MERPHI

Design Review Document

For: Hyperspawn

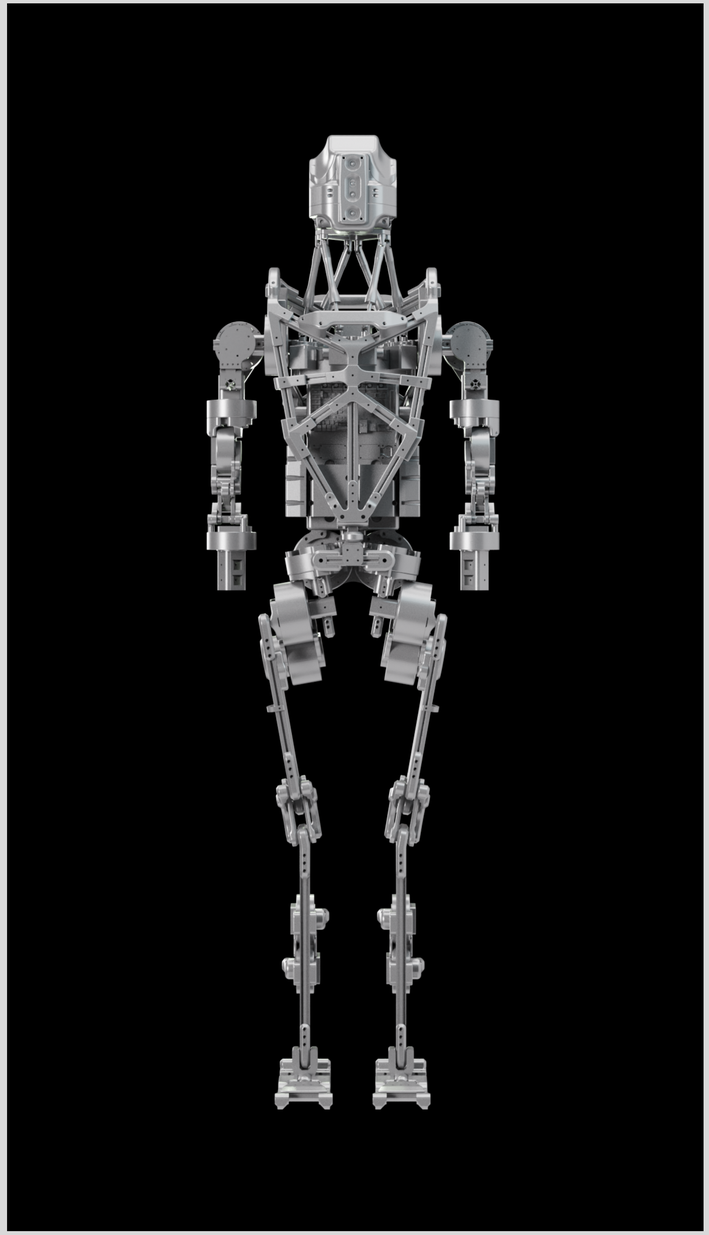
Ver 1.0 - 14 Mar 2024 - Gothenburg

www.merphi.se - +460737693905
filip.sperr@merphi.se - mehrdad@merphi.se

This report outlines the results of the Robotic Design Review performed by MERPHI's Design team on the Dropbear humanoid by Hyperspawn. The purpose of the review is to provide concise guidelines and ideas to support the future development of the product with a focus on industrial design and user experience.

The review is based on our initial evaluation of the product as well as the meeting held together with Hyperspawn (22th Jan 2024) where the products background and envisioned future were discussed. As the Dropbear robot is in the early stages of development, a distinct industrial design has yet to be created. Based on this we determined that the best direction for this review would be to provide guidance and inspiration for the future development of the products design language. Most of the ideas and guidelines in this report are therefore focused on more long term changes, but some are also more applicable short term.

The report is divided into two main sections: a general description of the most important design aspects for a humanoids and secondly a set of more specific guidelines and suggested changes for Dropbear. Please note that this section does not contain any detailed solutions, as that is outside the scope of this review.



Positive feedback

While the focus of the review is to find areas of improvement, we also want to highlight the positive aspects of the product to make sure they are not overlooked.

- Simple and efficient build: the simplicity of the robots build is a great asset and should be preserved. It can also be used as an aesthetic feature to differentiate Dropbear compared to other humanoids.
- Closeness to human proportions: the overall height, width and placements of joints are close to that of an adult human male. This creates a good starting point for future development.

A starting guide for humanoid industrial design

Before beginning to design a humanoid robot, the following questions need to be answered:

1. Who is this robot? What personality do you want to give him/her? What feeling/emotion do we want it to evoke in the audience?
2. Who is this robot for? Who should fall in love with this robot at first sight? Who should find it useful?
3. How visible do we want this robot to be? Is it an introverted or extroverted robot?
4. Where did this robot come from? Did it come from a robotic lab made by people who were trying to push the boundaries of science, or did it come from an industrial enterprise to showcase their capabilities or somewhere else?
5. Which capabilities of this robot do we want to expose to the audience, and which ones need to be hidden?
6. What makes this robot different from others? Or in fact, where is the focus? Is it in the legs like Atlas, or in the hands, like Phoenix, or in communication like Ameca?
7. What is that "one thing" that we want people to remember when they see this robot? It should be one, not two!
8. In what context will the robot operate? What type of people will it interact with and what are the most prominent features of the physical environment?
9. Last but not least, which areas of this robot are human-like, and which areas are not? In other words, what parts of this robot are directly inspired from human's body and what parts are inspired by other artifacts?

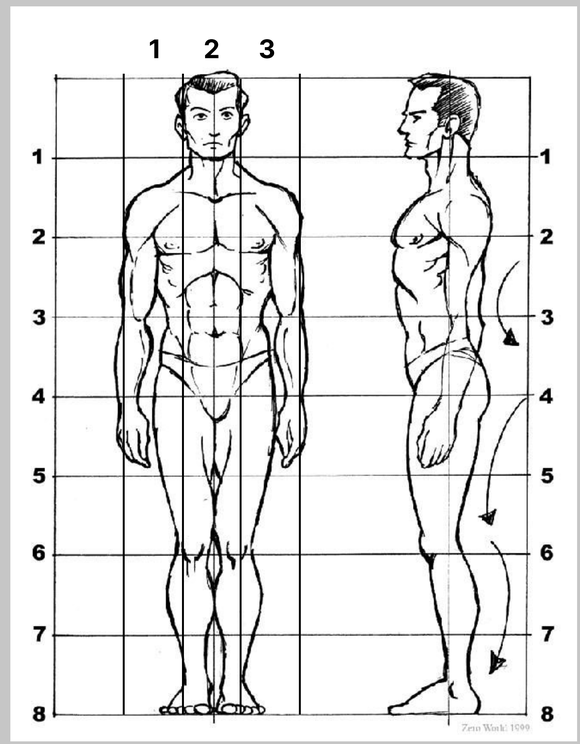
Consider that the same questions above can be asked of an individual. Start by asking these questions of yourself first. A tip for question 9: Are you wearing glasses now?

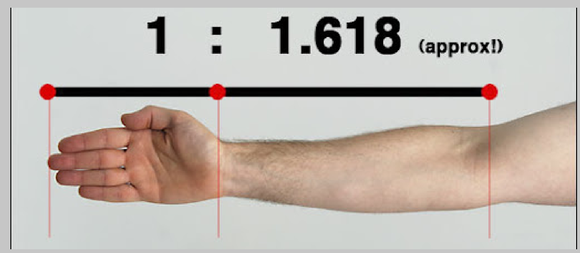
The above questions will help outline the basis for the design of the robot and the answers will be useful when proceeding through actual design process. In the following section we have outlined the most important aspects to consider when designing a humanoid. As this is a very complex endeavor, it is rarely possible to find perfect solutions to each area. Instead, the best design comes from finding a balance between the different aspects. The mentioned items are the most fundamental areas to consider, but in addition to them there are other areas such as lighting, labeling, voice, and sound, among others.

1. Proportions

Perhaps the most crucial aspect in humanoid design is proportion. Considering the fact that design proportions fulfill both aesthetic and functional goals. Designing proportion does not necessarily mean replicating the exact appearance of a human and measuring it, as there is no perfect human body, and sometimes slight deviations from a typical human might even be desired. Instead, it involves determining which proportions achieve the goals of the robot and are aesthetically pleasing to the human eye. There's a lengthy discussion on how to approach proportions, but the easiest way is to select a body type based on factors such as age, gender, and physical capabilities, then establish the relationships between different elements of the body. These relationships should then be followed as close as possible in the robots design.

For example, an adult body that is 180 cm tall typically consists of eight heads stacked on top of each other, with shoulder width equivalent to placing three heads side by side. While practitioners often use a standard mannequin's mesh, having a strategy for proportions helps address the limitations imposed by the size of actuators and links. The human body employs golden ratios (1:1.618..) in various locations and designing related links with respect to this ratio is a recommended practice. For instance, from the shoulder to the last knuckle of the hand, all joints could follow the golden ratio rule.





2. Coverability

This aspect defines how much of the system is covered by non-functional panels/ covers and how much is exposed. The answers to the above question can help solve this part. In humanoid design, there are often technical limitations on what can or can not be covered. These limitations stem from factors such as degrees of freedom (DoFs), weight limitations, component sensitivity or confidentiality, generated heat, environmental constraints, etc. An easy practice is to first identify which areas need to be covered and which need to be exposed. Start with the areas that are critical to cover and decide later on the exposed areas based on necessity or aesthetics.

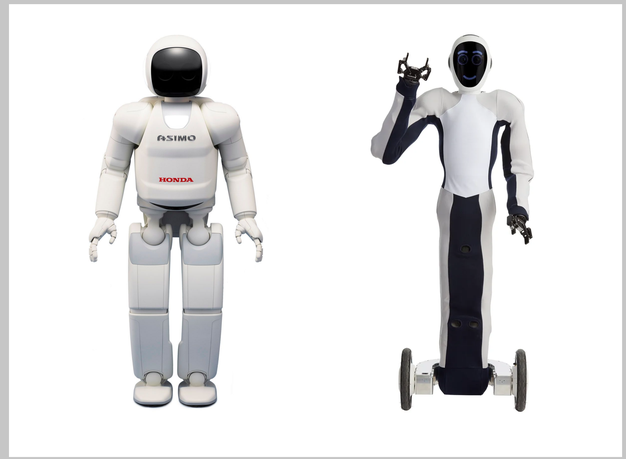
Recent trends intentionally avoid full coverage, although this approach requires careful attention to detail design of the structure and internal components. There are mainly three trends followed in this area:

1. Full coverage: These robots are often highly commercial and intended for direct interaction with humans, as seen in robots such as Asimo, Pepper, or Eve X1.

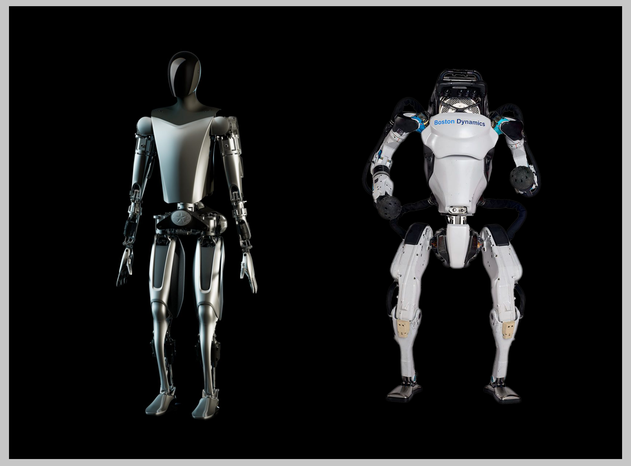
2. Partial cover: This type of coverage offers design flexibility and does not overly constrain the technical team, as observed in robots such as Tesla Optimus Gen 1, Surena 4, and Atlas.

3. Exposed structure: In this approach, the inner structure is not separated from the outer non-functional cover. It manifests in two forms: either the inner structure is designed to appear aesthetically pleasing without any non-functional covers, or non-functional covers are designed to look functional and structural.

There's no right or wrong approach here; it all depends on the intended usage of the robot.



Fully covered robots: Asimo and Eve X1



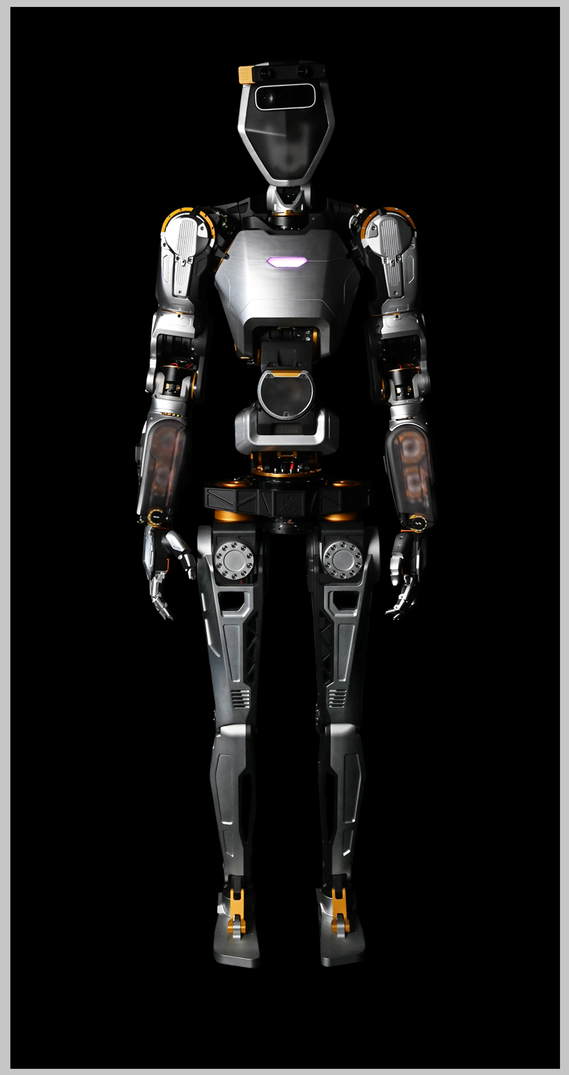
Partially covered: Tesla Optimus and Atlas

3. Forms and geometries

The first question to address here is whether we are designing the forms of the robot based on human bones, muscles, skin, or clothing/gear. For example, when designing the shape of the feet, are we following human feet forms or shoe forms? It's crucial to establish this at the beginning of the process and maintain consistency. Of course, a mix of all is an option as long as a skeleton with exposed bones isn't wearing gloves! What we define as basic geometric shapes, which form the basis of most mechanical components such as actuators and standard bars, cannot be found exactly in nature, or in this context, the human body. Therefore, based on the requirements, some compromises must be made.

A robot with fully organic and fluid shapes isn't the most efficient, and a purely geometrical robot isn't highly desirable. Finding the right balance and mix of forms has a significant impact on the robot's aesthetics. Some components can contribute to creating more organic forms. For instance, cable sets and wire socks can create organic and fluid forms if exposed. One approach that significantly impacts the balance of forms is the repetition of a certain form.

A good practice here is to design a form for each type of actuator or joint and repeat that form wherever the same movement occurs. For instance, a "squircle" transforming into a circle can be used wherever there's a one-degree-of-freedom joint. However, controlling and balancing forms is much more challenging when the structure is exposed, and various types of elements with different geometries are visible. It is therefore usually better to focus on a limited set of forms. An example of this implemented can be seen in Phoenix, where a golden finish is applied on top of most actuators.



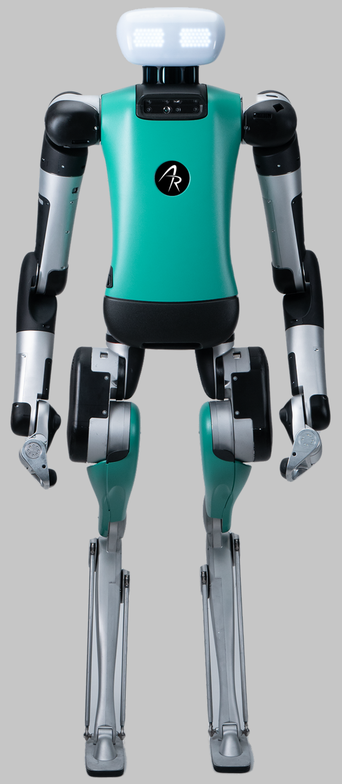
4. CMF

CMF stands for Color, Material, and Finish, and is a common term in design that's particularly important in robotics design. Balancing CMF in the right way greatly assists in achieving proportions and aesthetics, just as character and personality do. It's usually recommended to consider one color as the primary color and mix it with monochrome colors. Black and white are inevitable in robot design since most components use these tones.

Material can significantly influence how the audience perceives the robot's functionality. For example, a robot covered in fabric might seem suitable for use in elderly care homes, while a robot with a metal finish might appear more industrial. Considering what materials are used in the robots future context can therefore act as guidance in material selection. However, not adhering to stereotypes provides ample room for creativity, as long as there is purpose behind the choices.

The use of raw material components can also enhance the robot's attractiveness and be a distinct style in itself. For instance, the material of the camera lens can be left as is, without additional material on top of it. A common material used in humanoid design is rubber and elastomers, as they provide both coverage and an appealing look. However, manufacturing constraints and the limitations they impose on actuators should be considered.

Finish is an area that requires delicate attention from the designer. Finding the right balance between different finish types is a challenging task. A recommended practice here is, similarly to forms, to consider a certain finish and repeat it as a pattern all over the robot.



Digit is a good example of color usage. It has a distinct green color which makes it stand out and relies on monochromatic colors for other parts, which works well with the exposed metal.

5. Movement

The previously mentioned aspects are all relevant and noticeable when the robot is in a stationary mode. However, as soon as the robot begins to move, the audience's focus shifts to the movements, and other aspects become secondary. Whatever proportions, covers, forms, and CMF are being designed, they should be evaluated in terms of the desired movements. Just as in the mechanical and dynamic design of a robot, where everything revolves around Degrees of Freedom (DoFs) and Center of Gravity/Mass (CG/CM), the forms and other elements should be designed with DoFs in mind.

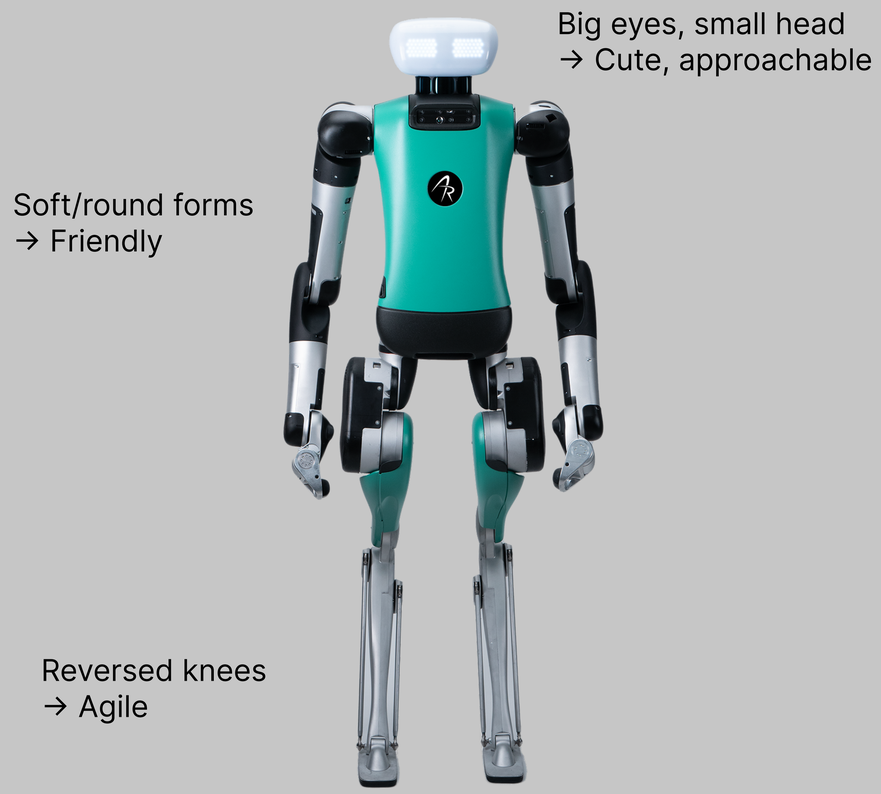
A good practice here is to visualize the robot's concept not only in a stationary mode but also in various poses to ensure that proportions and relationships match also here. Subsequently, observe the robot in several simulated movements and assess if the character and appearance of the robot change significantly in certain movements.

6. Character

This can be the most challenging aspect of the design; however, if we know what the character should embody, it becomes easier. If you have answered the question about the character and personality of your robot, then you need to search for any characteristics that exemplify that personality and see what features create the desired expression. Examining animations and movements that illustrate a particular character can be helpful here.

It's important to consider that the character of a robot is not limited to its head, face look, and expressions. The character is manifested in every single element of the body. Consistency in the use of certain forms and CMF can assist here. Additionally, certain characters have corresponding proportions. For instance, an agile and quick robot may have thinner legs and avoid using extra panels on the legs. As the choice of character can affect large parts of the design, it is good to have a general outline of the desired character early on the the development process.

Different parts of Digit contribute to its character:



7. HRI

HRI (Human-robot-interaction) is an important aspect when creating a successful robot with high user acceptance. The robot must not only function well, but also communicate and interact appropriately with its surroundings. Exactly how the robot should communicate will depend on its context, but the important part is that the robots current status is obvious to the humans around it. This could for example mean showing if the robot is teleoperated or autonomous, active or in stand-by. By clearly showing that robots status, you help the humans acquire situational awareness around it, improving both safety and transparency which are both important for user acceptance.

Questions to ask here include how clearly the status should be shown and which states or actions should be highlighted. If the robots behavior differs a lot between modes and if the context is prone to accidents, the robot's status should be very clearly shown, for example using strong lights. The key to good HRI is to study the context where the robot will operate and the people in it. What factors affect how humans currently communicate? What cues in the environment and in their behavior are used to assess and predict situations? Answering these questions will help you determine the best way to communicate the robots status and intentions and make sure it can seamlessly integrate into its use context.

Car lights is a great example of how lights can be used to communicate status and intention to the people around it, helping others predicts its movement and act accordingly. To avoid accidents, the robots must communicate in a similar fashion.

As colored lights is one of the simplest ways to show the robots status, we have included a chart below to support the creation of a color system for your robot. Whichever system you end up with, consistency in how you use the colors is important for understandability. One important note here; the color chart is designed for selecting **lights, not physical color.**

System	Psychology The colors psychological effect	Technical What the color indicates in HMI/HRI	Emotion The emotions the color evokes	Robot Awareness The message the color is conveying	Alternative saturations/tones	Gradients
#FA3232	Energy, Passion, Excitement, Urgency Eastern Cultures (e.g., China): Represents good luck, happiness, and celebration.	**Alert/Warning:** Red is commonly used to signify warnings, errors, or critical alerts. It suggests that there might be an issue or an abnormal condition that needs attention.	**Emotions:** Passion, love, excitement, energy, anger **Contexts:** Often associated with strong, intense feelings.	**Behavior:** Error/Issue Alert: rapid blinking in red. **Purpose:** Communicates that an error or issue has occurred and requires attention. For conveying energy or excitement, it is better to use orange forms of red →	#FF6464 #B40000 #FF5C00	
#FF9600	Creativity, Enthusiasm, Warmth, Activity	**Maintenance Mode Indicator:** Orange or flashing orange signals that the system is in maintenance mode or undergoing a maintenance operation. It can also be used as an awareness mode.	**Emotions:** Enthusiasm, warmth, creativity, energy **Contexts:** Often associated with a lively and energetic atmosphere.	**Behavior:** Understanding/Processing: A rotating or swirling pattern in orange tone. **Purpose:** Communicates that the robot is processing information or thinking. Common process can use more yellow tones or slight change to yellow →	#FF7700 #DD8200 #FFC148	
#FFF546	Neutrality, Warmth, Optimism, Happiness Eastern Cultures (e.g., China): Symbolizes pornography, betrayal, and dishonesty.	**Acknowledgment Indicator:** Yellow or flashing yellow indicates that an operator's input or acknowledgment is required.	**Emotions:** Happiness, warmth, optimism, energy **Contexts:** Evokes a sense of brightness and positivity.	**Behavior:** Positive Affirmation with attention: Brief flashes of bright yellow indicates affirmation and draws attention. **Purpose:** Reinforces neutral interactions or semi-successful task completion. Greener tones can be more positive →	#FFE248 #ECC600 #C4FF46	
#46FF64	Positivity, Growth, Completion, Freshness Middle Eastern Cultures: Associated with luck and fertility.	**Power/ completion Indicator:** Indicates that the machine or system is powered on and operational. It can also be used in case of task completion.	**Emotions:** Nature, growth, harmony, freshness, balance **Contexts:** Associated with environmental themes and often used to convey positivity, acceptance and affirmation.	**Behavior:** Positive Affirmation and Task Completion: Gradual transition to a bright green/yellow tones. **Purpose:** Indicates successful completion of a task or user command. A more saturated green tone is more positive →	#81FF46 #00D422 #00AA3C	
#008C3C	Maturity, Stability, Completion, Tranquility	**Completion/ stability Indicator:** Indicates that the machine or system is stable and the task "was" completed. It can also be used for positive indications with less importance.	**Emotions:** Nature, stability, calmness, maturity, balance **Contexts:** Associated with environmental themes and often used to convey positivity, long lasting acceptance and affirmation.	**Behavior:** Maturity of a level or calmness of the agent: Steady transition to blue or colder colors conveys calmness. **Purpose:** Indicates a stable and long lasting positivity of a situation. A more blue tone is more welcoming →	#00983C #007A34 #009999	
#64FFFF	Trust, Reliability, Hygienic, Tech-savvy	**Communication/ smartness Indicator:** Indicates the status of communication between different components or devices within the system (IoT). Can also indicated the state of smartness, automation on a system.	**Emotions:** Calmness, trust, serenity, hygienic, futuristic **Contexts:** Commonly used in tech products and evokes a sense of curiosity and optimism to the future.	**Behavior:** Engagement and interaction: Dynamic, patterns or sequences of blue to green. Or subtle pulsating of cyan/blue. **Purpose:** Indicates a playful and interactive mode, encouraging engagement with the user.	#00C3C3 #00A8A8 #00E0FF	
#00C8FF	Professionalism, Predictability, Calmness Eastern Cultures (e.g., China): Symbolizes immortality.	**Readiness/ standby Indicator:** Indicates the status of readiness to receive a command or to initiate a task. It can also indicate the full/stable power status.	**Emotions:** Calmness, trust, predictability, professionalism **Contexts:** Commonly used in professional settings and to convey a sense of reliability.	**Behavior:** Ready to engage or start: Steady or subtle illumination of medium blue. **Purpose:** Signifies that the robot is in a standby or neutral state, not actively engaged in a specific task. It can get more welcoming by adding more purple tones →	#00D4FF #00ACFF #5200FF	
#9600FF	Mystery, Luxury, Sophistication, Creativity Brazilian Culture: Symbolizes mourning and death.	**Mode Indicators:** Indicates the status of a unique feature being activated. This color is not commonly used in HMI systems but can be used to distinguish the system's novel features.	**Emotions:** Creativity, luxury, mystery, sophistication **Contexts:** Often used to convey a sense of elegance or uniqueness.	**Behavior:** Welcoming and readiness for a new interaction: A steady of flashing purple. **Purpose:** Signifies that the robot is inviting the users for a new (first time) or unique interaction. Tones of pink makes it more welcoming and less neutral →	#7000FF #8600E3 #BB64FF	
#FF64C8	Romance, Sweetness, Femininity, Affection Japanese culture: Sometimes symbolizes masculinity.	**Mode Indicators:** Similar to purple, it indicates the status of a unique feature. This color is also not commonly used in HMI systems but can be used to distinguish the system's novel features.	**Emotions:** Romance, sweetness, innocence, femininity **Contexts:** Often used in contexts related to romance or a gentle, affectionate atmosphere.	**Behavior:** Welcoming/Initiation: Gentle signaling or steady pulsing of pink with a gradient to blue. **Purpose:** To signal that the robot is ready for interaction and to create a welcoming atmosphere. Tones of pink mixed with white makes it more innocent and soft →	#D764FF #B50075 #FFB2E4	
#FFFFFF	Purity, Simplicity, Cleanliness, Neutrality Eastern Cultures (e.g., China): Associated with death, mourning, and funerals.	**Neutral/Normal Operation indicator:** White is often used to indicate that a device is in its default or normal state. It can also be used to convey general information or indicate an active status.	**Emotions:** Purity, simplicity, cleanliness, innocence **Contexts:** Associated with a clean and neutral aesthetic. It can also feel fundamental or standard.	**Behavior:** Neutral state: Steady illumination in a neutral color (e.g., white or soft blue). **Purpose:** Signifies that the robot is in a standby or neutral state, not actively engaged in a specific task. Warmer or colder tones of white can be more engaging →	#FAECFF #E2F6FF #FFFEE5	
Useful for: →	Guiding the user towards certain feelings or ideas	Showing the technical status of the system	Enhancing the social aspect of the interaction	Conveying a specific message to the user	More uniqueness	More engaging

"© 2024 MERPHI. All rights reserved. This color guideline is expressly crafted for the robotic community and is protected by international copyright laws. Any use, reproduction, or distribution must include proper attribution to the creator, MERPHI Sweden"

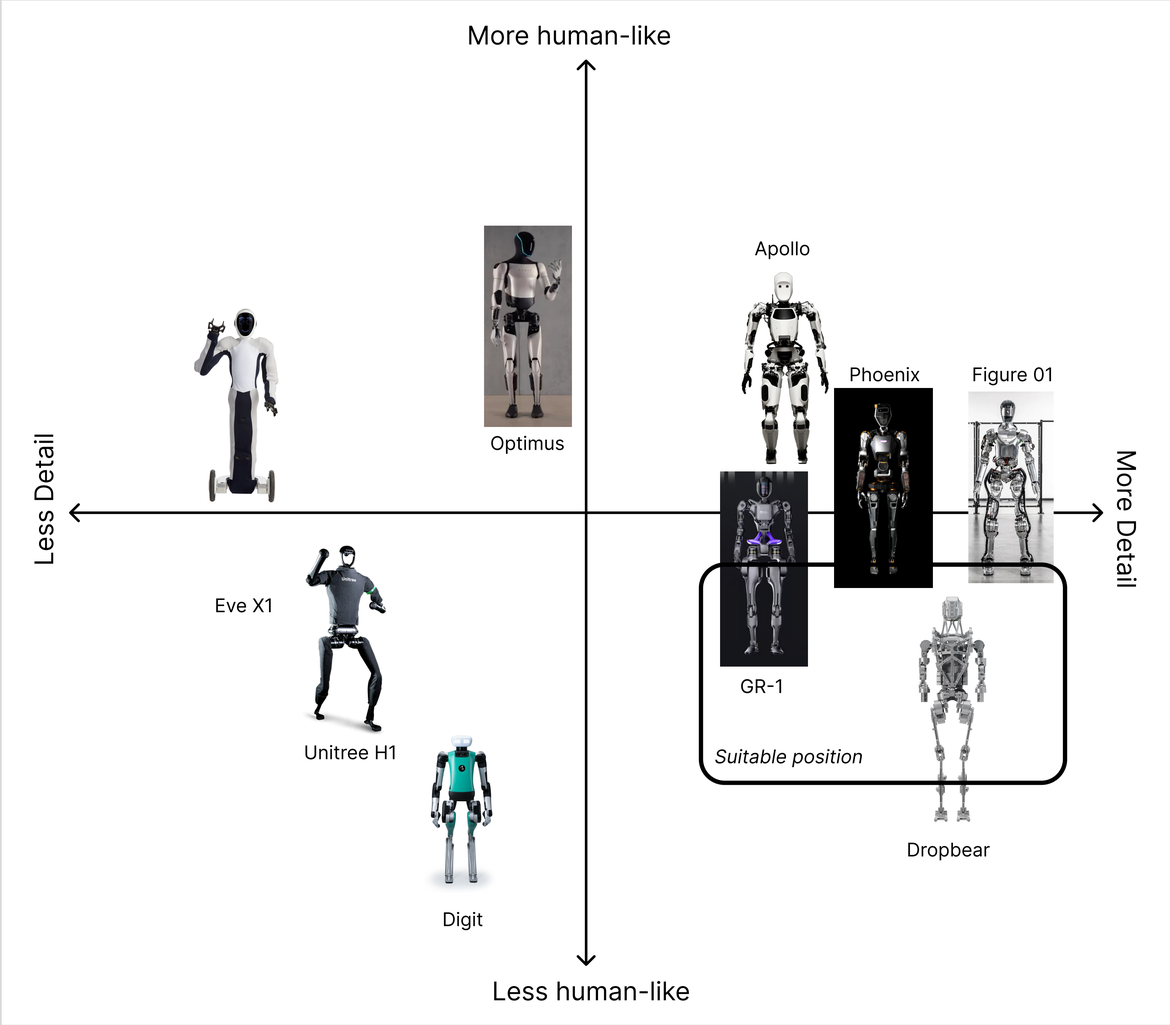
This section will outline some more concrete guidelines for Dropbear. The starting point were a set of criteria collected from the initial meeting and the material provided by Hyperspawn. A small competitor analysis was then performed to identify stylistic gaps on the market. Dropbear is already differentiated from most competitors, however we don´t want it to be too far from human-likeness due to the teleoperation, and thus the suitable area was moved a bit higher. The conclusions from the competitor analysis and the design criteria were then combined to developed a design language which is summarized in a series of guidelines and a mood board below.

General criteria for Dropbear:

- Should work in different contexts
  - Industrial and social
- Cost efficient production
- Suit the vision for an open source platoform
  - Support assembly and modifications
- Will used both full automation and teleoperation
- Should be aesthetically differentiated from other humanoids

Technical considerations

- Support a great range of motion
- Low weight of parts
- Maximize sensors field of view
- Protect robot and environment during use



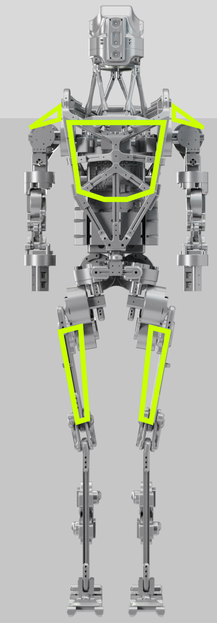
Coverage

1. Minimize use of covers and make them small and simple

What:

To save cost and retain the detailed rugged aesthetic of the robot, there should be no or very few plastic covers, especially in the early generations. Prioritize areas that can have a significant effect on the proportions, like the thighs and shoulders, or need to be covered for technical reasons, for example if the boards in the chest need protection. The first iterations might even work better without any non-functional covers, for the sake of efficiency.

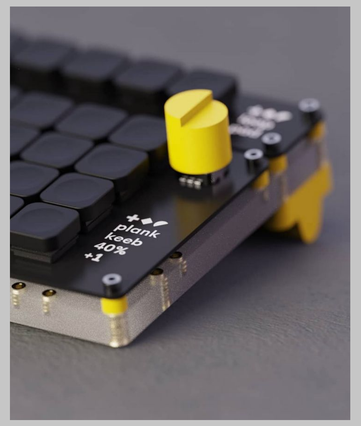
For future iterations, these areas might be suitable places for coverage. If any other area needs to be covered for technical reasons, that should be the highest priority.



2. Exposed fasteners, handles and gripping areas

What:

Both the exposed fasteners and the handles/gripping surfaces invite the users to handle and modify the robot themselves. This is in line with the vision for open source and also contributes to the desired aesthetic, which is semi-industrial and detailed.

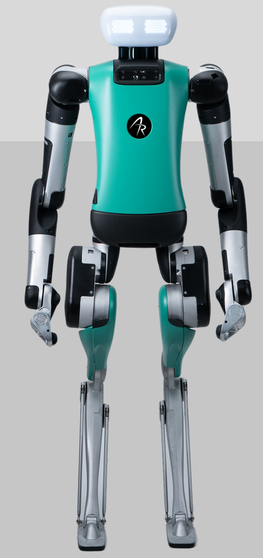


CMF

3. Clearly sectioned and separated parts

What:

As the robot is already very detailed and will have most of its detail exposed we should lean into it further by having clearly separated parts across the entire robot, thus the detailed nature of it will be coherent throughout the design. This can be used both on a micro level to distinguish separate components/parts using color, material or form, or to divide and group different sections of the robot, like the chest, lower arm, shank etc. An important note here is to have some reason behind the sectioning, so that grouping or separation of parts is in line with their functions or the perceived “anatomy” of the robot.

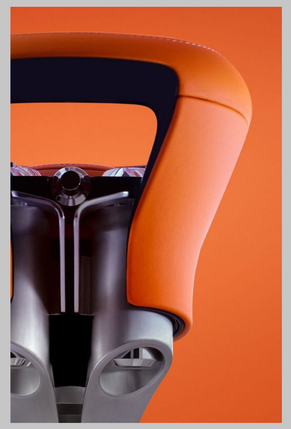


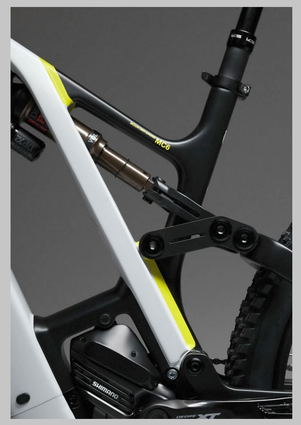
Digit uses CMF so divide its neck, torso and waist area, creating a meaningful balance.

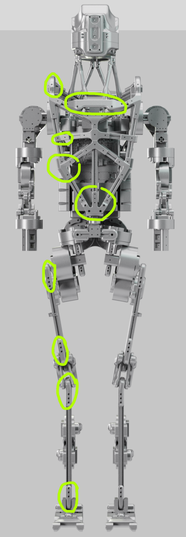
4. Use fairly bright colors across the robot

What:

The robot will operate around people and must thus provide good visibility for safety. Using brighter colors (monochromatic with one more saturated color) will support this and is also allow you to use color to differentiate the robots look. The bright and colorful parts should be concentrated to the robots details and extremities, as these are the parts people need to keep track of to avoid collisions and accidents. Implementing the color on the brackets is therefore a good starting point, as they will also become nicely spread across the robot.





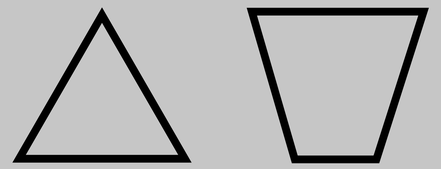


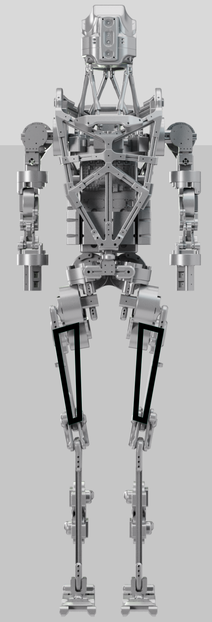
Proportions

5. Convey stability

What:

Due to its efficient build the robot has quite skinny legs. However, when the robot is in use it needs to convey stability to those around it to ensure trust and acceptance. Increasing the thickness of the legs by expanding the structure or by adding small covers could address this issue. Using shapes that convey stability, like the ones to the right, (integrated with human proportions) could also help. This would further help create a better balance between the upper and lower body.





6. Strive towards human-like proportions

What:

We want to associate the design with a human, as it will be teleoperated to some degree. While this can be partly achieved using the forms as mentioned earlier, we also want the overall proportions to stay fairly close to that of an average adult human. This is important not only for the perception of the robot, but also to make controlling it smoother. The mechanical structure is of course the basis for the proportions, but since it is affected by technical limitations, proportions can also be enhanced through forms and details on the robot. For example, if a section of the robot is too long or wide, we can use color and forms to “move” the perceived border of the limb to be more aligned with human proportions. Like how Eve X1 uses a black section to make its arm look thinner. Note that we do not necessarily want exact human proportion, only “mostly accurate”, since this will help differentiate the robot visually from its competitors.

Details

7. Slightly rounded details

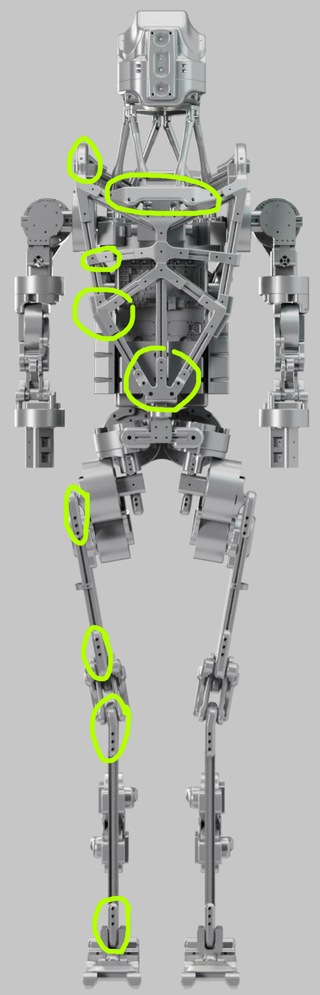
What:

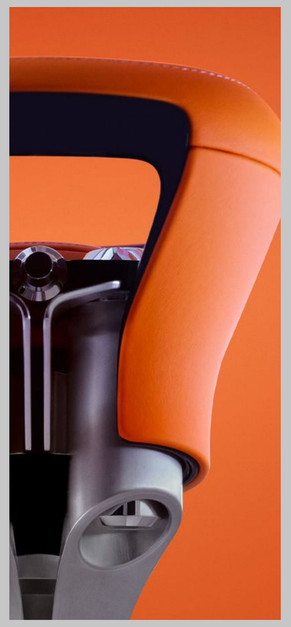
As mentioned, we want people to associate the robot with a human. To achieve this, we can use slightly rounded details to give the overall design a softer look. This would mainly concern the brackets and smaller plastic parts, which currently are sharper. Too limit the complexity of the parts and avoid becoming too human-like, we should not use completely organic shapes, rather slightly rounded/bent/soft versions of basic geometry.

8. Protected extremities

What:

The extremities of the robot, edges, corners, knees, elbows, should be protected and not have sharp points. This will protect both the robot and its surroundings, especially during teleoperation, where the users sense of space is diminished and they a more prone to bump into things. The same type of forms as mentioned above can be used here to create softer/rounder points.





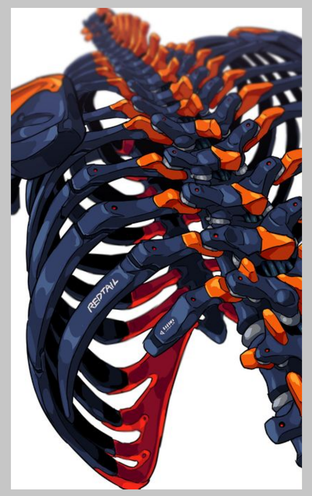
Details

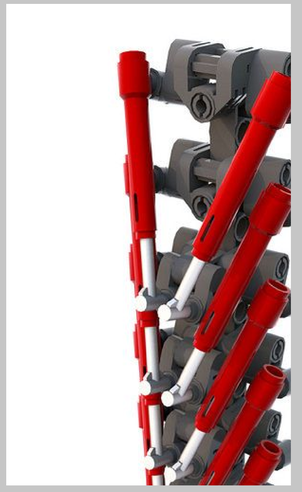
9. Use repeated colors and details across the robot

What:

As we cannot rely on covers to create a coherent aesthetic we must instead utilize the existing parts and smaller additions to achieve it. Coherency is one of the most important factors in creating a pleasant aesthetic, and relates to how certain colors, patterns and features are repeated in logical places around the product. Using the same type of semi-rounded shapes for all the brackets, using a specific color around any interaction points or highlighting the same section or component on each joint can create this coherency.

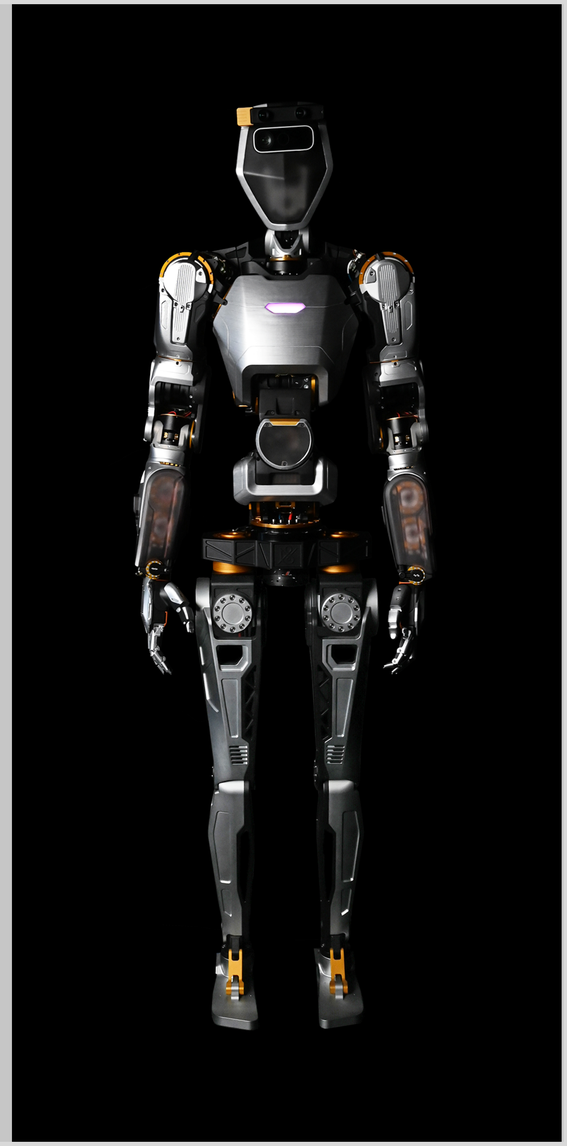
Try to find what elements or features are repeated across the robot and apply the same CMF and forms to these areas.





←Repeated colors/shapes for the structural parts, as well as the cable sleeves.

Repeated gold color on structural elements →



Details

10. Cable management should contribute to the design aesthetic

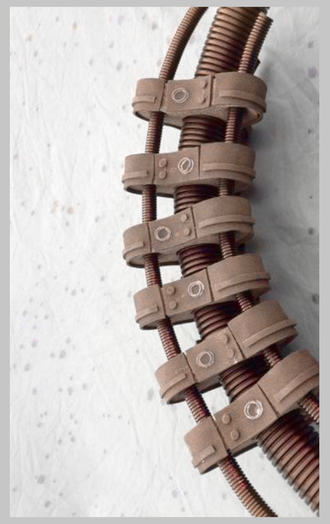
What:

Due to the minimal coverage, most of the cables will be visible from the outside. It is therefore important to put care into what the cables look like. By using colored cable sleeves, applying patterned clamps or aligning how the cables are organized, you can create aesthetic details that also bind the design together, as the cables travel across the entire robot.

1.

2.

3.



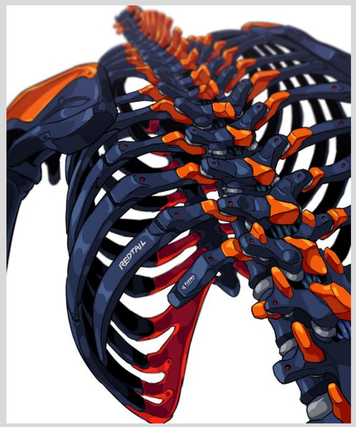
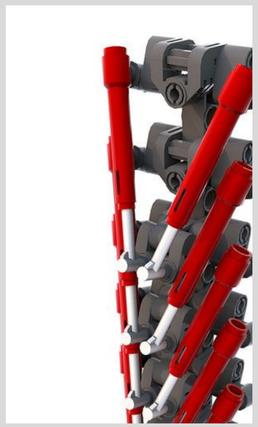
1. Organize how cables connect to components. This is especially important in areas where there are a lot of cables coming together.

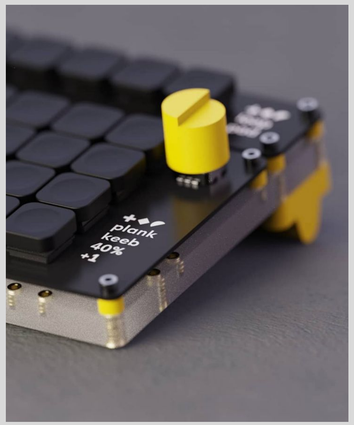
2. Use cable sleeves to align the cable appearance with the overall design language. These cables can also be used to create forms that can contribute to the desired proportions.

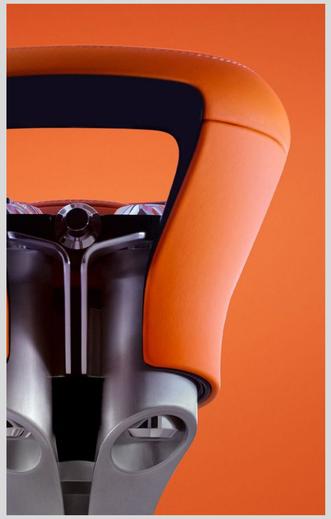
3. Use repeated clamp elements to stylize and connect the cables visually. Optimally the clamp design should also be connected with other elements on the robot.

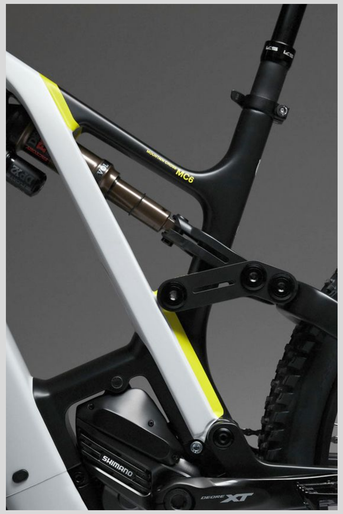
Suggested Mood Board

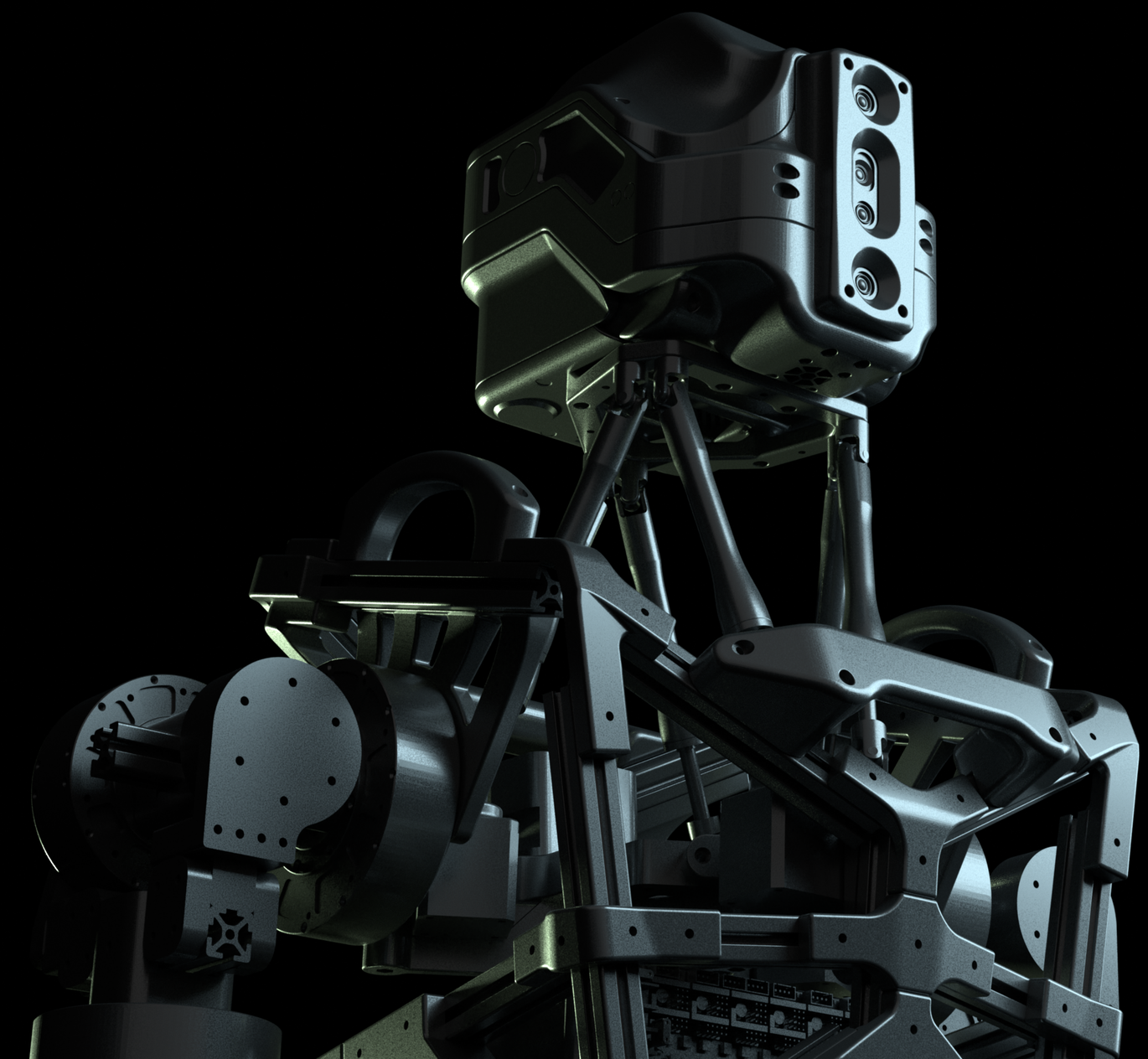
The mood board emphasizes on exposed structures and components, using CMF to create order for the detailed and technical forms. It also highlights the repetition of colors and details and binds the industrial shapes together with rounder forms to create a more balanced expression, suitable for a versatile and functional robot.









MERPHI X

Hyperspawn Robotics

MERPHI

This document was created as a quick review of a robotic product. Since it was based on a non-financial agreement, it does not present an in-depth analysis and concepts. For more questions, consultations, or projects, please reach out to us.

www.merphi.se - +460737693905
filip.sperr@merphi.se - mehrdad@merphi.se