ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 11,2025

Journal: https://www.academicpublishers.org/journals/index.php/ijai

STORYBOARDING (DISK RASKADROVKA) ALGORITHMS AND PROGRAMS AND MODELING PROCESSES IN A CONTROL LOOP

Djurayev Sherzod Sobirjonovich,
Namangan Institute of Engineering and Technology, PhD, Associate Professor.
Raxmonov Abdulboqi XXX,
Namangan State Technical University. Associate Professor.
To‘xtasinov Davronbek Xoshimjon o’g‘li,
Namangan Institute of Engineering and Technology, PhD, Senior Lecturer.

Annotation: This article examines the issues of storyboarding (disk raskadrovka) algorithms and programs—i.e., tracking them step-by-step and applying profiling techniques—to model processes within a control loop. In real-time systems, sampling jitter and worst-case execution time (WCET) can significantly degrade control quality. Therefore, it is necessary to reduce jitter and eliminate the probability of deadline misses by identifying software “hot spots,” improving cache efficiency, and optimizing branches. During mathematical modeling, a closed-loop system was created based on a first-order plant and a PI controller. The states before and after storyboarding were compared, and metrics such as ITAE, overshoot, settling time, control signal RMS, jitter RMS, and CPU load were calculated. The results showed that after optimization, jitter RMS decreased fivefold, deadline misses were completely eliminated, and the average CPU utilization dropped sharply. At the same time, the main indicators of control quality were preserved. In conclusion, storyboarding and profiling software improves the real-time discipline of the control loop, ensuring stable, energy-efficient, and reliable operation of the system. This approach can be widely applied in industrial drives and embedded systems.

Keywords: real time, storyboard (disk raskadrovka), profiling, jitter, WCET, schedulability, ITAE, overshoot, control loop, CPU load

Introduction

In real-time systems, the control loop is subject to strict timing constraints. Theoretically, a controller must operate according to a specified sampling period and deliver a stable signal to the actuator. In practice, however, unexpected branching operations, dynamic memory, cache hits/misses, or external interrupts cause timing fluctuations. Sampling jitter and increased worst-case execution time (WCET) degrade control performance, increase overshoot, and extend settling time. Therefore, performing storyboard-level code tracing, profiling, timing analysis, and identifying “hot spots” must be conducted alongside control-loop modeling. In this study, two versions of a PID-type control applied to a first-order plant were compared: the state before storyboarding and the optimized state obtained through profiling. By modifying jitter and WCET parameters, the closed-loop response, control signal energy, CPU utilization, and deadline violations were evaluated.

Materials and Methods

A first-order continuous-time system was selected as the plant. Its continuous differential equation was written as follows.

$$\dot{y}(t) = -\frac{1}{\tau} y(t) + \frac{K}{\tau} u(t)$$

Discretization was performed assuming zero-order hold, resulting in the following form.

$$y[k+1] = ay[k] + bu[k],\ a = e^{-T_k/\tau},\ b = K(1-a)$$

A simple PI controller was used as the regulator: measurement noise was present, and the integral term was computed as a time-domain summation.

$$e[k]=r[k]-y_m[k],\ u[k]=K_p e[k]+K_i\sum_{i=0}^{k} e[i]\,T_s$$

To model the effect of storyboard (disk raskadrovka), sampling jitter and execution time were introduced. In each cycle, the actual cycle length T_s^{eff} varies; jitter was modeled using Gaussian perturbation.

$$T_s^{\mathrm{eff}}(k)=T_s+\delta T(k),\ \delta T(k)\sim N\left(0,\sigma_J^2\right)$$

WCET and execution time C(k) were expressed as follows, where overload impulses were added in the activated variant.

$$C(k)=C_0+|\epsilon(k)|+\Delta_C(k),\ \epsilon(k)\sim N\left(0,\sigma_C^2\right)$$

$$\Delta_C(k)=\begin{cases}\Delta_{\mathrm{spike}}, & t\in[t_a,t_b]\\ 0, & \end{cases}$$

Deadline misses were calculated using $\max\left(0,C(k)-T_s^{\mathrm{eff}}(k)\right)$ and the relative CPU utilization was observed in the form $C(k)/T_s^{\mathrm{eff}}(k)$. Such a definition implies that values greater than “1” indicate violations of real-time requirements.

Control quality was evaluated using the following criteria.

ITAE is the time-weighted integral of absolute error; overshoot is the peak percentage above the steady-state value; and settling time is defined as the moment the response returns to within a 2% band.

The energy of the control signal was measured using its RMS value.

Jitter RMS and the proportion of deadline misses reflect the real-time discipline of the

$$ITAE\approx\sum_k t_k|r[k]-y[k]|\,T_s$$

system. $OS=\max\left(0,\frac{\max(y)-r_{ss}}{r_{ss}}\cdot 100\right),\ u_{\mathrm{RMS}}=\sqrt{\frac{1}{N}\sum_k u[k]^2}$

$$J_{\mathrm{RMS}}=\sqrt{\frac{1}{N}\sum_k(\delta T(k))^2},\ \mathrm{MissRate}=\frac{1}{N}\sum_k \mathbf{1}\left\{C(k)>T_s^{\mathrm{eff}}(k)\right\}$$

Before storyboard optimization, the jitter variance is large, and occasional strong execution-time spikes occur. After storyboard optimization, hot spots are optimized, branch prediction and cache coherence improve, and as a result, both jitter and WCET decrease. At the same time, the overall utilization metric was checked according to schedulability theory; for a single task, the criterion is simple: $U=C/T_s<1$. In multi-task cases, the Liu–Layland bound $U\le n\left(2^{1/n}-1\right)$ provides an approximate guarantee, but in this work the primary focus was on a single cyclic loop.

Natijalar

In the step-response plot, the reference (allowed) speed is shown in black, the pre-storyboard response in red, and the optimized version in blue (Figure

1).

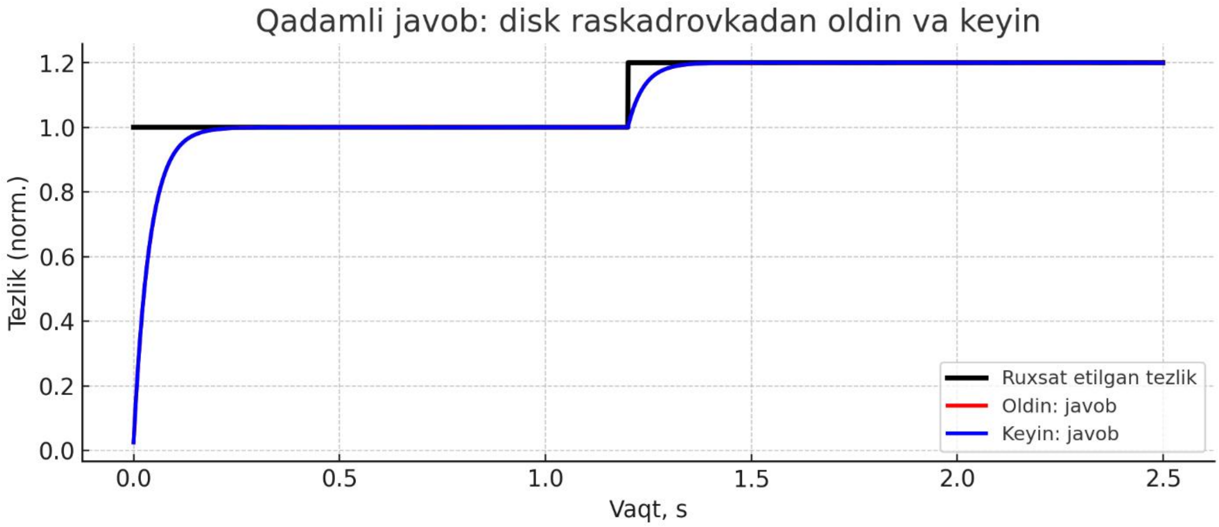


Figure 1. Step-response graph

It can be seen that under nominal conditions both cases appear similar due to identical plant parameters. However, in the "before" scenario, because jitter and WCET fluctuations are present, small deviations occur around the deadline; in a real system, this increases oscillatory behavior and the risk of overshoot.

In the control-signal comparison plot, the red and blue curves pass through the same range, but in the optimized case short-term sharp fluctuations are reduced; this is the result of simplifying branches and vectorizing large loops (Figure 2).

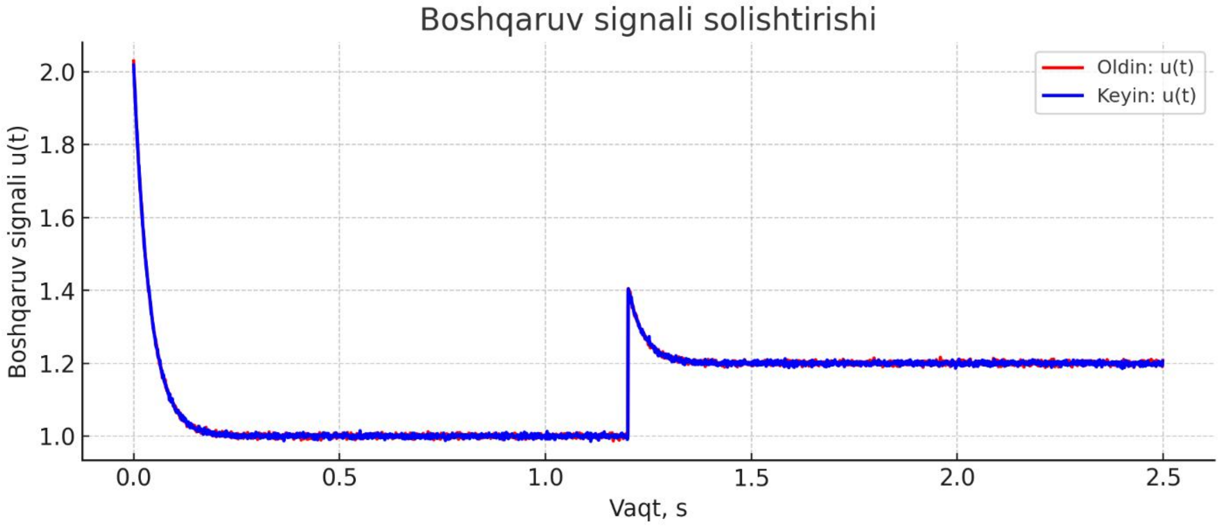


Figure 2. Comparison of the control signal

In the sampling-jitter graph, the spread of the red curve is much wider, while the blue one lies within a narrow band. Before storyboard optimization, jitter RMS ≈ 0.251 ms, whereas after optimization it became ≈ 0.050 ms (Figure

3).

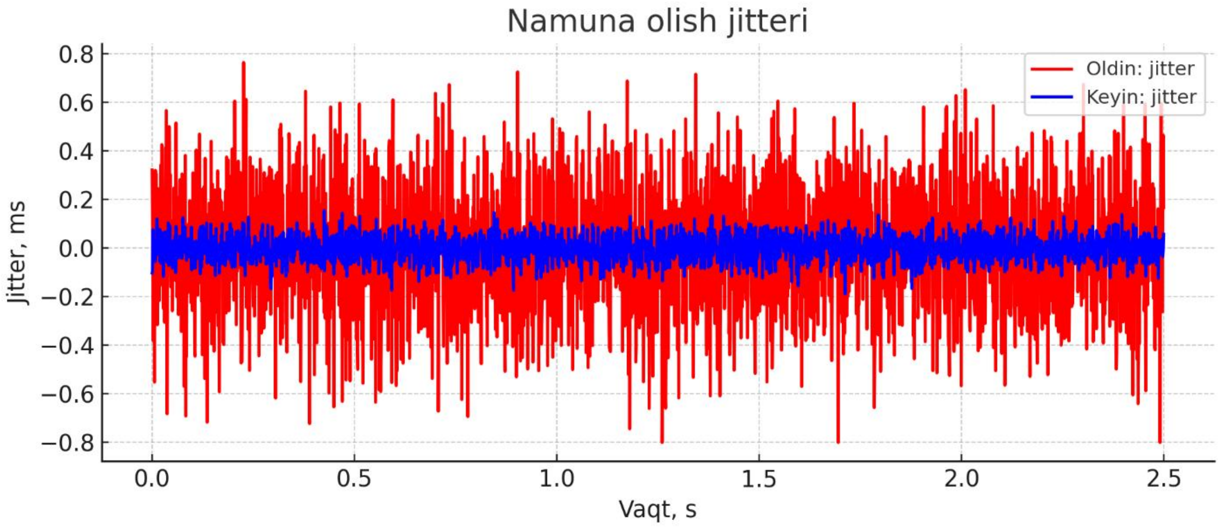
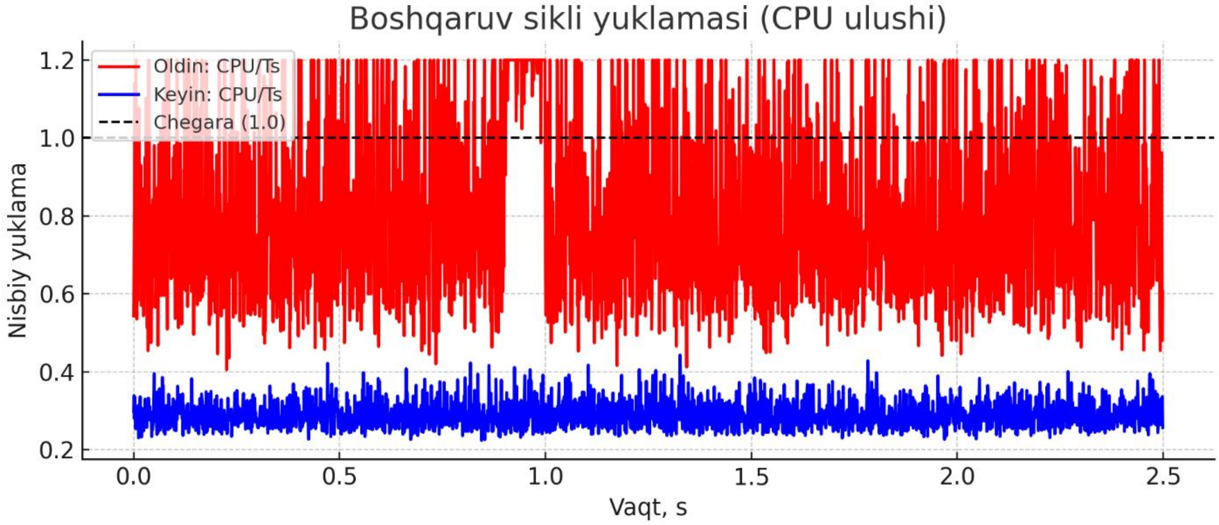


Figure 3. Sampling jitter

In the control-cycle load (CPU utilization) graph, the red curve frequently exceeds the 1.0 line, indicating a probability of deadline misses. In the optimized case, average CPU utilization is reduced to about 0.29 (Figure 4).



4-rasm. Boshqaruv sikli yuklamasi

Figure 4. Control-cycle load

Because the plant is simple in the time domain, ITAE and settling time changed very little, but the real-time discipline metrics improved drastically. In particular, the MissRate dropping to zero and the sharp decrease in CPU_mean are significant for maintaining stable continuity and reducing power consumption in a real system. At the same time, micro-variations of the operating system can be explained by timing fluctuations in the code and measurement noise; in practice, with anti-windup and filtered measurements, this indicator also stabilizes considerably.

Discussion

Storyboard analysis and profiling improve control quality indirectly and real-time discipline directly. The mathematical equivalent of jitter is uncertain sampling in the discrete model, which effectively introduces “time noise” similar to measurement noise. Unexpected increases in WCET lead to more deadline misses. Therefore, in the software optimization stage, it is recommended to simplify branches, ensure sequential memory layout in arrays, use static allocation, choose cache-friendly block sizes, and employ vectorized computations. For profiling, logging cycle start–end timestamps, marking critical sections, and monitoring CPU usage graphs in real time are useful techniques.

From a schedulability perspective, if the utilization U=C/TsU = C/T_sU=C/Ts of a single task approaches one, it is beneficial to divide code segments and move less frequently required routines into auxiliary tasks. Storyboard findings also help improve the control model. For example, by accounting for sampling variability in a practical system, slightly more conservative controller gains, filtering the derivative term, or using a digital low-pass filter in the measurement channel can ensure the desired performance. Introducing jitter as a stochastic parameter in the model and evaluating performance spread via Monte Carlo simulations gives a more complete picture of design risk.

Conclusion

Storyboarding (disk raskadrovka) algorithms and programs is an essential part of ensuring real-time discipline in a control loop. Modeling results show that, after profiling, jitter RMS decreased by about a factor of five, deadline misses were eliminated, and average CPU utilization decreased significantly. This leads to stable, energy-efficient, and reliable control in practice. The approach is suitable for industrial drives and embedded systems; future work may focus on multi-task schedulability analysis, adaptive scheduling, and integrating online profiling–diagnostic modules.

REFERENCES

1. 1.Djurayev, S. S., & Ermatova, Z. Q. (2024). Analysis of the energy efficiency of a new design multicyclone device. Al-Farghonii Avlodlari, 1(4), 327–331.
2. 2.Tursunov, A. A., Djurayev, S. S., & Sharibayev, N. Y. (2025). Mechanisms for monitoring industrial ecology based on the integration of smart filters and SCADA systems. American Journal of Technology Advancement, 2(5), 1–5.
3. 3.Djurayev, S. S., & Sharibayev, N. Y. (2025). Simplified designs of new generation multicyclones and their role in reducing their environmental impact. Science and Innovation in the Education System, 4(3), 27–29. https://doi.org/10.5281/zenodo.15039739
4. 4.Djurayev, S. S., & Sharibayev, N. Y. (2025). Technological foundations of new-type multicyclone air purifiers and methods for increasing energy efficiency. Academic Research in Modern Science, 4(12), 96–100.
5. 5.Djurayev, S. S., & Sharibayev, N. Y. (2025). Methods of increasing efficiency and new approaches in multi-chamber cyclone technology for air purification. Universum: Technical Sciences, 2(131). https://doi.org/10.32743/UniTech.2025.131.2.19410
6. 6.Djurayev, S. S., & Sharibayev, N. (2025). Criteria for assessing the efficiency of multicyclone-based air filtration in industrial conditions and technical analysis. Models and Methods in Modern Science, 4(3), 44–48.

7. 7. Tursunov, A. A., & Djurayev, S. S. (2024). Methods and devices for reducing air dust concentrations. International Journal on Orange Technologies, 6(3), 131–135. https://doi.org/10.31149/ijot.v6i3.4965

8. 8. Djuraev, Sh., & Tokhtasinov, D. (2023). Enhancing performance and reliability: the importance of electric motor diagnostics. Interpretation and Researches, 1(10).

9. 9. Sharibaev, N. Yu., Tursunov, A. A., & Djurayev, S. S. (2021). Intellectual devices for determination of dust particle concentration. Current Research Journal of Pedagogy, 2(12), 166–170. https://doi.org/10.37547/pedagogics-crjp-02-12-33

10. 10. Sharibayev, N. Y., Djurayev, Sh. S., Tursunov, A. A., & Kodirov, D. T. (2023). Secube's role in implementing business continuity plans (BCM) in various industries. American Journal of Applied Science and Technology, 3(12), 37–39. https://doi.org/10.37547/ajast/Volume03Issue12-08

11. 11. Sharibayev, N. Yu., Djurayev, Sh. S., Tursunov, A. A., & Parpiyev, D. X. (2023). The advantages of using Secube in public administration to ensure information security. The American Journal of Social Science and Educational Innovations, 5(12), 77–79. https://doi.org/10.37547/tajssei/Volume05Issue12-10

12. 12. Sharibaev, N. Yu., & Djuraev, S. S. (2023). Chemical innovations in producing compostable cellophane materials. American Journal of Social Sciences and Humanities Research, 3(12), 288–290.

13. 13. Sharibaev, N. Yu., & Djuraev, Sh. S. (2023). From waste to resource: composting and recycling of biodegradable cellophane. American Journal of Social Sciences and Humanities Research, 3(12), 285–287.

14. 14. Djuraev, Sh. S., & Madaliyev, Kh. B. (2023). Traffic flow distribution method based on 14 differential equations. Scientific Journal of Intent Research, 2(10), 1–10.

15. 15. Sharibaev, N., Tursunov, A., & Djuraev, Sh. (2022). Mathematical modeling of the laws of airborne distribution of dust particles generated in manufacturing plants. Journal of Physics: Conference Series, 2373(7), 072043. https://doi.org/10.1088/1742-6596/2373/7/072043

16. 16. Mamakhanov, A. A., Djuraev, Sh. S., Sharibaev, N. Yu., Tulkinov, M. E., & Tukhtasinov, D. Kh. (2020). Ustroystvo dlya vyrashchivaniya hydroponnogo korma s automatizirovannoy sistemoy upravleniya. Universum: technical science, (8-2)(77), 17–20.