFP

Time “Now”

Saturation Flow Rate

Past

Future

Red

Time “Now”

Green

Predicted queue

Flow adds to the back of the queue

Past

Future

Cruise speed
Prediction of Queue

- It will be apparent that these predictions of queue lengths cannot be completely accurate.

- The prediction errors may become serious and so various validations have been incorporated into SCOOT.

- As long as the validation has been accepted, the queue model could be used continuously if the traffic condition is stable in the future.
Congestion

- Widespread congestion may occur when the queue grow in length and extend backwards into its upstream junction.

- The traffic model measures the proportion of cycle time that the detector is occupy by a queue, moreover, the optimiser use this information to reduce the likelihood of queue blocking the upstream junction.
Measures of Traffic Behavior

- To estimate current size of queue at link with the control area.

- From these estimates, SCOOT calculates an average value for the sum of the queues; this value is used as a measure of the inefficiency of traffic movement and is called Performance Index (PI).

- The SCOOT optimiser continuously searches for signal settings that make the PI as small as possible.
Measures of Traffic Behavior

- The total number of stops can be weighted and summed with the average queue into the PI.

- The proportion of a cycle time that vehicles are stationary over detectors can be weighted and summed into the PI (indicate congestion).
Measure of Traffic Behavior

- The degree of saturation is defined as the ratio of the average flow to the maximum flow which can be pass through the intersection from a particular approach and calculated by the traffic model.

- Traffic model measure average travel demand (the sum of the average flows across all the detectors in the area) and the average value of PI.

- If a large increase in PI without much change in the demand, it suggests that abnormal event, such as accident, has occurred.
SCOOT Signal Optimiser

- The system contains a set of parameters that control all the signals settings in the area.

- If this set of parameters unchanged, then the associated signals will be controlled by a fixed time plan.

- However, in normal operations, the optimiser makes frequent changes by small alternations to the parameters so as to adapt the fixed time plan to variations in the traffic behavior.
SCOOT Signal Optimiser

- A few seconds before each stage change, it estimate every junction whether it is better to make change earlier, latter, or as scheduled.

- To implement the alternation to minimize the “max DS” on the approach of that junction.

- Calculation is to take account of current queue length, approach congestion measurement and minimum green time constrains.
SCOOT Signal Optimiser

- The sequence of installing process:
  - fix time plan,
  - split optimiser,
  - offset optimiser,
  - cycle time optimiser.
SCOOT Signal Optimiser

1. Fix Time Plan
A few seconds (5 secs) before each stage change at every SCOOT intersection is scheduled to occur, the optimizer estimates whether it is better to make the change earlier or later;

Any one decision by the optimizer may alter a scheduled stage change time by no more than a few seconds (Maximum allowed changed time)

The signal optimizer will minimize the maximum degree of saturation on the approaches at each intersection.
Split Optimiser

Change of green duration:

- Temporary change (e.g. 4 secs): it is made to the change of green durations to take account of the cycle-by-cycle random traffic variations.

- Permanent change (e.g. 1 sec): it is made to the stored values of green duration so that longer term trends in the traffic demands can be followed.

- Over a period of several minutes, the proportions of green time can be completely revised by SCOOT to meet a new pattern of traffic flows.
Split Optimiser

- Each junction will be threaded by the split optimiser independently and performed more frequently than other optimisers.

- For example, in a network of 50 junctions with an average of 3 stages per junction, there will be 150 decisions per cycle.

- If some decisions are missed, then the split plan will remain unchanged.
Split Optimiser

Cycle by Cycle  |  Junction Independent  |  Stage Specification

Missing Decision  |  Making Decision

No Change  |  Stage Change  |  Stage Change
As Schedule  |  Early  |  Latter

Temporary Change  |  Account Cycle by Cycle

Account Each Temporary Change  |  Permanent Change  |  Random Variation Flow

Change Stage Value  |  Follow Long Term Traffic Demand

After Several Minutes
1. Based on the CFP data, the degree of saturation at major road and minor road would be 95% and 55% follow the scheduled.

2. With the objective of minimize the maximum degree of saturation, a temporary change are made to increase the green duration of major road by 4 secs and reduce the green time of minor road;

3. The corresponding degrees of saturation achieved a balance and both are changed to 90%.
Offset optimiser

- At each intersection, the offset optimizer makes the offset decision once every cycle.

- Since the offset of one intersection is altered relative to adjacent intersection, the offset between an adjacent pair of intersections may alter twice per cycle.

- Decisions are taken during a predetermined stage within every cycle time.
Offset optimiser

- To use cycle flow profile information to estimate overall traffic progression in those street which are immediately upstream and downstream.

- To compare the “sum of PI” : scheduled offset / occurring earlier or latter.

- Offset optimiser are modified when congestion occur: to improve the coordination on shorter street at the expense of longer street, since the longer street has a larger queue storage space to prevent potential spillback.
Offset optimizer

How the offset optimizer operate?

- The offset decisions at A~E are influenced only by the movements represented in the “mini-area”.

- Offset decision are taken once per cycle for each “mini-area”;

- Totally new signal offsets may evolve where timing alterations accumulate over several cycles of the signals.
Offset Optimiser

Estimation
Each Junction Cycle by Cycle

Comparison
Cycle Flow Profile Inform. Schedule & Early & Latter

All Adjacent Junction
Minimum Sum of PI

Decision

Change Relative Offset

Amend All Stage Change Times

After Several Cycle

Evolve New Offset Plan

Congestion

Adjacent Prevent Spillback

Log Street Fine Space for Queue
Cycle Length Optimiser

- The signal controlled intersections are grouped into “sub areas” which have pre-set boundaries.

- All signals within a sub area are operated by SCOOT on a common Cycle Length.

- Also, some intersections can be operated on one half of the common cycle time of the sub-are; this is referred to as “double-cycling” and is of particular value for signal controlled pedestrian crossings.
Cycle Length Optimizer

- **Constraints:**
  - The cycle length would be re-optimized in increments of a few seconds at interval of not less than 2.5 minutes;
  - Each sub-ease is independent of other sub-areas, between preset upper and lower bounds;
  - The lower bound is determined by the considerations of safety, pedestrian crossing time and min green time (30-40 secs);
  - The upper bound is set to give maximum traffic capacity but without unduly long red times (90-120 secs).
In SCOOT, the cycle length will increase when the traffic demand is increasing:
Cycle Length Optimizer

Optimization Strategy

- Optimized interval: 2.5-10 mins;

- Cycle Length increment: 4s, 8s, 16s, 32s (depends on the length of scheduled cycle);

- Objective: to provide maximum traffic capacity of the intersection;

- Optimization Method: the cycle length is incremented or decremented to ensure that the most heavily loaded intersection operates at a maximum degree of saturation of about 90%.
  1) if all stop-lines are less than 90% saturated, the CL decreased;
  2) if the degree of saturation exceeds 90%, SCOOT will increase the cycle length to increase the capacity.
Cycle Time Optimiser

Common Cycle Length

Operate 90% DS

DS < 0.9

Cycle Time Reduce; Demand Fix; Capacity Decrease

DS Increase

DS > 0.9

Cycle Time Increase; Demand Fix; Capacity Increase

DS Decrease

DS Critical Intersection = 0.9
Minor Intersection < 0.9

System DS – 0.9

New Cycle Plan

Implement within 2.5 Min

Mini Area Save Delay

Lower Bound
* Pedestrian Crossing
* Minimum Green

Single & Double CL Decision

Upper Bound
* Traffic Capacity
CL Optimizer (Example)

Scheduled Cycle Length

Optimized Cycle Length
Control with users’ adjustment

Sometimes, the users may not satisfy with the optimized result and want to adjust the optimization process to face some particular issues.

- For example: to optimize the signal along an arterial, traffic engineers prefer to provide the arterial flows a better level of service. Then, a higher weight is given to the corresponding directions.
Congestion Management

SCOOT includes functions to deal with the occurrence of congestion:

- It will automatically move the offset to these congestion directions, to provide the congestion movements with a larger green band.

- Gating facility is also used to limit the flow of traffic into a particularly sensitive area by restraining traffic on user specified roads.
Congestion Management

Upstream Control Strategy

At the upstream, the gating facility is used to limit the traffic flows into the sensitive area.

Downstream Control Strategy

At the downstream, a proper signal settings is provided to discharge vehicles ASAP.
Bus Priority
Bus Detection

- The SCOOT allows for buses to be detected either by selective vehicle detectors, i.e. using bus loops and transponders on buses, or by an automatic vehicle location (AVL) system.

- The best location for detection will be a compromise between the need for detection as far upstream as possible and the need for accurate journey time prediction.

- Bust detectors need to be located downstream of any bus stops, as SCOOT does not attempt to model the bus dwelling time.
Priority Techniques

- Priority can be given to individual buses: extension to prevent a bus being stopped at the start of red and recalls to start the bus green earlier than normal.

- In SCOOT MC3, intermediate stages between the current stage and the bus stage can be skipped.

- Differential priority allows different levels to be given to certain buses, e.g., limited priority to late buses and high priority to very late buses, but no priority to those ahead of schedule.

Controller by user set parameters to prevent the priority causing undesired extra delay to other vehicles.
Bus Priority

If a bus is detected towards the end of Stage 1 (Orange), it will receive an extension of green time.
If bus is detected during a red period, it will receive a recall (the stage 2 and 3 are shorten so that stage 1 starts earlier)
If the bus is detected during a red period, the following stage 3 would be skipped so that the stage 1 starts earlier.
Applications

Over 50 cities all over the world have implemented SCOOT into applications.

In North America:
- Anaheim, California, USA
- Santiago, California, USA
- Oxnard, California, USA
- Minneapolis, Minnesota, USA
- Red Deer, Alberta, Canada
- Toronto, Ontario, Canada
Deficiencies of SCOOT

- Due to the limitation of local controllers, SCOOT cannot skip phase or change the phase sequence.
- The objective function is not sufficient for use in various traffic conditions.
- SCOOT does not provide good results to deal with congestions, especially for those caused by incidents.
Introductions:


References

Algorithm and Functions


References

Updated Versions


References

Materials Provided by the Company

- Advice Leaflet 1: The “SCOOT” Urban Traffic Control System
- Advice Leaflet 2: Congestion Management in SCOOT
- Advice Leaflet 3: SCOOT control of pedestrian facilities
- Advice Leaflet 4: Bus Priority in SCOOT
References

Other Evaluation Papers


