CONCEPT 01

CORLEO

Explore new frontiers Novel interactive four-legged off-road mobility

Hydrogen canister housing

Hydrogen storage alloy canisters are employed to enable flexible layouts despite the limitation of space to achieve efficient housing. Swappable and portable canisters provide a good refueling solution even in an outdoor environment where appropriate facilities are difficult to access.

Patent application: 2025-043181

Stirrups

Stirrups and handholds are equipped to detect weight shifts of the rider to maneuver the machine. The length of the stirrups is automatically adjusted by the machine to help the rider maintain the optimal posture at all times.

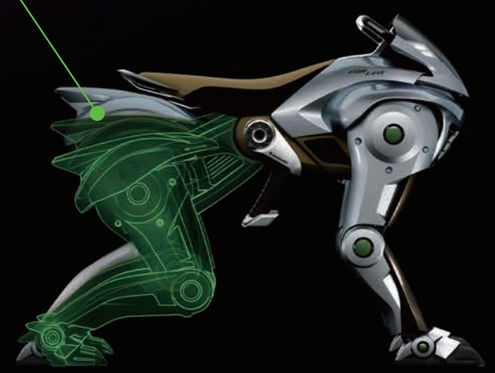
Patent application: 2025-013589

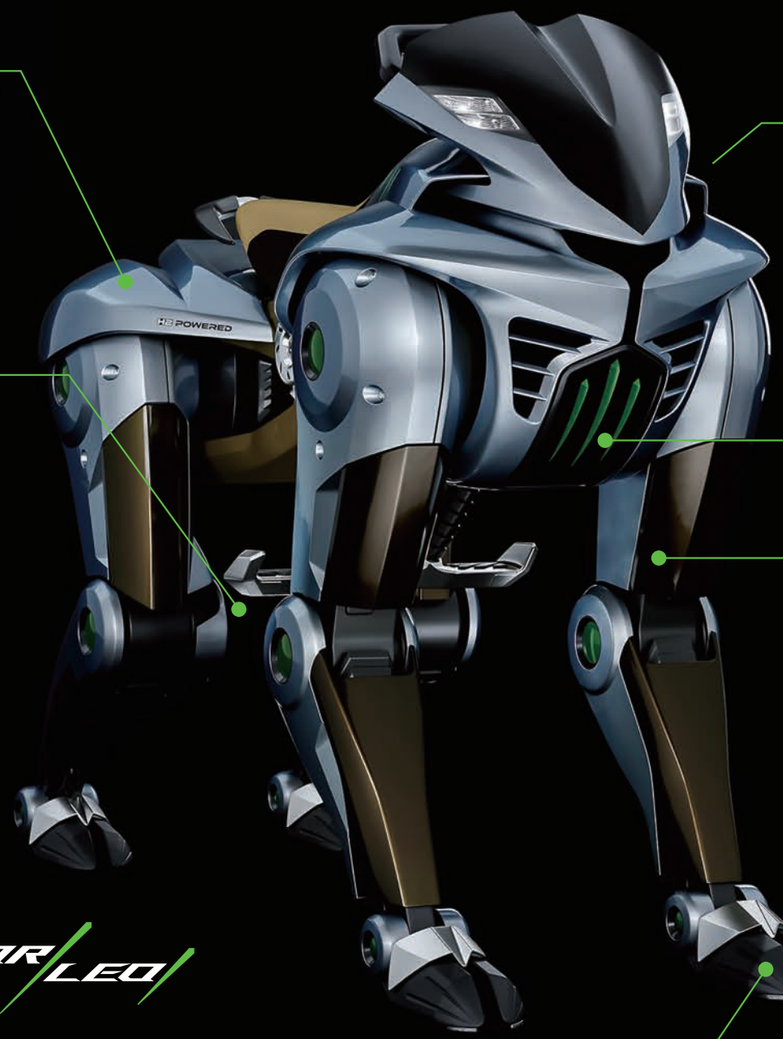
Patent application: 2025-013591

Swing arm

A movable shaft is installed in the mid-section of the chassis to enable the rear-leg mount to swing vertically relative to the front-leg mount, in order to absorb the impact and vibration related to walking and running. This mechanism can also provide attitude control at the level higher than that is difficult by the legs alone. For example, the vehicle can keep the saddle horizontal even when climbing, allowing the rider to avoid facing upward and to easily confirm the topographic conditions ahead.

Patent application: 2025-013587





Power unit

A 150 cc hydrogen engine for electricity generation is adopted to achieve a compact and efficient layout in the limited space engine bay. Electricity is generated using hydrogen supplied from canisters mounted in the rear section, in order to power actuators located in the four legs and vehicle body.

Patent application: 2024-231649

Cooling system

In the front section of the chassis, the radiator for cooling the engine and the inter-cooler for cooling intake air heated by the turbocharger are housed so as to achieve an efficient layout. The temperatures of the engine and intake air are appropriately controlled to prevent the abnormal combustion,one of the major issues posed by hydrogen combustion engines.

Patent application: 2025-013588

Leg suspension

The suspension is designed to achieve smooth bending and stretching movements of the legs. A broad range of flexible motion is secured to offer a comfortable ride and supporting dynamic actions, including making agile jumps.

Patent application: 2025-013590

Rubber hoof

The legs have left-right divided cloven hooves made of rubber, a material that is slip-resistant and absorbs land surface irregularities. These hooves can adapt to all different types of terrain, including grassland, rocky ground, and loose gravel, enabling the vehicle to maintain a stable attitude. Also, by absorbing landing impact, the structure helps the legs keep the shock-absorbing control operations to a minimum, thus reducing energy consumption.

Patent application: 2025-013578

CORLEO aims to provide the rider with a distinctively novel mobility experience characterized by the feeling of having personal communication with the machine. The machine detects the rider's behavior to assist safe operation. The four-legged structure supports strong off-road riding performance on rugged rocky ground or uneven woodland surfaces, easily jumping hurdles. The rider will feel like riding on a lion, the animal associated with the vehicle's name, to go on an adventurous trip to locations inaccessible with previous mobility capabilities and have a view of magnificent natural landscapes.

This machine has adopted an advanced off-road mobility control concept for employing autonomous control to prevent dangerous operation and ensure safety while reflecting the rider's intentions, in a bid to overcome the challenge of off-road travel posed by the safety-joy trade-off dilemma. According to this concept, safety can be assured for all types of riders regardless of age and gender while delivering a thrill similar to the sense of adventure specific to off-road vehicle maneuvering. This has been made possible by utilizing the Kawasaki Group's technological assets, specifically by combining design concepts about maneuverability and stability established for motorcycle development and mechatronics design and system control technology built for robot development.

Also, development of additional features is planned for various purposes, such as stable ultralow-speed travel that is difficult for conventional two-wheelers to perform , and safe tandem riding. The machine's use is not limited to leisure. Its strong ruggedness will be suitable for disaster rescue and relief operations.

Robotics

(1) Four-legged mobility

CORLEO represents a novel off-road personal mobility model proposed by Kawasaki. It is characterized by a four-legged structure with good off-road adaptation to ensure stability as well as a distinctively novel-concept maneuvering system — the machine detecting the riders' behavior constantly while allowing them to have fun maneuvering the vehicle, looking to deliver a strong sense of security by having the person and the machine move as one (human-machine interaction), and the rider expanding their moving capability, notably for barreling over even the worst terrain effortlessly while feeling like being merged with the machine.

(2) System control

Flexible motion, a pivotal feature in robotics for a four-legged structure, is to be achieved by synchronously controlling drive shafts in the legs and chassis using the torque controller along with the less than one millisecond cycle time controller. This provides not only attitude control but also fine tune control to absorb contact impact and stabilize travelling performance. Discussions are underway to increase the number of drive shafts in order to enable finer control.

It is equipped with an inertial measurement unit (IMU), a basic function for a four-legged robot, to provide attitude control, and a switch for riding mode change (walking, running, etc.). In order to verify and develop these basic functions, it is essential to conduct simulations using a physical engine in an appropriate environment to do comparisons with actual machines in order to increase reliability.

CORLEO's system control is composed of the following four elements:1. Torque control as centerpiece; 2. safety control — safety units designed to ensure deceleration stop in a safe position in the event of abnormalities and to be able to continue to move in case of a software abnormality in order to secure a safe state of hardware; 3. learning control — utilizing behavior logs of actual machines to step up from imitative learning to reinforcement learning in order to enhance performance; and 4. control for human-machine interaction — detect weight shifts of the rider to read the rider's intent and reflect

it in system control, aiming to provide intuitive operability for all types of riders regardless of skill level.

For the development environment of CORLEO, a hybrid development environment platform is built by combining a model-based process and machine learning models. The model-based process is to express the machine dynamics and control algorithm using mathematical models and start performance verification at the design stage. Machine learning models are to be used in learning for environmental recognition and control optimization utilizing data from actual machines and simulations. Moreover, the MLOps (Machine Learning Operations) process is introduced to be able to adapt machine learning models to the environment flexibly and promote their evolution while operating them at the same time. This will enable constant control optimization in accordance with changes in ground surface conditions and the user's operating characteristics. This cyclical approach consisting of MBSE (Model-Based Systems Engineering)/MBD (Model-Based Definition), ML (Machine Learning), and MLOps provides a key basis to support CORLEO's highly reliable and adaptative control functionality.

(3) Adaptive shared control

CORLEO is equipped to be maneuvered using input received from the rider's weight shift, and is designed to use this function for two major purposes: one is to extend human capabilities; and the other is, in a dangerous situation such as that carrying the possibility of jumping off a cliff, to make appropriate corrections to the rider's command, by overriding the person's maneuvering intentions autonomously, which is a form of robotic control technology that has already been applied notably to medical robots and power-assisted suits. In the CORLEO system, the rider's intentions and robotic operating conditions are shared between the human and the machine involved, and appropriate robotic processes are adopted to adjust the level of autonomous interference control according to the rider's skill levels. This represents a method known as "adaptive shared control." Using this method, CORLEO is able to read the intentions of all types of riders regardless of experience and skill levels and ensure their safety in a manner suited to each person, thus achieving a groundbreaking robotic feature for human-machine interaction, which makes CORLEO a distinctively novel mobility invention and also shows a stark contrast with the conventional robotic process of ensuring safety by following completely unilateral procedures with no consideration for human input.

(4) Issues

In order to implement CORLEO, enhance its traveling performance, and enable high-level control, it is necessary to make advancements in various technology fields. For the design of the vehicle body, additional advancements are needed in materials technology. To create a four-legged structure with a size sufficient to accommodate human riders and that can achieve high-speed traveling and make dynamic jumps, the materials to be adopted must be highly durable and lightweight at the same time. This requirement is crucial particularly for the legs, a section responsible for performing high-speed motions while supporting the entire body. Weight reduction is key to substantially improve kinematic performance in traveling at high speed and making jumps.

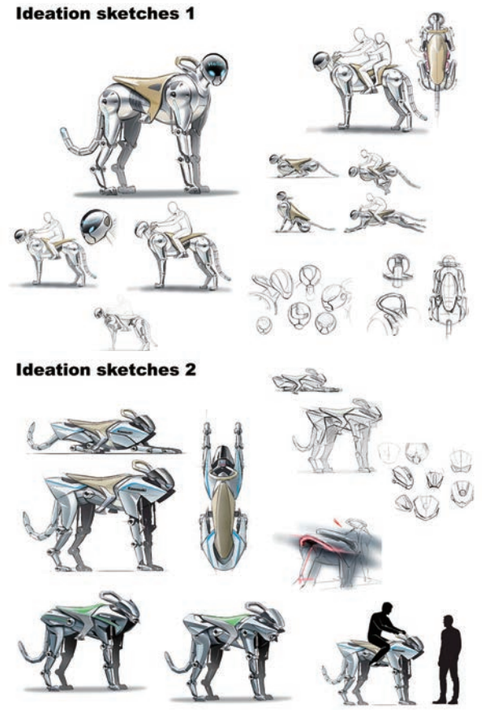
For control functions, advancements need to be made principally in sensing technology, in order to improve sensing performance and build more advanced signal-processing capabilities. For example, to ensure stable motion and prevent collision and falling when traveling at high speed, it is necessary to establish technology to have a view of the road ahead over a range of tens of meters to recognize topographical features and hurdles with a high degree of accuracy, process signals at high speed and reflect the results in control operations.

To implement the adaptive shared control process, it is essential to establish a highly advanced human-machine interface that can detect the rider's weight shift based on input from handholds and stirrups and read the rider's intentions to reflect them in control operations.

Appearance design

The appearance design of CORLEO contains elements that evoke a sense of mobility while being suggestive of animals. The most difficult challenge was to determine which of the two elements — motorcycle or robot animal — should be emphasized more, although the general image was determined early on based on the basic concept of off-road mobility. A stronger emphasis on the former element will likely result in something like an ordinary vehicle just with legs attached but lacking a playful mind, and that on the latter is likely to effect a deviation from the target mobility concept and rejection of communication with the human. There were additional crucial requirements to meet to represent Kawasaki's traditional motorcycle design philosophy that values the quality of being

Initial design sketch



"powerful" and "sporty." A myriad of ideas were brainstormed and processed to satisfy standards for universal approachability, an animal-like dynamic appearance that can arouse interest in riding, and the feasibility of the mobility technology in a physical sense, before the present design was finalized.

Ergonomics verification

In pursuit of safety, ergonomics verification tests were conducted with cooperation received from the equestrian club of Kobe University. Test participants rode the clay mock-up and reported their feelings of safety and stability. Also, adequacy evaluations were conducted for the stirrups in terms of the height, proportion to prevent the rider from being caught, footwork and other issues. The obtained feedback was used to establish a more comfortable riding position and functional beauty supported by a technical basis.

Clay mock-up

Navigation system (operation panel)

The instrument panel is installed in the front part of the machine. Information to be provided includes not only navigation data, such as a route map and estimated time of arrival, but also advice to assist optimal riding performance in consideration of road surface conditions and the center of gravity position, as well as environmental information such as altitude and the time of sunrise and sunset. The panel is also equipped with a navigation light to indicate the route by highlighting the path on the ground surface, as a measure to support the rider to move along the right path even under conditions of low visibility, such as in the evening.

Rider's view during the evening

Power unit

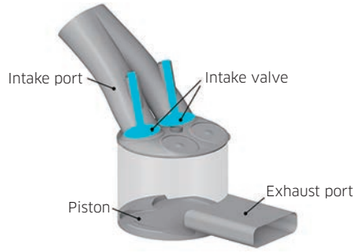
(1) Power unit design concept

CORLEO's power unit has adopted a series hybrid system where the actuator is powered by electricity generated by the Hydrogen internal combustion engine. The power unit has must satisfy two major requirements: "small in size and weight, and capable of high output" to be able to produce sufficient power to meet the output requirement of the unit despite the limited space; and "carbon neutral" by using hydrogen. In order to satisfy the above requirements, The power unit design concept was determined based on hydrogen combustion, with specifications including a rated output of at least 15 kW and an engine displacement of 150 cc. values determined by analyzing CORLEO's travelling pattern.

(2) Turbocharged two-stroke engine

While hydrogen engines virtually do not emit carbon dioxide (CO_2) while running, they can generate nitrogen oxides (NOx) when burned around the stoichiometric air-fuel ratio. As it is difficult to contain an exhaust gas purification catalyst due to space constraints, the combustion concept has been designed to create a lean-burn engine using a turbocharger as a measure to reduce NOx emissions, thus enabling clean operations. However, lean combustion means a lower output. To address this issue and achieve the required output, the concept has employed a turbocharged poppet-valve two-stroke engine that uses Kawasaki's prior art.

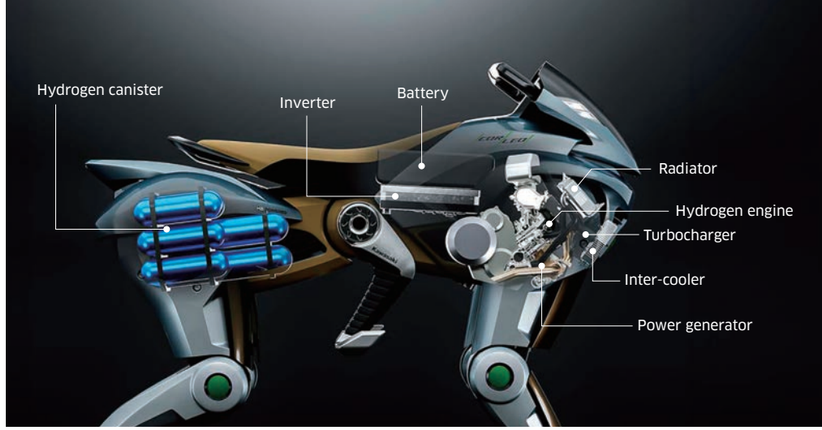
A two-stroke engine completes a power cycle with two strokes of the piston in one revolution of the crankshaft to do the intake and exhaust processes at the same time (scavenging), a mechanism capable of high output and thus is expected to improve the output of a small-displacement and lean-burn engine. With the existing two-stroke engine, however, carbon neutrality cannot be achieved due to its structure to feed a mixture of fuel and engine oil (for lubrication), which inevitably involves the engine oil being burned together with fuel, resulting in CO_2 emissions. To overcome this problem, Kawasaki's two-stroke engine has been employed. This technology has a proprietary mechanism that uses a poppet valve synchronized with the revolution of the crankshaft, a standard feature of the four-stroke engine, for the intake valve. This mechanism allows for independent processes for fuel feed and lubrication, eliminating the need for mixing fuel and lubrication oil, thus achieving carbon neutral operations with virtually zero CO_2 emissions. Moreover, a turbocharger is installed to improve the efficiency of scavenging in the engine for the intake process, which is conducive to higher output and stable combustion. In addition, for the fuel feed system, a direct-injection system (where fuel is directly injected into the combustion chamber) is adopted to hinder fuel from being blown out toward the exhaust side during the gas exchange process, thus helping improve combustion efficiency and promote exhaust gas purification.



(3) Hybrid system configuration

The concept has adopted a series hybrid system, with the overall structure comprised of generator (generate electricity), inverter (process electricity generated) and battery (store electricity generated). A compact configuration is achieved by uniting the generator and the gear box to be built into the engine, a technique that has applied processes established chiefly for building motocross engines.

The inverter and the battery are located under the seat for efficient layout. The battery can be accessed independently, easily by removing the seat, a structure allowing the battery to be charged independently as a measure to secure a longer range.



(4) Hydrogen storage alloy canister

Due to its high layout flexibility, hydrogen fuel contained in hydrogen storage alloy canisters is adopted. This allows multiple containers of different sizes to be housed, which is important in order to make effective use of the limited fuel storage space of CORLEO. As far as small-size containers go, the hydrogen storage alloy canister excels in the storage capacity per container compared with the high-pressure hydrogen tank, offering good storage efficiency of the entire system housing multiple containers. CORLEO contains a total of six canisters of two different sizes, which can secure an adequately long range.

The canisters are easy to replace, which is important for easy hydrogen refueling. And being portable and swappable like dry-cell batteries, this option can provide a good refueling solution in outdoor environments where appropriate facilities are difficult to access.

Intellectual property

More than ten applications for patent, design, and trademark have been completed for features characteristic to CORLEO, especially related to hydrogen engine-based power unit and hydrogen canister, swing arm, hoof, and stirrup. Also, for device configurations and designs that are currently in the process of improvement, application filing process is underway. At the same time, additional plans are on the table to file applications for services that will be developed by utilizing the machine, with a view to building a patent portfolio of a new off-road mobility encompassing both hardware and software functions. The relevant IP strategies do not only aim to prevent imitation by other companies but also seek to secure a competitive edge by obtaining patents and facilitate the formation of partnerships and consortiums with various business corporations. This is also to build co-creation frameworks to accelerate development activities, rather than pursuing monopolistic policies for technology development and service deployment.

Conclusion

CORLEO is a result of combining expertise built up by Kawasaki while operating the mobility business and robotics business, which we understand has received the highest-ever praise for its concept, performance, and styling design, constituting a reason for the global resonance the technology had. Going forward, we are aiming for early commercialization, looking to form partnerships with various business and other organizations while utilizing internal expertise at the same time.

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