Motion Simulation of an SSL Robot for RoboCup

In the SSL, robots are compact platforms that rely on an overhead vision system (SSL-Vision) for global localization and must demonstrate precise motion control, fast decision-making, and reliable path-following under dynamic game conditions. These requirements place high demands on low-level kinematics, control software, and hardware integration. RoboHub current prototype demonstrates the correct mechanical layout but lacks a validated inverse kinematics model and motion control software, which prevents accurate trajectory execution in both simulation and on-field tests.

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Context of use: Education
Level of education: Bachelor

Impact on society

What impact is expected from your technology?

What is exactly the problem? Is it really a problem? Are you sure?

RoboHub currently lacks a digital twin, control software, and an inverse kinematics model. This limits testing, optimization, and preparation for RoboCup. The pain is that hardware-only testing is inefficient, costly, and unsustainable. By providing a digital twin, the project eases this pain for students and RoboHub, enabling faster, safer, and more sustainable development.

Are you sure that this technology is solving the RIGHT problem?

Yes. The real problem is not just missing software, but inefficient and unsustainable robot development. The digital twin addresses the deeper issue by reducing waste, supporting iterative design, and enabling fair competition preparation. It is not a temporary fixit supports long-term research and education goals.

How is this technology going to solve the problem?

The digital twin simulates robot dynamics and control, allowing safe, low-cost testing of inverse kinematics and motion algorithms. This reduces the need for repeated hardware trials, prevents component wear, and ensures that only validated designs are implemented physically. It has a strong theoretical foundation (inverse kinematics, control theory) and its success will be validated through simulation and real robot testing.

What negative effects do you expect from this technology?

Higher computer resource use (energy consumption).

Risk that students rely too much on simulation and overlook real-world complexity.

Possible overconfidence in simulation results if not validated with hardware.

In what way is this technology contributing to a world you want to live in?

It contributes to sustainable engineering education by reducing waste, increasing accessibility to robotics, and promoting international collaboration. It aligns with professional values of responsibility, innovation, and knowledge sharing. The project builds a culture of testing ideas safely in a virtual environment before real-world deployment an approach valuable beyond RoboCup.

Now that you have thought hard about the impact of this technology on society (by filling out the questions above), what improvements would you like to make to the technology? List them below.

Optimize simulation code to reduce energy usage.

Ensure strong documentation so future student teams can reuse the digital twin.

Combine simulation with systematic hardware validation to avoid over-reliance on virtual models.

Where possible, use sustainable materials for the physical robot components.

Hateful and criminal actors

What can bad actors do with your technology?

In which way can the technology be used to break the law or avoid the consequences of breaking the law?

Unlikely. The digital twin only simulates robot movement and control. It does not interact with sensitive data or critical systems. At most, someone could use the code without permission (plagiarism or copyright violation).

Can fakers, thieves or scammers abuse the technology?

Abuse potential is very limited. Someone could claim the simulation results as their own, or repurpose it to mislead about robotic capabilities. However, the software itself does not enable theft, harassment, or fraud.

Can the technology be used against certain (ethnic) groups or (social) classes?

No. The technology is unrelated to peoples identity, ethnicity, or social background. It is strictly about robot simulation and control.

In which way can bad actors use this technology to pit certain groups against each other? These groups can be, but are not constrained to, ethnic, social, political or religious groups.

Very unlikely. The project is niche and limited to an academic/competition setting. No clear way exists to use it for polarization or division.

How could bad actors use this technology to subvert or attack the truth?

Very limited. A possible misuse could be presenting simulation results as proof of robot capabilities without hardware validation, misleading stakeholders about performance. But this risk is minor and manageable.

Now that you have thought hard about how bad actors can impact this technology, what improvements would you like to make? List them below.

Require clear documentation of assumptions and limits of the simulation (avoid misuse as proof).

Apply open-source licensing with attribution requirements to prevent plagiarism.

Educate students about proper academic integrity and responsible use of the simulation results.

Privacy

Are you considering the privacy & personal data of the users of your technology?

Does the technology register personal data? If yes, what personal data?

No. The digital twin only processes robot parameters (wheel geometry, trajectories, motor commands). It does not collect or store any personal data.

Do you think the technology invades the privacy of the stakeholders? If yes, in what way?

No. The simulation and control system do not affect stakeholder privacy.

Is the technology is compliant with prevailing privacy and data protection law? Can you indicate why?

Yes. Since no personal data is collected, GDPR and other data protection laws are not triggered.

Does the technology mitigate privacy and data protection risks/ concerns (privacy by design)? Please indicate how.

Yes, by design. It does not need or process personal data, which is the strongest form of privacy protection (data minimization).

In which way can you imagine a future impact of the collection of personal data?

None expected. Even if extended, the technology would likely remain technical (robot/trajectory data only). Only if future versions introduced user monitoring (e.g. logging Xbox controller inputs per student), privacy considerations would arise.

Now that you have thought hard about privacy and data protection, what improvements would you like to make? List them below.

Explicitly document that no personal data is collected (to reassure future users).

If logging user activity in the future, ensure anonymization and minimal storage.

Educate future student teams about GDPR basics to avoid unintended issues.

Human values

How does the technology affect your human values?

How is the identity of the (intended) users affected by the technology?

The technology empowers students and researchers by giving them the tools to simulate, test, and innovate. It enhances their professional identity as engineers by fostering skills in robotics, control, and sustainability. It does not stigmatize or impose beliefs, but instead encourages curiosity, teamwork, and competence.

How does the technology influence the users' autonomy?

The digital twin increases autonomy: students can test and make decisions independently without always needing access to physical robots. It is not addictive and has no commercial attention-driven design. However, users remain dependent on accurate simulation models if the model is incomplete or misleading, autonomy could be limited.

What is the effect of the technology on the health and/or well-being of users?

Mostly positive. It reduces stress and risk by providing a safe test environment where mistakes dont damage hardware or cause injuries. It can reduce frustration from repeated physical failures. Negative effects are minimal, but long hours in front of a computer could lead to fatigue if not managed.

Now that you have thought hard about the impact of your technology on human values, what improvements would you like to make to the technology? List them below.

Ensure clear communication of the limits of the simulation, so students dont develop false confidence.

Encourage balanced use: combine simulation with physical testing to keep learning grounded in reality.

Include documentation/tutorials that empower students further, supporting both autonomy and well-being.

Stakeholders

Have you considered all stakeholders?

Who are the main users/targetgroups/stakeholders for this technology? Think about the intended context by answering these questions.

Name of the stakeholder
Students (current project team)

How is this stakeholder affected?
Gain hands-on learning, simulation skills, and practical testing environment.

Did you consult the stakeholder?
Yes

Are you going to take this stakeholder into account?
Yes

Name of the stakeholder
RoboHub (client)

How is this stakeholder affected?
Gains a validated digital twin and software that improves robot development.

Did you consult the stakeholder?
Yes

Are you going to take this stakeholder into account?
Yes

Name of the stakeholder
University (Fontys)

How is this stakeholder affected?
Benefits from educational outcomes, documentation, and reusable teaching material.

Did you consult the stakeholder?
Yes

Are you going to take this stakeholder into account?
Yes

Name of the stakeholder
Future student teams

How is this stakeholder affected?
Reuse and expand the digital twin for their own projects.

Did you consult the stakeholder?
No

Are you going to take this stakeholder into account?
Yes

Name of the stakeholder
RoboCup organization

How is this stakeholder affected?
Ensures compliance with competition standards and rules.

Did you consult the stakeholder?
No

Are you going to take this stakeholder into account?
No

Name of the stakeholder
Mentors & supervisors

How is this stakeholder affected?
Oversee the project, ensure academic quality and knowledge transfer.

Did you consult the stakeholder?
Yes

Are you going to take this stakeholder into account?
Yes

Did you consider all stakeholders, even the ones that might not be a user or target group, but still might be of interest?

Name of the stakeholder
IT support at Fontys

How is this stakeholder affected?
Ensures students have access to computing resources and simulation

software.

Did you consult the stakeholder?
No

Are you going to take this stakeholder into account?
No

Name of the stakeholder
Broader RoboCup community

How is this stakeholder affected?
Can benefit if project outputs are shared openly

Did you consult the stakeholder?
No

Are you going to take this stakeholder into account?
No

Now that you have thought hard about all stakeholders, what improvements would you like to make? List them below.

Improve stakeholder consultation by involving RoboHub earlier in testing feedback.

Document the digital twin clearly to support future student teams.

Share simulation results and models with the broader RoboCup community to maximize educational impact.

Data

Is data in your technology properly used?

Are you familiar with the fundamental shortcomings and pitfalls of data and do you take this sufficiently into account in the technology?

Yes. We are aware that simulation data is always an approximation of reality. Models may oversimplify or miss real-world conditions. Correlation causation, and bias can be introduced if models are not validated with real robot experiments. The project takes this into account by planning both simulation and hardware validation.

How does the technology organize continuous improvement when it comes to the use of data?

The simulation models and collected data will be iteratively improved through testing and feedback. Results from the digital twin will be compared against physical robot tests to refine the accuracy of models. This creates a feedback loop that avoids self-fulfilling errors.

How will the technology keep the insights that it identifies with data sustainable over time?

Sustainability is ensured by documenting all assumptions, models, and datasets so future student teams can reuse them. Data is stored in shared repositories (OneDrive/Teams) accessible to RoboHub. As RoboCup rules evolve, models can be updated without starting from scratch.

In what way do you consider the fact that data is collected from the users?

No personal user data is collected. Data relates only to robot trajectories, kinematics, and control signals. There is no exploitation or monetization of user data, so fairness is not an issue.

Now that you have thought hard about the impact of data on this technology, what improvements would you like to make? List them below.

Emphasize robust documentation of assumptions and limitations of the data.

Store simulation datasets in an open, standardized format to ensure reusability.

Include version control for models so future teams can track changes in data handling.

Regularly validate models against real-world robot performance to prevent simulation drift.

Inclusivity

Is your technology fair for everyone?

Will everyone have access to the technology?

Yes, within the university and RoboHub context. The digital twin is built with open-source tools, so future student teams can also access and use it. However, access is limited to those with sufficient computing resources and technical knowledge. Those without access would not suffer a significant societal setback, but they might miss out on a valuable learning opportunity.

Does this technology have a built-in bias?

No inherent bias. The simulation models robots and physics, not people. The only bias risk is technical oversimplifications in the model might favor certain testing conditions but not others. This is addressed by validating against real robot data.

Does this technology make automatic decisions and how do you account for them?

The digital twin uses algorithms (inverse kinematics, controllers) to calculate robot movement. These are explainable, deterministic, and well-documented. No opaque AI or machine learning is involved, so decisions are transparent and verifiable.

Is everyone benefitting from the technology or only a a small group? Do you see this as a problem? Why/why not?

The main beneficiaries are students, RoboHub, and RoboCup participants. It is a niche technology, so not everyone benefits directly. However, the broader value is in knowledge-sharing and education, which benefits society indirectly. This limited scope is not a problem because the project was never intended for mass adoption.

Does the team that creates the technology represent the diversity of our society?

The project team is a diverse group of international engineering students with different technical backgrounds. While not fully representative of society as a whole, the diversity in educational and cultural perspectives supports inclusivity in design and documentation.

Now that you have thought hard about the inclusivity of the technology, what improvements would you like to make? List them below.

Provide thorough documentation and tutorials so that future students with different levels of knowledge can use the technology.

Ensure that open-source sharing is prioritized so others outside the team can benefit.

Continue fostering diverse, international teams to avoid narrow perspectives in development.

Transparency
Are you transparent about how your technology works?

Is it explained to the users/stakeholders how the technology works and how the business model works?
Yes. The technology is explained through the Plan of Approach, final report, and documentation. There is no commercial business model it is an educational project. Goals (building a validated digital twin and motion control system) are clearly stated, and users can see how the simulation behaves.

If the technology makes an (algorithmic) decision, is it explained to the users/stakeholders how the decision was reached?
Yes. The algorithms (inverse kinematics, control laws) are fully deterministic and based on known engineering theory. Their logic can be documented in equations and flowcharts. Unlike machine learning systems, there is no black-box behavior. Decisions are explainable and verifiable.

Is it possible to file a complaint or ask questions/get answers about this technology?
Yes, within the educational and project setting. Stakeholders (students, RoboHub supervisors, mentors) communicate directly during development. Questions can be addressed in team meetings, and documentation serves as a reference for future teams.

Is the technology (company) clear about possible negative consequences or shortcomings of the technology?
Yes. It is acknowledged that simulations are approximations of reality and can miss unforeseen real-world effects. Overreliance on the digital twin without hardware validation could lead to incorrect assumptions. These limitations are explicitly documented.

Now that you have thought hard about the transparency of this technology, what improvements would you like to make? List them below.
Provide more user-friendly documentation (step-by-step tutorials, annotated code).

Add clear disclaimers about simulation limitations to prevent misuse or overconfidence.

Create a structured handover process for future student teams (e.g. FAQ, troubleshooting guide).

Sustainability

Is your technology environmentally sustainable?

In what way is the direct and indirect energy use of this technology taken into account?

Direct energy use comes mainly from running simulations on computers. This is less than the energy/material waste of building and testing multiple physical prototypes. Indirectly, by reducing trial-and-error on hardware, the project saves energy and resources in production and assembly. Improvements could include optimizing code for efficiency and using energy-efficient computing hardware.

Do you think alternative materials could have been considered in the technology?

For the physical robot, yes. Sustainable or recyclable materials could be prioritized when replacing parts. For the simulation itself, no physical resources are consumed except hardware already available at the university.

Do you think the lifespan of the technology is realistic?

Yes. The digital twin can be reused and updated for future RoboCup projects. As long as software documentation and models are maintained, the lifespan can be extended across multiple student teams. Hardware components of the physical robot have a shorter lifespan but can be replaced and reused modularly.

What is the hidden impact of the technology in the whole chain?

Upstream impact: Manufacturing laptops/PCs for simulation, and producing robot parts, has environmental costs (resource extraction, energy).

Downstream impact: E-waste from old hardware or discarded robot components.

Mitigation: Reduce hidden impact by reusing existing hardware, repairing parts where possible, and responsibly recycling components.

Now that you have thought hard about the sustainability of this technology, what improvements would you like to make? List them below.

Optimize simulation software to reduce computational load and power use.

Use modular robot designs to maximize reuse of hardware across future student projects.

Source any new components from sustainable suppliers.

Encourage repair and recycling of robot hardware to reduce downstream e-waste.

Document best practices so future teams can continue sustainable development.

Future

Did you consider future impact?

What could possibly happen with this technology in the future?

In the near future, the digital twin could become a standard tool at RoboHub for teaching and testing robot control. If widely shared, it might become a reference framework for other RoboCup teams, spreading sustainable simulation practices. On a larger scale, it could inspire similar digital-twin approaches in other fields of robotics and engineering education.

Sketch a or some future scenario (s) (20-50 years up front) regarding the technology with the help of storytelling. Start with at least one utopian scenario.

Digital twins become standard in all robotics and engineering education worldwide. Students test everything virtually before building, drastically reducing waste and accelerating innovation. RoboCup evolves into a hybrid competition where real-time simulation and physical robots co-exist. This approach inspires industries (healthcare, mobility, manufacturing) to adopt sustainable simulation-first methods, making development safer and greener.

Sketch a or some future scenario (s) (20-50 years up front) regarding the technology with the help of storytelling. Start with at least one dystopian scenario.

Overreliance on digital twins leads to engineers losing touch with real-world problem solving. Simulations dominate education, but real-world validation is neglected, causing robots to fail in practice. If commercialized by a company, the digital twin could become closed-source, blocking future students from free access and creating inequality between wealthy institutions and smaller ones.

Would you like to live in one of this scenario's? Why? Why not?

The utopian scenario is highly desirable because it aligns with sustainability, education, and innovation. The dystopian scenario is undesirable, as it creates over-dependence on virtual tools and could increase inequality in education. A balanced approach that combines digital twins with physical testing avoids this outcome.

What happens if the technology (which you have thought of as ethically well-considered) is bought or taken over by another party?

If the project is commercialized, access might be restricted, and sustainability goals could be lost. To prevent this, open-source licensing and clear documentation should be maintained, ensuring that future students and

RoboCup teams can freely use and adapt the tool.

Impact Improvement: Now that you have thought hard about the future impact of the technology, what improvements would you like to make? List them below.

Maintain open-source licensing to keep access fair and transparent.

Encourage a hybrid model that combines digital twin testing with physical validation.

Share models broadly within the RoboCup community to prevent exclusivity.

Build in flexibility so the digital twin can adapt to future RoboCup rule changes.