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The Bielefeld Anthropomorphic Robot Head “Flobi”

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***Abstract*— A robot’s head is important both for directional sensors and, in human-directed robotics, as the single most visible interaction interface. However, designing a robot’s head faces contradicting requirements when integrating powerful sensing with social expression. Furher, reactions of the general public show that current head designs often cause negative user reactions and distract from the functional capabilities.**

Therefore, this contribution presents a novel anthropomorphic robot head called “Flobi”, which combines state-of-the-art sensing functionality with an exterior that elicits a sympathetic emotional response. It can display primary and secondary emotions in a human-like way, to enable intuitive human-robot-interaction. To facilitate further research on facial appearance, the exterior is fully modular and replaceable.

While current state-of-the-art still requires trade-offs when integrating sensing and social expression, Flobi has been designed to enable service robotic applications, with high-resolution, wide-angle stereo vision, gyroscope motion compensation and stereo audio. For ease of integration, the head is self-contained, including 18 actuators, sensors and control boards, all in a human-head sized package.

I. The Challenge of Sensing vs. Expression

Building robots that are well suited for interaction with humans is a challenging task that needs to be addressed by a range of disciplines. One of the most challenging issues in this vein at the moment, and for the foreseeable future, is the design of a robot’s head. This is because a head has to realize multiple functions with partially contradicting requirements. Most important among these are active sensing and social expression for intuitive human-robot interaction.

Corresponding to the first function, many robotic heads have been reported on in the literature that exhibit powerful, active sensing capabilities: Here, many, often large, sensors are packed together and combined with few, powerful actuators for rapid, accurate motion. Examples include POP-EYE [1], Cog [2] and the Karlsruhe Humanoid Head [3].

A recognizably distinct line of research has given us robotic heads with social expressiveness that is intuitively understandable to humans. These usually need many, small actuators that are capable of smooth motion with varying dynamics. The exterior of such robots tends to be non-frightening and generally signals the robot’s capabilities to the non-technical eye. Examples of this approach include Kismet [4], iCub [5], Infanoid [6] and iCat [7].

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Obviously, both of these lines always exhibit features of the other: Social robot heads also need sensors and sensor heads also have an exterior. However, their requirements partially contradict each other and therefore it is no surprise that most projects so far have chosen a trade-off that favors either sensing or social communication. We have summarized the relevant state-of-the-art briefly in section II.

However, we believe that the state of the art has advanced to a level where significant progress can only be made if both aspects are implemented, and evaluated, in conjunction.

It has long been recognized that the motion of directed sensors, such as cameras, is interpreted socially by humans, even if not intended to do so [8]. This has two consequences:

Firstly, any kind of robotic head, when directed at humans, has a social impact and adverse reactions can result if the effect of its exterior and motion are not adequately considered. The consequences of failing to address this fact can readily be discerned from popular reporting about robotics research, which abounds with negative remarks about appearance.

Secondly, the social impact of a robot cannot be divided from its function and studies of social behavior therefore benefit from the use of a head whose function is comparable to a functional system.

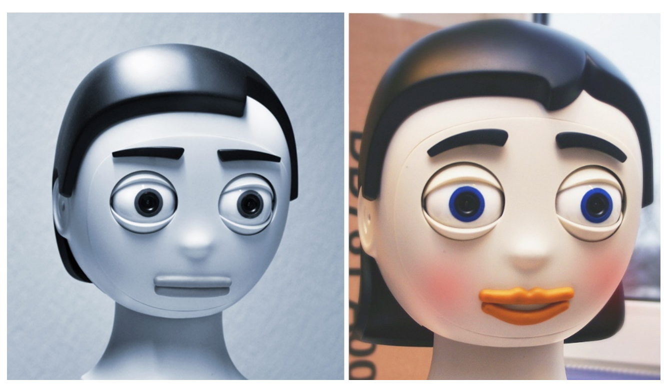


Fig. 1. Flobi male-neutral (left) and female-smiling (right) configurations.

The “Flobi” head is our contribution towards addressing both the requirements for a sensor head and the requirements for social interaction. On the sensor side, the head combines a wide-angle, high resolution stereo camera setup with gyroscopes for motion compensation and stereo microphones for speaker localization and speech recognition. The cameras are actuated on two tiers (“eyes” and “neck”) to provide both high rotational speed as well as large pan and tilt range. The mechanical construction has been optimized to reduce noise, to improve auditory perception.

To facilitate social interaction, we have designed the head to, firstly, feature a standard exterior that prevents the uncanny valley [9] effect and affects the user in a positive way. Secondly, it facilitates experimentation with very different exteriors through swappable plastic masks. We have already produced a number of such masks and can swap the full set in less than five minutes. To the best of our knowledge, this is the first robotic head to allow this level of experimentation.

Furthermore, we will present a novel, patent-pending magnetic actuation system for the robot’s mouth. It is both closer to the human motion range than previous constructions and at the same time hides the mechanism from view.

Last, but not least, heads intended for human-robot-interaction are expected to be employed in a variety of areas, from service robotics to psychological studies. This puts constraints on both the physical packaging as well as the level of control expertise (and hardware) available. Therefore, we have designed the head to be a self-contained package, including actuators and motor controllers (excluding only the power supply). The motor controllers are a custom design to fit the space requirements and they provide all real-time sensitive control aspects, thus reducing the burden on the end-user’s side.

II. State of the Art

A large number of anthropomorphic robotic heads have been reported on in the literature and a good overview is available in [10]. Naturally, they all have different strenghts and weaknesses and we have attemped to present a representative sample, containing the respectively best heads in several categories.

The WE-4RII head [11], has a particular wide range of emotional expressions available. Nexi, a robotic head which suceeds the seminal works in social robotics by Cynthia Breazeal, has been chosen as the newest development in that line[12]. The iCub head [5] is one of the smallest, fastest and best-documented heads. A widely available commercial social platform is the iCat [7]. The predecessor to the current head was the android head BARTHOC [13]. An example of a typical sensor head for service robotics is the Karlsruhe Humanoid Head (KHH) [3].

Table I compares the mentioned heads in terms of the offered degrees of freedom (DoF) for the moving parts, their basic sensor equipment, motion range and speeds for sensor-related motions and the size of the heads. Additionally, we have specified whether technology is clearly visible to the casual observer, i.e. because of holes, exposed motors or unnatural sensors. Where the tables is empty, the information was not available from the published literature, ”n/a” means that the joint was not present.

[1]estimated from size of contained SwissRanger SR3 series camera

	WE-4RII	iCub	Nexi	ICAT	BARTHOC	KHH
Breadth (cm)	18.6	15.2	~24[1]	18	14	
Eye DoF	3	3		0	3	3
Neck DoF	4	3		2	4	4
Eyebrow DoF	8	LED	4	2	2	n/a
Eyelid DoF	6	n/a	4	4	2	n/a
Mouth DoF	5	LED	1	2	3	n/a
Stereo Vision	yes	yes	yes	no	yes	2x
Stereo Audio	yes	yes		yes	no	6ch
Gyroscope	yes	yes		no	no	yes
Eye pan (°/s)		180				
Eye pan range		90				
Apperance	A	A	A	Z	A	T
Tech visible	yes	no	yes	no	no	yes

TABLE I

Comparison of anthropomorphic robot heads.
(A - anthropomorphic, Z - zoomorphic, T - technomorphic)

To put the sizes given into context, the breadth of human ranges from an average of 13.1 centimeters (cm) at age 2 [14], to an average of 15.15cm for adults [15], with a fairly small standard deviation of only 0.5cm. While this does not constitute hard lower/upper bounds for robotic head design, it suggest that anything out of that range will be noticed.

From the comparison, it is evident that achieving breadths close to humans is difficult, particularly when many actuators and/or sensors are present. Only two of the presented heads currently achieve a breadth smaller than 17.3cm, which was the absolute maximum in the US Army study cited above.

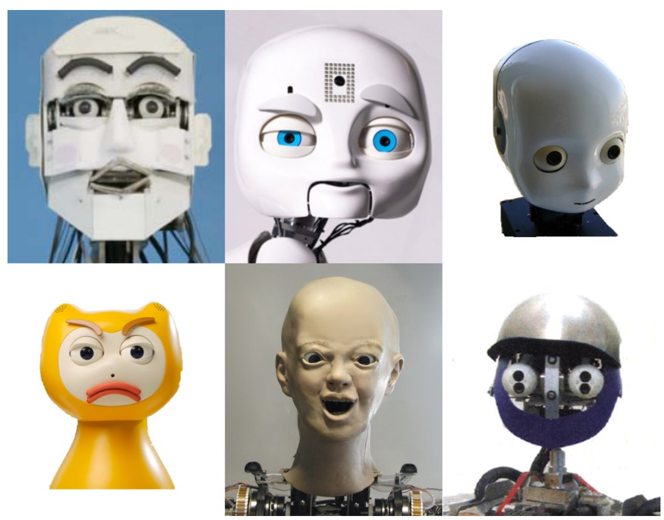


Fig. 2. Heads for comparison. From left to right and top to bottom: WE-4RII, Nexi, iCub, iCat, ANON, Karlsruhe Humanoid Head.

In terms of sensing and motion range, the capabilities of the human head are a useful baseline that has been proven in the real world. Beira et al [5] summarize that three DoF are sufficent for the eyes and four for the neck. Almost all platforms have this eye range, and split between three and four DoF in the neck.

With regard to eye ranges, Beira et al. give 90° respectively 80° degrees as the ranges for pan and tilt. Saccade speeds are given as 166-850°/s. Unfortunately, very little information about achieved speeds is available from the literature.

III. Requirements and Concepts

Flobi has been designed to provide an extensible head platform, which combines state-of-the-art sensing functionality with an exterior that elicits a sympathetic emotional response and can display primary and secondary emotions, to enable human-robot interaction.

As outlined before, integrating both capabilities in one robotic head is still a scientific and engineering challenge and requires trade-offs. In the following, we will describe what we believe is a reasonable base-line that allows further experimentation.

A. Appearance Concept

As the exterior encases the head, we address it first, to identify limits that also affect functional requirements.

The appearance concept has to address two issues: 1) How to design a face that can convey understandable expressions and 2) how to make people *like* the face, or at least not react adversely to it.

To achieve understandability, all previous social robots have used an exterior that alludes to what people already know. Zoo-morphic and anthropomorphic exteriors are most common and while some technomorphic faces have been proposed, they always pick up features from either of the above, for example cameras recognizable as "eyes".

According to the familiarity thesis [16], [17], [18] we anthropomorphize because it allows us to explain things we do not understand in terms that we do understand and what we understand best is ourselves as human beings. This suggests that going for a human-like shape is a ideal, because it facilitates this natural tendency. To support this, in previous research, we have shown that increased human likeness also increases speculation about the robots intentions, suggesting that people feel more able to do so [19], [20].

However, the second issue – that the robot should not cause adverse reactions – can be a problem for human-like faces. According to the uncanny valley hypothesis [9], when movements and appearance are *almost but not completely* human-like, there are unfulfilled expectations and the result is an unpleasant impression from the observer. While there is some work to overcome this, most notably Ishiguro's android research [21], the level of complexity and external machinery involved still precludes their widespread application for autonomous robots.

Zoo-morphic shapes have been suggested as one way out, e.g. by Fong et al [22]. It is not clear, however, whether this solves the issue, because the uncanny valley hypothesis may apply to anything which is "very close, but not completely the same". In any case, it is not optimal with relation to understandability.

One conclusion from this is that the optimal exterior is an important topic for further research and that a research head should facilitate experimentation with different exteriors. This is one of the main conceptual ideas behind the design of the Flobi head and will be discussed in detail section IV.

Of course, even with the ability to experiment, one has to start somewhere and we have designed our new robot to use a comic-like human face, shown in figure 1. The comic nature is far enough from realistic not to trigger unwanted reactions, but close enough that we can take advantage of familiarity with human faces. One advantage we have already explored is the use of "babyface" attributes.

Last, but not least, it is known that slight deviations from an otherwise "normal" appearance evoke unpleasantness [23]. This leads to the last appearance requirement, to prevent such deviations. Specifically, we have designed Flobi not to have holes in the mask, as these are definitely deviations from natural appearance. This requirement had quite a few implications and has, amongst other things, lead to the development of the new magnetic actuation mechanism, described in section V-C.

B. Sensor Requirements

Current basic sensor technology almost universally includes stereo vision, at least stereo audio and usually a gyroscope for motion compensation. Actuation of these is required to offer both fast camera motion (to reduce visual dead-time) as well as velocity control (for smooth pursuit). We have specified Flobi to have exactly these sensors and to support at least 400°/s saccade speed.

Direct 3D sensing using laser-range finders or time-of-flight cameras is also becoming more common, particularly with mobile robots. However, we consider current commercially available sensors of these types to be too large to fit the size requirements. In addition, they can be placed elsewhere on the robot (e.g., on the chest) without big loss of functionality. Therefore, we have opted not to include such sensors but may look at this again in the future, when such sensors have become smaller.

C. Function - Appearance Match

Velocity control is also a requirement for the expressive parts of the face, to allow for dynamic, expressive motion at varying speeds. The accurate, repeatable and coordinated velocity control of multiple actuators, in turn requires real-time processing with low temporal jitter. As this is a non-trivial requirement and requires considerable expertise to realize on a standard PC, we have opted to design custom motor control boards which already implement the necessary control algorithms and real-time support. They are described in section VI-B.

To give an indication of Flobi's abilities to the naive uses, Flobi has to have large large eyes (due to good visual capabilities), normal ears (due to available hearing capabilities) and a small nose (due to non-existent olfactory capabilities).

D. Resulting specifications for Flobi

The Flobi head has an overall 18 degrees-of-freedom (DoF): 3 in the eyes (individual pan, joint tilt), 2 in the eyebrows (individual rotation), 4 in the eye-lids (individual up-down, upper and lower lid), 3 in the neck (pan, tilt, swing) and finally, 6 in the mouth (two individual lips, with left, middle and right point moveable up-down). Additionally, two LEDs (one red, one white) are placed behind each cheek.

Pan speed for the eye has been measured to be at least 400°/s, which is comfortably within human range. The head has a breadth above the ears of 16.5cm, which is slightly larger than the average adult head, but still well within human normal range and smaller than any other robotic head with this number of DoF. The full weight of the head is 2.4kg.

	Degrees of Freedom					pan	
Breadth	Eye	Neck	Mouth	Lids	Brows	Range	Speed
16.5cm	3	3	6	4	2	45°	400°/s

TABLE II

SUMMARY OF FLOBI'S SPECIFICATIONS.

IV. MODULAR FACE DESIGN

As outlined in the appearance concept, the optimal exterior for a human-directed robot head is still subject of further research. However, in all existing robot heads, changing the exterior would require considerable work.

In contrast, we have constructed the Flobi head to explicitly enable such research through a modular surface construction. The individual parts can be freely combined and are attached to the core using magnets only. See figure 3 for an overview of the available parts.

Through exchange of the parts, different characters can be created. So far, we have varied the colors of the parts and the form of hair, lips and eyebrows.

Apart from the change of exterior, this modular approach also enables easy access to the underlying hardware. In particular, the face and neck masks can be removed in a few seconds while leaving the rest of the mask in place. The only visible part of the face that can not be replaced quickly are the eye-lids and eye-balls.

A. Baby Face Cues

The initial design emphasizes the so-called "babyface" cues, which is a quality of facial appearance. The babyface is characterized by a small head, a curved forehead, placement of eyes, nose and mouth relatively low on the face, a small nose, a small chin and large round eyes. As the name implies, these features are commonly found in babies and are associated with vulnerability.

In adults with similar features, communication partners tend to over-generalize and assume they they have similar qualities [24]. This is intended to make the robot head appear non-threatening and increases the likelihood that people like it. Additionally, the large eyes improves the ability to identify the robot's gaze, which is an important social cue.

B. Hole-free lip construction with large motion range

To completely prevent holes in the mask, which would cause adverse reactions because they deviate from expectations, the lips are attached using magnets. Behind the mask,

Fig. 3. Parts and example configurations. [Best viewed in color].

coupled magnets are actuated on a sliding axis, with the motion range overlapping between upper and lower lips (cf. figure V-C).

The large, and overlapping, motion range allows more natural looking facial expressions, because the corners of the mouth are not fixed.

To illustrate this, we have marked the middle position of the mouth in figure 4 using a red bar. As you can see, when corners are fixed, smiling is realized by pushing the middle of the lip down, as opposed to the upward motion of the corners that humans do. This construction shown is from the ICAT, but is commonly used for other social robot heads. In contrast, the Flobi head can truly pull up its mouth corners, to realize a convincing, natural looking smile – and without any holes or exposed hardware.

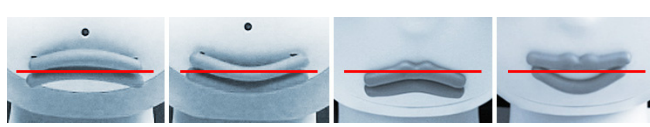


Fig. 4. iCat (left) and Flobi (right) motion ranges. Red bar is center

C. Secondary emotion display

A total of four LED´s were used to project a diffuse white or red light onto the cheek surface. This simple technique gives the robot the ability to change the color of its cheeks to show states like healthy or shame, respectively. Blushing is one of a very few symptoms displaying a secondary emotion, i.e. shame is explicitly an unique human emotion and, interestingly, there has been no research on shame within the context of social robotics yet.

V. Core Structure Design

The core structure provides anchor points for the mask, the sensors and the exterior expression elements (eyebrows and lips). There is one actuator per degree of freedom, 18 in total.

The primary design requirements are human-like size and motion and to hide actuators.

A. Human-like size and motion

Due to the large number of actuators and their size, not all of them can be mounted directly at the actuated joint. Instead, we have applied a tendon-mechanism, which allows placing the motor away from the joint. As shown in figure 5(a), most of the motors are placed on a circular support in the middle of the head, to achieve an even weight distribution. The motor axis is connected to a triangular wedge, that converts rotary motion to a pull and push motion, driving a bowden cable.

While the required speeds and forces for most parts are quite small, the tendon design introduces some friction that is difficult to predetermine. Therefore, motors in the upper head have been selected to be Maxon type 203893 with gear ratio 67:1 which delivers well above the required parameters. The same motors are used for eye-motion but here, static levers are used to actuate the eyes. All motors are equipped with encoders for velocity control.

Because we have a substantial number of motors packed tightly together, heat buildup could be a potential issue. The friction in the bowden cables allows us to turn off the motors when in holding position, thus reducing heat production. However, we have added temperature sensors on each actuator, to be able to provide safety power-down in the unlikely event of overheating condition. Additionally, these sensors may be used to indicate the current "effort".

B. Natural neck-motion

For the neck, the primary requirement was to have the pan, tilt and swing axes cross each other in a common point. Human observers are very sensitive to whole head motion and motion looks unnatural if these axes do not intersect. Some previous heads have this (e.g. [3]), but not, so far, in this size range.

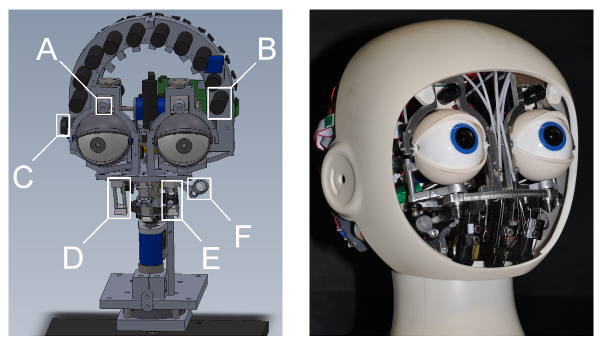
The neck is actuated using Faulhaber 2224 DC motors, with gear ratio 66:1 for the tilt and swing and 43:1 for the pan axis. These motors are compact and provide maximum torque that is comfortably beyond the requirements. More importantly, the larger gear ratio for tilt and swing can provide holding power within the motors sustained output parameters, which is important for holding positions outside of the default. The default position can be held with almost no force, because of the balanced weight distribution.

As Beira et al. have found, robust and flexible construction of small robotic necks can be an issue and if robustness is placed at a premium, their serial construction with shock-protection clutch may be preferred [5]. However, for service robotics we expect the head to be primarily up-right and not experience direct shocks through falling and have thus preferred a slightly less robust construction because of the closer to natural motion generated.

C. Natural looking lip motion

For the lips, the primary issue was to provide multiple degree of freedom motion without introducing holes in the mask, as these would have caused an undesirable appearance. Additionally, upper and lower lip must have overlapping ranges to achieve human-like lip emotion expression.

Our novel solution to this problem was to couple lips with magnets to a sliding joint that is placed under the mask. Each lip has three points of contact (left, middle, right), with individual actuation. The sliding joints for each respective point of both lips are mounted on a common guide, so that the motion ranges may overlap.



(a) CAD model of head (b) front view with detached mask

Fig. 5. Flobi design and final prototype. A: eyelid actuator, B: detached motors, C: microphone holder, D: lip guide, E: lip guide with magnet, F: LEDs

VI. Sensors and Electronics

The Flobi head has been designed to be readily usable in varying contexts. With regard to sensors, we have chosen industry standard components and connectors. With regard to motor control, custom controller boards have been designed that support serial communication and can be controlled from any computer.

A. Sensors

For vision, two Point Grey Research "Dragonfly 2" cameras are used, because they are available in a remote-head configuration that separates the sensor board from the image processing components. The sensor is small and light-weight and can be placed directly into the eye-ball of the head, with the larger processor board attached at the rear.

The camera is available in several resolutions sensors and exchangeable lenses. Flobi is equipped with a 1036x776@30fps color RGB sensor and M12 micro lenses with 4mm focal length, which translates to a visual field of 94° degrees. The use of other M12 lenses is easily possible, without changes to the rest of the head. The cameras use standard 1394a FireWire connections.

One issue when using the remote head is the connection cable, which is a flat ribbon-type cable that does not withstand lateral motion well. We have twisted the cable and added additional clamps at both ends to make it withstand all eye motion.

The microphones used are DPA 4060-WM miniature omni-directional mikes with high sensitivity. DPA offers a variety of standard connectors to attach these.

The current setup uses one 2-axis gyroscope from InvenSense (IDG-600) and one 1-axis gyroscope from Epson (X3500W) on a separate circuit board. This board was extracted from a Nintendo Wii-Motion Plus controller and is placed inside the head. Unlike other gyroscope solutions (like the Xsens MT9 for example) the sensor is directly connected to the motor controller without any intermediate processing on a PC. Because all processing is done in realtime on the motor controller board itself there is no bus induced latency.

B. Motor Controllers

All time critical calculations and control loops are handled using a custom designed circuit board. Calculations that suffer from delays and are timing sensitive, such the vestibo-ocular-reflex (VOR) based on gyroscope information, are executed directly on the motor control board. To fit inside the head the circuit board was designed to be as small as possible and is currently 37mm by 68mm (cf. figure 6)

The latest revision (xscon2) is based on an 8 bit Atmel XMega64 microprocessor which offers 64KByte Program flash, 4KByte SRAM and is running at 32 MHz.

All motor control boards (slaves) and the host PC (master) are connected to one bus. that is using differential signaling (RS422) to reduce serial errors caused by to the electrically noisy environment. On top of this, a custom protocol is responsible for the communication, allowing single device addressing, multicasts and synchronous command execution.

The H-Bridges on the board can drive 3 motors with up to 16V/2A (24kHz PWM) and could be easily extended for motors up to 36V if necessary. The speed, velocity and position control is run at a frequency of 500Hz.

The board has connections for a variety of different sensors: Motor position feedback is based on quadrature encoder pulses (QEP) attached to the motor axis (relative) as well as on absolute feedback measured after the gearbox using an analog potentiometer.

In order to detect fault conditions, wearout and other problems that could arise, motor current, voltage, temperature and the voltage supplied to the CPU voltage regulators are measured as well.

As the board was designed with having expandability in mind, there are a total of 8 spare I/Os on different connectors (ADC, UART, SPI) for expansions. The controller which is controlling the 3 eye actuators for example is using the SPI connector for the gyroscope connection.

The firmware running on the XMega processor is written in C with some minor lines of assembly code. The binary size is around 15KByte for 3 connected motors.

As one of our key concerns was to fit all the necessary control electronics inside the head itself every controller is responsible for 3 motors. Besides saving space, controlling multiple motors with a single circuit board enables simple, tight synchronization. As this head uses three motors for the eye movement, being able to synchronize the single motor movements simplifies stereo vision.

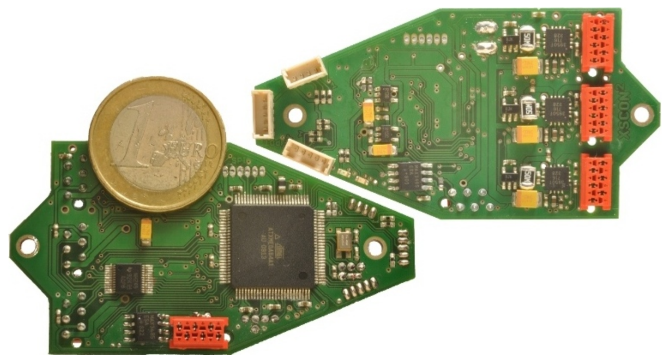


Fig. 6. Motorcontroller (left: top, right: bottom)

VII. Tests

We have performed several tests to establish that the exterior design can fullfill the requirements, with regard to likability and expression of varying character. Firstly, we have performed tests using a static mask to determine the efficacy of the babyface and the different characters. Secondly, we have tested understandability of the emotional expressions. Lastly, we have performed early testing of the motor speeds.

A. Babyface and different characters

As mentioned before, baby face cues are commonly associated with childlike traits, including naivety, submissiveness, honesty, and social warmth. In a first study, we found that people rated Flobi to have highly childlike traits [25], indicating support for the prediction.

In a second study, we performed a very simple change: Compare "masculine" and "feminine" hair and lip-styles, cf. figure 7. The images were shown to 100 subjects.

As predicted, the "masculine" robot was perceived as more masculine than a "feminine" robot. Importantly, we demonstrated that the masculine robot was perceived as more dominant than the feminine robot, whereas in tendency, the feminine robot was perceived as warmer than the masculine counterpart. Moreover, as predicted, stereotypically male tasks were perceived more suitable for the masculine robot relative to the feminine target and vice versa. Taken together, our findings demonstrate that gender-schemata are applied

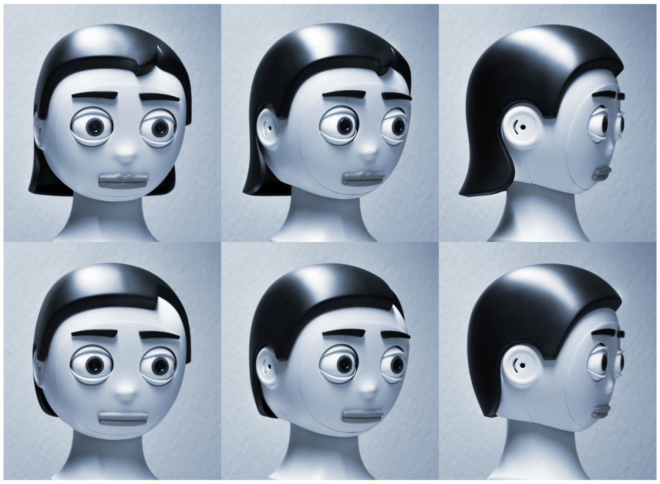


Fig. 7. Different hair and lip-styles

to social robots, thereby influencing trait and application attributions [25].

B. Emotion understandability

Moreover, the face was designed to display the facial expressions of five universal basic emotions [26] happiness, sadness, fear, surprise and anger. In a first study N = 259 subjects evaluated the emotional displays of the robot (see figure 8) and successfully recognised happiness (83,3%), sadness (99,2%), anger (81,2%), surprise (54,5%) without presenting any additional context [27]. Fear received a lower score of only 33,4%, which is a result that will be further investigated. One early hypothesis is that displays of fear are dependent on body posture, too.

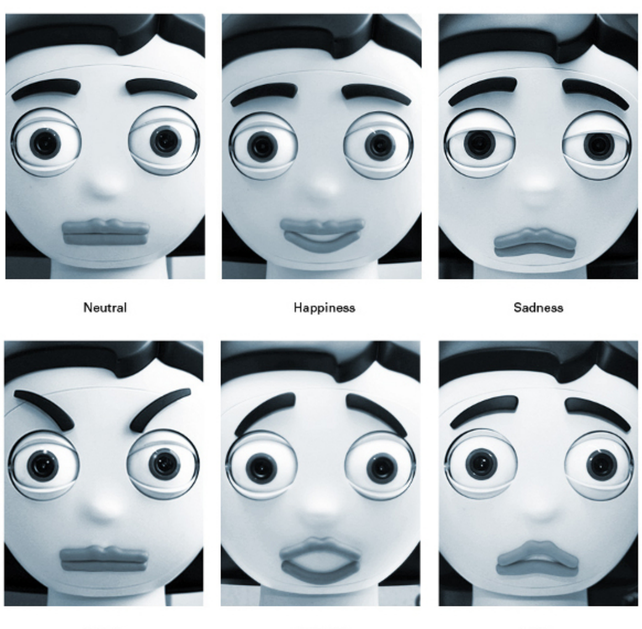


Fig. 8. Basic Emotions

C. Motor performance

The performance targets where those of a human adultand we have achieved eye-saccade speeds in the 400-500°/s range and neck pan speeds of at least 180°/s. The eye-saccade speeds are in regular use.

However, for the neck it has been found that the rigid construction of the joints does not make it advisable to use the full speeds. While the hardware has been designed to sustain a joint-limit collision without braking, *sustained* exposure to the normal operation forces results in considerable wear. This is primarily due to the spatial consequences of aligning the yaw, pan and tilt axes of the neck to concide in a common point. In other words, the joint is too small. Further work will be necessary to produce a small, yet robust neck joint. In this, we find ourselves in the good company of Beira et. al [5], who have gone through several neck constructions, finally achieving at a robust construction which unfortunately still does not have human-equivalent motion.

VIII. CONCLUSION

We have presented "Flobi", a novel anthropomorphic robot head which combines state-of-the-art sensing functionality with an exterior that elicits a sympathetic emotional response. It can display primary and secondary emotions in a human-like way, to enable intuitive human-robot-interaction.

Flobi's exterior can be easily and quickly modified, which facilitates user studies on the effect of different robot appearances. Flobi's sensor package is targeted at service robotics and includes not only fast stereo cameras but also stereo microphones suitable for speaker localization and speech recognition. A summary of Flobi's specifications is provided in section III-D and table II.

The effects of Flobi's static and dynamic features have been analyzed in several user studies. Results indicate that test subjects liked Flobi's design and applied different expectations with respect to its functions depending on different static features such as hair cut. Also, it has been shown that Flobi's dynamic expressions are well readable by human subjects who were able to discriminate between the facial expressions related to basic emotion classes. The uncanny valley effect has been prevented by using a novel patent-pending actuation mechanism that prevents holes in the mask.

Flobi has a high level of integration, by including all motor control on-board. Thus, it can be readily integrated with existing robotics applications and requires neither specialized robotics expertise nor real-time support on the control side.

Future work will see Flobi integrated with other robotic bodies and also the addition of further sensor capabilities and sensory processing on-board. User studies with Flobi in public spaces are also currently being carried out. Last, but not least, work on increasing the robustness of the mechanical construction, in particular the neck, is also ongoing.

A video demonstrating Flobi's capabilities is available online[2].

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