Today’s Web QoE

Webpages are complex entities
• Fetch hundreds of objects shared over tens of domains through multiple connections
• Parse and execute JavaScript and CSS
• Dynamic requests and personalized views via cookies

Both academia and industry rate Web QoE with page completion time – **onLoad** –
• Alexa reports onLoad and quantiles
• Google ranks search results according to onLoad

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Google’s Speed Index

Considers visual progress of page loading process

\[
SI = \int_{\text{begin}}^{\text{end}} \left( 1 - \frac{\text{painted}}{\text{total}} \right) \, dt
\]

Computationally expensive
Distorts experiments by inflating realization time (DOM +41%, onLoad +22%).
No spatial bias considered (center VS sides do not have the same visual importance)
Inconsistent across platforms (video frames on desktop, paint events on mobile)

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Web QoE Metrics – What to compute, where, how

<table>
<thead>
<tr>
<th>Type</th>
<th>Metric Name</th>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>TTFB (TTLB)</td>
<td>L3, L4, L7</td>
<td>First (last) byte of payload received</td>
</tr>
<tr>
<td>Instant</td>
<td>DOM</td>
<td>L4</td>
<td>Document Object Model (i.e., <code>index.html</code>) fetched and parsed</td>
</tr>
<tr>
<td></td>
<td>onLoad</td>
<td>L7</td>
<td>All bytes of payload received</td>
</tr>
<tr>
<td></td>
<td>TTFP (TTLP)</td>
<td></td>
<td>First (last) paint event rendered on screen</td>
</tr>
<tr>
<td>Time</td>
<td>SpeedIndex</td>
<td>L7</td>
<td>Integral of complementary visual progress</td>
</tr>
<tr>
<td>Integral</td>
<td>BytIndex</td>
<td></td>
<td>Integral of complementary byte-level completion</td>
</tr>
<tr>
<td></td>
<td>ObjectIndex</td>
<td></td>
<td>Integral of complementary object-level completion</td>
</tr>
<tr>
<td>Compound</td>
<td>YSlow</td>
<td>L7</td>
<td>Yahoo’s 23 weighted expertise-driven heuristics</td>
</tr>
<tr>
<td>Scores</td>
<td>PageSpeed</td>
<td>L7</td>
<td>Google’s PageSpeed Insight heuristics</td>
</tr>
<tr>
<td></td>
<td>dynaTrace</td>
<td>L7</td>
<td>dynaTrace’s compound score</td>
</tr>
<tr>
<td>Human</td>
<td>MOS (Mean Opinion</td>
<td></td>
<td>User rating based on personal experience</td>
</tr>
<tr>
<td>Perception</td>
<td>Score</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Time Instant and Time Integral Metrics

![Graph showing the relationship between Time and SpeedIndex](image)

Experimentations over Alexa top-100 Webpages (10 runs)
• Events have an order relationship (no first paint possible before first byte)
• Metrics show a significant variance (e.g., onLoad: median=3s, 90th=13s)
• (Object, Byte)Index are clustered with SpeedIndex hinting for similarities

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How do such metrics correlate?

Pearson correlation coefficient between metric pairs
• (Object, Byte)Index are highly correlated with the SpeedIndex and with several time instant metrics, suggesting for a sound replacement
• Compound metrics (Yslow, Page Speed) are poorly correlated

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Referenced tools:
4: [https://sites.google.com/a/webpagetest.org/docs/using-webpagetest/metrics/speed-index](https://sites.google.com/a/webpagetest.org/docs/using-webpagetest/metrics/speed-index)