Acceleration-Based Optimal Shift Point Algorithm for GT3 Racing

ACCRPMMonitor - Assetto Corsa Competizione

1 Objective

Find the RPM at which shifting to the next gear provides better acceleration than staying in the current gear, optimizing lap times by maximizing acceleration throughout the power band. This algorithm is specifically optimized for GT3 race cars, which typically feature high-revving engines with strong power delivery near redline.

2 Mathematical Formulation

2.1 Step 1: Acceleration Calculation

For each pair of consecutive telemetry data points $(i-1, i)$, calculate the instantaneous acceleration:

$$a_i = \frac{v_i - v_{i-1}}{t_i - t_{i-1}} \tag{1}$$

where:

- a_i = acceleration at point i (m/s^2)
- v_i = speed at point i (m/s)
- t_i = timestamp at point i (seconds)

Group acceleration values by RPM buckets (100 RPM intervals):

$$\text{RPM}_{\text{bucket}} = \left\lfloor \frac{\text{RPM}_{\text{avg}}}{100} \right\rfloor \times 100 \tag{2}$$

Average all acceleration values in each bucket to create the acceleration function:

$$A_{\text{gear}}(\text{RPM}) = \frac{1}{n} \sum_{i \in \text{bucket}} a_i \tag{3}$$

where n is the number of samples in the RPM bucket $[\text{RPM}, \text{RPM} + 100)$.
This gives us the acceleration function $A_{\text{gear}}(\text{RPM})$ for each gear.

2.2 Step 2: Gear Ratio Estimation

Find the overlapping speed range between gear N and gear $N+1$:

$$V_{\text{overlap}} = \left[\max\left(V_{\min}^{N}, V_{\min}^{N+1}\right), \min\left(V_{\max}^{N}, V_{\max}^{N+1}\right)\right] \tag{4}$$

Calculate the RPM-to-speed ratio for each gear in the overlap region:

$$R_N = \frac{1}{n_N} \sum_{i:v_i \in V_{\text{overlap}}, \text{gear}=N} \frac{\text{RPM}_i}{v_i} \tag{5}$$

$$R_{N+1} = \frac{1}{n_{N+1}} \sum_{i:v_i \in V_{\text{overlap}}, \text{gear}=N+1} \frac{\text{RPM}_i}{v_i} \tag{6}$$

The gear ratio between gear N and gear $N+1$ is:

$$\text{GR}_{N\to N+1} = \frac{R_N}{R_{N+1}} \tag{7}$$

2.3 Step 3: Short-Term Acceleration Crossover Detection

For each RPM level in gear N, predict the RPM after shifting to gear $N+1$:

$$\text{RPM}_{N+1} = \frac{\text{RPM}_N}{\text{GR}_{N\to N+1}} \tag{8}$$

Calculate the acceleration advantage ratio (relative improvement):

$$R_A(\text{RPM}_N) = \frac{A_{N+1}(\text{RPM}_{N+1}) - A_N(\text{RPM}_N)}{A_N(\text{RPM}_N)} \tag{9}$$

2.3.1 Fixed 3% Threshold for Short-Term Acceleration

To prioritize short-term acceleration and shift as soon as the next gear becomes advantageous, use a fixed low threshold:

$$\theta_{\min} = 0.03 \quad \text{(3\% advantage)} \tag{10}$$

Find the **first** RPM where shifting provides at least 3% advantage:

$$\text{RPM}_{\text{optimal}} = \min\{\text{RPM} \mid R_A(\text{RPM}) > 0.03\} \tag{11}$$

This approach:

- **3% threshold**: Shifts as soon as next gear provides meaningful advantage
- **First crossing**: Takes the earliest RPM where 3% advantage is met
- **Short-term optimization**: Prioritizes immediate acceleration gain
- **Prevents late shifting**: Some GT3 cars benefit from earlier shifts
- **Fixed threshold**: Consistent behavior across all vehicles

3 Algorithm Pseudocode

function FindOptimalShiftPoint(gear_N)
  // Step 1: Calculate acceleration curves
  $A_N \leftarrow$ CalculateAccelerationCurve(gear_N)
  $A_{N+1} \leftarrow$ CalculateAccelerationCurve(gear_{N+1})

  if InsufficientData(A_N) **or** InsufficientData(A_{N+1}) **then**
    return FallbackMaxSpeedMethod(gear_N)
  end if

  // Step 2: Estimate gear ratio
  GR $\leftarrow$ EstimateGearRatio(gear_N, gear_{N+1})

  if GR ≤ 0 **then**
    return FallbackMaxSpeedMethod(gear_N)
  end if

  // Step 3: Find crossover point with fixed 3% threshold (short-term optimization)
  $\theta_{\min} \leftarrow 0.03$ // 3% advantage for short-term acceleration

  // Sort RPMs in ascending order to find FIRST crossing
  sorted_rpms $\leftarrow$ sort(A_N.keys())

  for each rpm $\in$ sorted_rpms **do**
    $a_{\text{current}} \leftarrow A_N$[rpm]
    $\text{rpm}_{\text{next}} \leftarrow$ rpm/GR
    $a_{\text{next}} \leftarrow A_{N+1}$[ClosestRPM($\text{rpm}_{\text{next}}$)]

    // Calculate relative advantage (percentage improvement)
    $R_a \leftarrow (a_{\text{next}} - a_{\text{current}})/a_{\text{current}}$

    // Return FIRST RPM where next gear provides 3%+ advantage
    if $R_a > \theta_{\min}$ **then**
      return rpm   // Shift as soon as 3% advantage is met
    end if
  end for

  // No crossing found - use fallback
  return FallbackMaxSpeedMethod(gear_N)
end function

4 Example Calculation

Consider shifting from 2nd gear to 3rd gear:

4.1 Given Data

- At 6800 RPM in 2nd gear: $A_2(6800) = 2.5 \text{ m/s}^2$
- At 6500 RPM in 2nd gear: $A_2(6500) = 2.8 \text{ m/s}^2$
- At 6200 RPM in 2nd gear: $A_2(6200) = 3.0 \text{ m/s}^2$
- Gear ratio: $\text{GR}_{2\to 3} = 1.31$
- Minimum advantage threshold: $\theta_{\min} = 0.03$ (3%)

4.2 Analysis at 6800 RPM

After shifting to 3rd gear:

$$\text{RPM}_3 = \frac{6800}{1.31} \approx 5191 \text{ RPM} \tag{12}$$

If $A_3(5191) = 3.1 \text{ m/s}^2$, then:

$$R_A(6800) = \frac{3.1 - 2.5}{2.5} = \frac{0.6}{2.5} = 0.24 = 24\% \tag{13}$$

Since $24\% > 3\%$, this is a valid shift point with significant advantage. **(SHIFT NOW!)**

4.3 Analysis at 6500 RPM

After shifting to 3rd gear:

$$\text{RPM}_3 = \frac{6500}{1.31} \approx 4962 \text{ RPM} \tag{14}$$

If $A_3(4962) = 2.4 \text{ m/s}^2$, then:

$$R_A(6500) = \frac{2.4 - 2.8}{2.8} = \frac{-0.4}{2.8} = -0.14 = -14\% \tag{15}$$

Since $-14\% < 3\%$, staying in 2nd gear is better. **(TOO EARLY, STAY IN GEAR)**

4.4 Analysis at 6200 RPM

After shifting to 3rd gear:

$$\text{RPM}_3 = \frac{6200}{1.31} \approx 4733 \text{ RPM} \tag{16}$$

If $A_3(4733) = 3.05 \text{ m/s}^2$, then:

$$R_A(6200) = \frac{3.05 - 3.0}{3.0} = \frac{0.05}{3.0} = 0.017 = 1.7\% \tag{17}$$

Since 1.7% < 3%, the advantage is marginal and not significant. **(TOO EARLY, WAIT)**

This example shows how the 3% threshold shifts as soon as next gear provides meaningful short-term acceleration advantage.

5 Key Parameters

- **RPM Bucket Size**: 100 RPM (groups similar RPM levels)
- **Minimum Time Delta**: 0.01 seconds (10 ms, filters noise)
- **Maximum Time Delta**: 1.0 seconds (filters different laps)
- **RPM Match Tolerance**: ±200 RPM (acceptable range for gear ratio lookup)
- **Minimum Data Points per Gear**: 50 full-throttle samples
- **Minimum Samples per Bucket**: 3 samples for statistical reliability
- **Full Throttle Threshold**: $\geq 95\%$ throttle position
- **Minimum Speed Threshold**: > 0 km/h (excludes stationary data)
- **Fixed Advantage Threshold** ($\theta_{\min}$): 0.03 (3%) for short-term acceleration optimization
- **Redline Pull Detection**: Speed at 90%+ RPM vs max speed (95% threshold)
- **Fallback Redline Shift Point**: 98% of max observed RPM
- **Sustained Power Parameters**:
  - Speed range: $\Delta v = 15$ km/h
  - Sampling interval: $\delta v = 2$ km/h
  - Partial throttle weight: $(w_p, w_s) = (0.2, 0.8)$ when $\tau < 0.85$
  - Full throttle weight: $(w_p, w_s) = (0.4, 0.6)$ when $\tau \geq 0.85$
  - Minimum speed: 30 km/h

6 Fallback Strategy

If acceleration-based method fails (insufficient data, invalid gear ratio, etc.), use an intelligent maximum speed fallback that adapts to redline behavior.

6.1 Redline Detection

Check if the vehicle continues to accelerate strongly near redline:

$$\text{RPM}_{\text{top10\%}} = 0.90 \times \text{RPM}_{\text{max}} \tag{18}$$

$$v_{\text{top}} = \text{avg}\,\{v_i \mid \text{RPM}_i \geq \text{RPM}_{\text{top10\%}}\} \tag{19}$$

$$\text{PullsToRedline} = \begin{cases} \text{true} & \text{if } v_{\text{top}} \geq 0.95 \times v_{\text{max}} \\ \text{false} & \text{otherwise} \end{cases} \tag{20}$$

6.2 Adaptive Fallback Shift Point

$$\text{RPM}_{\text{optimal}} = \begin{cases} 0.98 \times \text{RPM}_{\text{max}} & \text{if PullsToRedline} \\ \max\{\text{RPM}_i \mid v_i \geq 0.99 \times v_{\text{max}}, \text{gear} = N\} & \text{otherwise} \end{cases} \tag{21}$$

This approach:

- Shifts at 98% of max RPM for cars that accelerate well to redline (e.g., high-revving GT3 cars)
- Uses the highest RPM (not lowest) that achieves 99% max speed for cars with traditional power curves
- Prevents premature shifting by always preferring higher RPM ranges

7 Benefits

1. **Physics-based**: Directly uses Newton's second law ($F = ma$)
2. **Vehicle-specific**: Adapts to each car's unique power curve
3. **Track-independent**: Works on any track configuration
4. **Self-optimizing**: More data yields better shift points
5. **Robust**: Graceful degradation with fallback strategy
6. **Optimal for lap times**: Maximizes acceleration = minimizes time
7. **Fixed 3% threshold**: Shifts as soon as next gear provides meaningful advantage
8. **Short-term acceleration focus**: Prevents late shifting, optimizes immediate gain
9. **High-quality data**: Filters out invalid telemetry (speed = 0, throttle ¡ 95%)
10. **Intelligent fallback**: Detects redline behavior and shifts accordingly

11. **Sustained power recommendations**: Separate system for corner/uphill gear selection

12. **Dual optimization**: Short-term (shift points) + sustained (gear recommendation)

8 Sustained Power Gear Recommendation

In addition to optimizing shift points for maximum short-term acceleration, the system provides real-time gear recommendations for sustained power delivery during corners and uphill climbs.

8.1 Objective

While the shift point algorithm optimizes for short-term acceleration (immediate gear changes), sustained power recommendations help drivers maintain optimal power delivery over longer durations, such as:

- Controlled wide turns requiring consistent acceleration
- Uphill climbs where maintaining momentum is critical
- Situations where partial throttle (¡85%) is used

8.2 Sustained Acceleration Score

For a given speed v and gear g, calculate a weighted score combining peak (current) and sustained (average) acceleration:

$$S_g(v, \tau) = w_p \cdot A_g(v) + w_s \cdot \bar{A}_g(v) \tag{22}$$

where:

- $A_g(v)$ = instantaneous acceleration at current speed in gear g
- $\bar{A}_g(v)$ = average acceleration over speed range $[v, v + \Delta v]$
- $\Delta v = 15$ km/h (sustained speed range)
- w_p = peak weight (instantaneous acceleration importance)
- w_s = sustained weight (average acceleration importance)
- τ = throttle position (0 to 1)

8.3 Throttle-Dependent Weighting

The weighting adapts based on throttle position:

$$(w_p, w_s) = \begin{cases} (0.2, 0.8) & \text{if } \tau < 0.85 \quad \text{(partial throttle - prioritize sustained)} \\ (0.4, 0.6) & \text{if } \tau \geq 0.85 \quad \text{(full throttle - balanced)} \end{cases} \tag{23}$$

At partial throttle (corners, uphills), sustained power is weighted more heavily (80%), as maintaining consistent acceleration matters more than peak instantaneous values.

8.4 Average Sustained Acceleration

Calculate the average acceleration over the next 15 km/h:

$$\bar{A}_g(v) = \frac{1}{n} \sum_{i=0}^{n-1} A_g(v + i \cdot \delta v) \tag{24}$$

where:

- $\delta v = 2$ km/h (sampling interval)
- $n = \lceil \Delta v / \delta v \rceil = 8$ samples

8.5 Optimal Gear Selection

Find the gear that maximizes the sustained acceleration score:

$$g_{\text{optimal}} = \underset{g \in \{1,2,3,4,5,6\}}{\arg\max}\ S_g(v, \tau) \tag{25}$$

The recommendation is only provided when:

- Current speed $v > 30$ km/h (sufficient data available)
- Acceleration curves exist (auto-generated configuration only)

8.6 Key Differences from Shift Point Algorithm

Aspect	**Shift Point**	**Gear Recommendation**
Optimization goal	Short-term acceleration	Sustained power delivery
Threshold	3% advantage required	Best overall score
Speed range	Instantaneous	15 km/h forward-looking
Use case	When to upshift	Which gear for corners/hills
Always active	Yes (gears 1-5)	Only with auto-config

8.7 Example Scenario

Consider a driver approaching a long uphill corner at 80 km/h with 70% throttle:

Given:

- Current speed: $v = 80$ km/h
- Throttle: $\tau = 0.70$ (partial) $\Rightarrow (w_p, w_s) = (0.2, 0.8)$
- Current gear: 4th

Calculation for 3rd gear:

$$A_3(80) = 2.5\ \text{m/s}^2 \quad \text{(instantaneous)} \tag{26}$$

$$\bar{A}_3(80) = \frac{1}{8}(2.5 + 2.4 + 2.3 + 2.2 + 2.1 + 2.0 + 1.9 + 1.8) = 2.15\ \text{m/s}^2 \tag{27}$$

$$S_3(80, 0.70) = 0.2 \times 2.5 + 0.8 \times 2.15 = 0.5 + 1.72 = 2.22 \tag{28}$$

Calculation for 4th gear:

$$A_4(80) = 2.8\ \text{m/s}^2 \quad \text{(instantaneous)} \tag{29}$$

$$\bar{A}_4(80) = \frac{1}{8}(2.8 + 2.6 + 2.4 + 2.1 + 1.8 + 1.5 + 1.2 + 0.9) = 1.91\ \text{m/s}^2 \tag{30}$$

$$S_4(80, 0.70) = 0.2 \times 2.8 + 0.8 \times 1.91 = 0.56 + 1.53 = 2.09 \tag{31}$$

Result: $S_3 = 2.22 > S_4 = 2.09$

The system recommends 3rd gear, as it provides better sustained power delivery through the corner despite 4th gear having higher instantaneous acceleration at 80 km/h.

9 Dynamic Audio Warning System

To provide real-time feedback, the system employs a dynamic beeping distance based on RPM rate of change:

9.1 RPM Rate Calculation

Track RPM history over a 200ms sliding window and calculate the rate of change:

$$\dot{\text{RPM}} = \frac{\text{RPM}_{\text{current}} - \text{RPM}_{\text{old}}}{t_{\text{current}} - t_{\text{old}}} \quad \text{(RPM/second)} \tag{32}$$

9.2 Dynamic Warning Distance

The beeping warning distance d_{beep} adapts to acceleration intensity:

$$d_{\text{beep}} = \begin{cases} 200 \text{ RPM} & \text{if } \dot{\text{RPM}} > 1500 \text{ RPM/s} \\ 150 \text{ RPM} & \text{if } \dot{\text{RPM}} > 1000 \text{ RPM/s} \\ 120 \text{ RPM} & \text{if } \dot{\text{RPM}} > 600 \text{ RPM/s} \\ 100 \text{ RPM} & \text{if } \dot{\text{RPM}} > 300 \text{ RPM/s} \\ 80 \text{ RPM} & \text{if } \dot{\text{RPM}} > 150 \text{ RPM/s} \\ 50 \text{ RPM} & \text{if } \dot{\text{RPM}} > 50 \text{ RPM/s} \\ 30 \text{ RPM} & \text{otherwise} \end{cases} \tag{33}$$

Beeping begins when:

$$\text{RPM}_{\text{current}} \geq \text{RPM}_{\text{optimal}} - d_{\text{beep}} \tag{34}$$

This approach provides earlier warning during rapid acceleration while avoiding premature beeping during steady-state driving.

10 Adaptive Learning Mode

The system supports continuous learning during normal driving:

1. **Real-time data collection**: Collects telemetry at 20 Hz during full-throttle acceleration
2. **Automatic filtering**: Rejects data when throttle $< 95\%$ or speed $= 0$
3. **Periodic updates**: Recalculates optimal shift points every 10 seconds
4. **Live adaptation**: Shift point thresholds update dynamically as new data is collected
5. **Persistent learning**: Optionally saves learned configuration for future sessions

This enables the system to continuously refine shift points as driving conditions and techniques evolve.