



Tactical Conflict Avoidance of Manned Traffic - Display Concepts for UAV Pilots

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Abstract

The number of collisions between manned and unmanned aerial vehicles (UAVs) has risen due to the increased use of UAVs. Pilots of manned aircraft can visually detect the usually much smaller UAVs only very late or not at all, which is why UAVs are required to avoid manned aircraft in lower airspace by most regulations. For the task of collision avoidance, the UAV pilot needs appropriate traffic awareness. While operating UAVs within the visual line of sight (VLOS), the UAV pilot can monitor the surrounding traffic himself, but operation beyond the visual line of sight (BVLOS) requires an additional airspace observer or a supporting detect-and-avoid system. In this work, a traffic display concept supporting UAV pilots is derived and proposed using the human-centered design process. Commonly used collision avoidance displays of manned and unmanned aviation are reviewed and the user context for the proposed traffic display is introduced. An online survey is conducted to gather user preferences for several 2D graphical elements of the traffic display. 25 experienced UAV pilots participated in the survey. The data is analyzed using Gwet's AC_1 agreement coefficient. Overall, fair agreement can be observed with individual coefficients for different 2D graphical elements ranging from poor to almost perfect agreement. With a developed heuristic, preferred 2D graphical elements are extracted and combinations reviewed to derive a complete traffic display design. The proposed traffic display design, based on user preferences, will be implemented for further evaluation in human-in-the-loop experiments.

Keywords Unmanned Aerial Vehicles · Human–Machine Interface · Collision Avoidance · Display Concept

1 Introduction

Since 1997 at least 16 confirmed and 11 suspected mid-air collisions between manned and unmanned aircraft occurred worldwide, where the manned aircraft was damaged or destroyed. In recent years an increase of encounters between manned and unmanned air traffic has been observed [1]. This trend correlates with the total number of unmanned aerial vehicles (UAV), which has doubled in Germany since 2015 and is expected to continue its growth [2]. Half of the

sightings of UAVs and almost all confirmed mid-air collisions with manned aircraft happened below 2500ft above ground level, mainly with lighter aircraft used for general aviation (GA) operations [3]. Flight test have shown that UAV can only be seen from a manned aircraft in close vicinity when a collision might not be prevented anymore [4]. To mitigate the risk of a mid-air collision, regulations have been put in place that small UAV operating in low-level airspaces have to always give way to manned aircraft, since the see-and-avoid principle used under visual flight rules (VFR) is not suitable for UAV due to their small size [5 UAS.OPEN.060 & UAS.SPEC.060]. During the operation of UAVs within the visual line of sight (VLOS) the UAV pilot should be capable of monitoring the surrounding airspace for manned traffic. However, most commercial UAV operations are predicted to be performed beyond visual line of sight (BVLOS), where a technical system is required to monitor the surroundings of the UAV in order to detect static and dynamic obstacles (e.g. other aircraft). Upon detection, the UAV pilot or the technical system can take action to

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avoid the obstacles. BVLOS UAV missions may only be performed within the “certified” and “specific”-categories of the European Union Safety Agency (EASA) and require a risk assessment [5, 6]. Therefore, EASA has accepted the standardised procedure Specific Operations Risk Assessment (SORA) which requires a tactical detect-and-avoid system (DAA) [7–9]. An integral part of such DAA systems is the human–machine-interface (HMI).

The research presented in this article gathers primary user input data for the user-centered design approach [10] and performs an agreement analysis with this data. Based on the analysis, user-preferred elements are identified and combined to a design for the first implementation.

2 State of the Art

To allow the integration of manned and unmanned aircraft in the U-Space airspace in the future, EASA proposes that all aircraft - manned and unmanned - be electronically conspicuous to the U-Space service provider. An example of a U-Space service provider in Germany is the company DRONIQ GmbH [11]. Following EASA’s proposal, such electronic conspicuity may be reached by each aircraft transmitting its self-determined position via (a) ADS-B broadcasting, (b) ADS-L short-range devices, or (C) ADS-L

web-based services [12]. For near term future operations it can therefore be assumed that the position of most aircraft in low-level airspace are available, by receiving the different transmission signals. In general, receivers can be located onboard the UAV, ground-based or a combination of both. Received position signals can be used in the UAV ground control station (GCS) to inform the pilot about near by traffic. Studies showcase collision avoidance systems capable of automatically detecting other intruders with computer vision technology for use in GA and for UAVs [13–15]. However, the novel research at hand focuses on the display designs and its elements.

2.1 Collision Avoidance Displays

Collision avoidance systems and their displays are commonly used in manned aviation. While an airborne collision avoidance system (ACAS) is mandatory for larger aircraft with a maximum takeoff mass of > 5700kg or > 19 passenger capacity, there are no requirements for lighter aircraft [16]. Several other (low cost) solutions for GA exist that range from low complexity LED to integrated radar-style or map-style displays [17]. Table 1 shows commonly used collision avoidance displays and their illustration methods for several categories. In general, the displays are either ownship-centered with a radar-style depiction of intruder or the positions

Table 1 Common Collision Avoidance Displays

System	Type ¹	Background	Units	Symbol- ogy Own- ship	Symbol- ogy Intruder	Horizontal Separation	Vertical Separation	Conflict Depiction	Avoidance Maneuver
ACAS [20]	integrated radar-style	black	ft & NM	icon	geometric symbol	radar view	+/- signs with value	coloring text audio	vertical
Garmin GTS TAS [21]	integrated radar-style	black or map	ft & NM	icon	geometric symbol	radar view	+/- signs with value	coloring text audio	N/A
FlarmLED [22]	dedicated low complexity	LED lights	deg	icon	lighting LED	LED color- ing	LED color- ing	coloring flashing LED audio	N/A
AIR Traffic Display [23]	dedicated radar-style	white	metric	icon	icon	radar view numeric value	+/- signs with value icon size	coloring audio	N/A
ForeFlight [24] Traffic Display	integrated map-style	map	ft & NM	icon	arrow	map view	+/- signs with value verti- cal view	coloring audio Text message	N/A
SafeSky [25]	dedicated map-style	black	ft & NM	arrow	icon	radar view	+/- signs with value verti- cal view	coloring audio	N/A
DJI AirSense [18]	integrated map-style	map	metric	arrow	icon	map view value	absolute value verti- cal view	coloring text	info text message

¹ Displays of type “dedicated” only provide traffic information to the pilot while “integrated” displays combine information from several systems. “Low complexity” displays use a limited number of lights to show the relative position of an intruder, while a radar-style display shows the relative lateral position on a centered top-view display around the ownship. A map-style display shows the position of the ownship and intruder on a map along with non-traffic-related information. This taxonomy is adapted from Santel [17].

of ownship and intruder are shown on a map. Radar-style displays use either a black or white background. The HMIs of Table 1 are analyzed for their different coding of traffic information. Besides the DJI Airsense system [18], only a few DAA systems and displays exist specifically for smaller UAV. The often-used MissionPlanner GCS software is also capable of displaying aircraft on a map based on incoming ADS-B signals. The open-source architecture allows users to select the criteria defining a traffic conflict (vertical and horizontal distances) as well as when an automatic evasive maneuver should be initiated. However, many traffic-specific features of MissionPlanner are still prototypical [19]. It is therefore excluded from further analysis.

2.2 System Architecture

In the course of this research, the authors make several assumptions on the architecture of a DAA system and how it interfaces with the UAV and its pilot. Specifically, the authors assume the following: A ground-based traffic receiver network receives all common traffic signals (ADS-B, ADS-L short range, ADS-L web-based) in the mission area. Signals are filtered and fused on a server. For the current mission area and the position of the controlled UAV, conflicts are being detected and a feasible conflict resolution is determined. Ownship, intruder, conflict and resolution data are continuously updated and shown on the traffic display along with No-Fly-Zones and obstacles. Among other tasks, the UAV pilot monitors the traffic display during the mission and uses conflict and resolution information to avoid traffic, if necessary (see Fig. 1).

In this architecture, the traffic display is shown on a tablet-device which has no direct connection to the controlled UAV and serves as an add-on solution. This architecture implies that the UAV pilot is in the control loop, manually

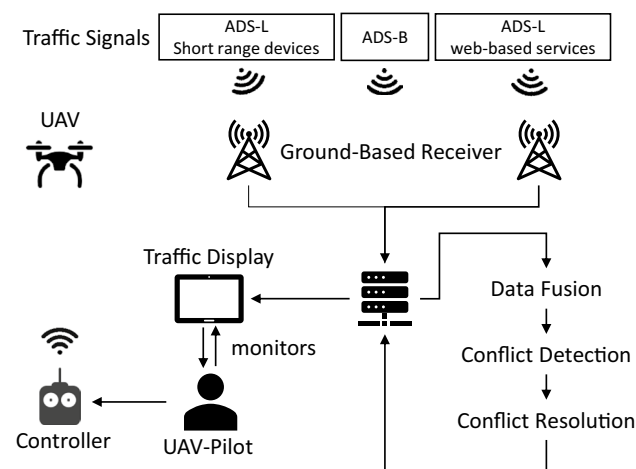


Fig. 1 Example System Architecture

commanding the conflict resolution maneuvers offered by the DAA system. This results in design challenges for displaying evasive maneuvers, because the proposed maneuvers should be easily understood and fast to command. Additionally, the traffic display should be designed in a way, that little or no training is necessary to understand the symbology for UAV pilots.

User-centered design might be a suitable method for the development of such a traffic display, since it enables fast development of HMI designs with a high usability. Due to the early involvement of users in the design process less design iterations are necessary until the final design [10]. This means that initial user-input is needed. In this work, initial user-input is gathered with an online survey in which participants were asked to select preferred 2D graphical elements. Those 2D graphical elements were derived through the performed analysis of traffic and collision avoidance displays used in manned and unmanned aviation in section 2.1. To derive a design suitable for the first implementation with the selected user-inputs, an overall agreement among the users of the design and depiction of elements needs to be present. Therefore the following hypothesis is formulated:

HYPOTHESIS 1 (H1)

Users of the traffic display agree on a preferred display method.

If the hypothesis is retained and users have a strong agreement about each 2D graphical element of the traffic display, this design can be detailed and implemented according to the user-preference. In contrast, if there is overall agreement, but not on each 2D graphical element, the display should offer several selection-options for the users to fulfill different preferences (if suitable for the 2D graphical element in question). The overall design decision for the first implementation will then be subject to further evaluation in human-in-the-loop experiments. Lastly, if no agreement exists and the hypothesis is rejected, the shown approach of the human-centered design approach might not be applicable to design a traffic display for UAV pilots. Figure 2 illustrates this procedure.

3 Method

Hypothesis 1 is explored using an online survey of experienced UAV pilots.

3.1 Experiment Design

The survey was performed in an online format. After being contacted by the authors, participants received a uniform resource locator link to the survey. First, the motivation and

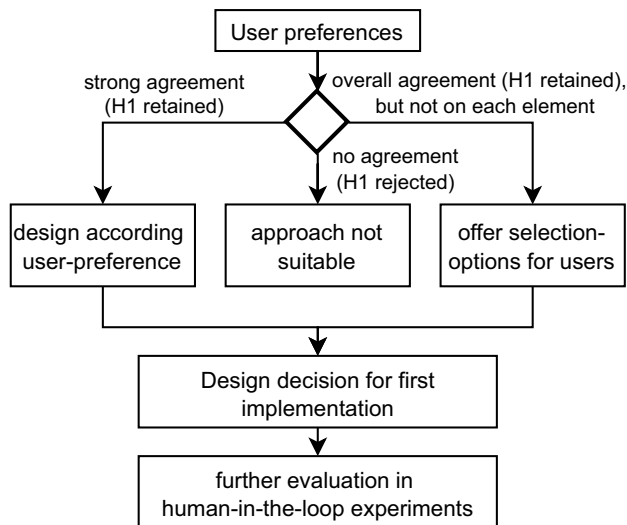


Fig. 2 Illustration of hypothesis procedure

background was presented and the participants provided their informed consent for their participation. Demographic data and information about experience in unmanned and manned aviation were collected, to validate the qualification to participate in the survey. Next, an introduction to the user context of a traffic display for UAV pilots was provided, which serves as an add-on display during their daily operations. The participants were then asked to select their preferred depiction of data for several design categories. Simplistic example sketches were provided for each question. In total 22 design-choice questions with two to seven response options were to be answered. Hereby, the questions were ordered in five categorical sections:

Symbols, Directions and Speeds

In total eight questions about the preferred depiction of position, speeds (horizontal and vertical), track and lost signals for ownship and intruder had to be answered. For each selection, an example image was shown.

Units

preferred units for horizontal and vertical distances as well as horizontal and vertical speeds were asked in four questions. Choices were given in textual form.

Map Display

Three questions about the preferred background, depiction of No-Fly-Zones and static obstacles were asked. Choices were given with example images.

Table 2 Topic of each survey question

Question	Description
Q1 ¹	Depiction of ownship
Q2 ¹	Depiction of intruder
Q3 ¹	Depiction of ownship's direction of flight
Q4 ¹	Depiction of intruder's direction of flight
Q5 ¹	Depiction of ownship's horizontal speed
Q6 ¹	Depiction of intruder's horizontal speed
Q7 ¹	Depiction of ownship's and intruder's vertical speed
Q8 ¹	Depiction of a loss of signal
Q9 ²	Unit for horizontal separation
Q10 ²	Unit for vertical separation
Q11 ²	Unit for horizontal speed
Q12 ²	Unit for vertical speed
Q13 ³	Background of traffic display
Q14 ³	Depiction of No-Fly-Zones
Q15 ³	Depiction of obstacles
Q16a ⁴	Use of color-coding to indicate vertical separation
Q16b ⁴	Use of variable sized icons to indicate vertical separation
Q16c ⁴	Indication of vertical separation (numeric vs. symbols vs. no indication)
Q17a ⁴	Use of color-coding to indicate horizontal separation
Q17b ⁴	Depiction of horizontal distance
Q17c ⁴	Depiction of a well-clear ⁶ circle around the UAV
Q18a ⁴	Use of color-coding to indicate a conflict
Q18b ⁴	Use of flashing to indicate a conflict
Q18c ⁴	Use of a pop-up window to indicate a conflict
Q18d ⁴	Use of a special indication to indicate a conflict
Q19a ⁴	Use of CPA for conflict depiction
Q19b ⁴	Use of a corridor to indicate well clear area
Q19c ⁴	Depiction of time and distance info for the conflict
Q20 ⁵	Depiction evasive maneuver course change
Q21 ⁵	Depiction evasive maneuver altitude change
Q22 ⁵	Depiction evasive maneuver hold position

Group: ¹Symbols, Directions and Speeds; ²Units; ³Map Display; ⁴ Separations and Conflicts; ⁵Evasive Maneuvers

⁶In this context, well-clear is defined as the minimum distance between two aircraft so that there is no collision hazard.

Separation and Conflicts

Four questions about the preferred depiction of separation (vertical and horizontal) and conflicts (indication and depiction) were asked. Choices were given with example images. For illustrative purposes, icons and velocity vectors were chosen. Within the four questions asked, several design combinations were shown, which

are separated within the data analysis (see Table 2, Q16 to Q19).

Evasive Maneuvers

Lastly, three questions about the preferred depiction of evasive maneuvers were asked: one for a course change, one for an altitude change and one for a hold maneuver. Choices were given with example images.

The sequence of sections was identical for all participants, but the sequence of questions within each section was randomized to control for sequencing effects. Table 2 shows the topics of all questions asked in the survey. After answering all questions, the participants had the chance to provide free-text comments.

3.2 Participants

Participants of the survey were approached by the authors either individually or through UAV online forums and were invited to forward the survey to other experienced UAV pilots. The participants received no compensation for their input and time. A total of 25 individuals participated in the survey.

Initially, participants self-reported demographic information as well as their qualifications as UAV pilots. All participants are considered experienced UAV pilots and their responses were included for further analysis. The participants' age ranged from 25 to 74 years ($M = 40.88$ years, $SD = 15.83$ years). All participants were male and had 1 to 27 years ($M = 4.64$ years, $SD = 5.42$ years) of experience as UAV pilot. Nine participants use UAV in a private context. Six use them commercially and 10 participants use them in both contexts. Five participants reported experience in manned aviation, while 10 were familiar with traffic / collision avoidance display (unmanned or manned aviation). Of those 10 participants, most were familiar with DJI Airsense or FLARM. One participant was also familiar with ACAS. Two participants responded in the free-text field at the end of the survey, that the traffic display needs to be easy to understand and topics asked seem to have a high detail of information.

3.3 Analysis

For the analysis of the data, a global statistical significance level $\alpha = .05$ was defined. Based on the self-reported experience as a UAV pilot, the qualification to be included in the data analysis was reviewed.

3.4 Treatment of data

With the responses of all participants for the 22 questions, Gwet's unweighted AC_1 values were calculated as a measure for inter-rater agreement. All calculations were performed with R version 4.1.2 using the irrCAC library [26].

For each question one rating per participant is available. In order to test hypothesis 1, the distribution of AC_1 values across all questions was analyzed using a one-sided t-test.

4 Results

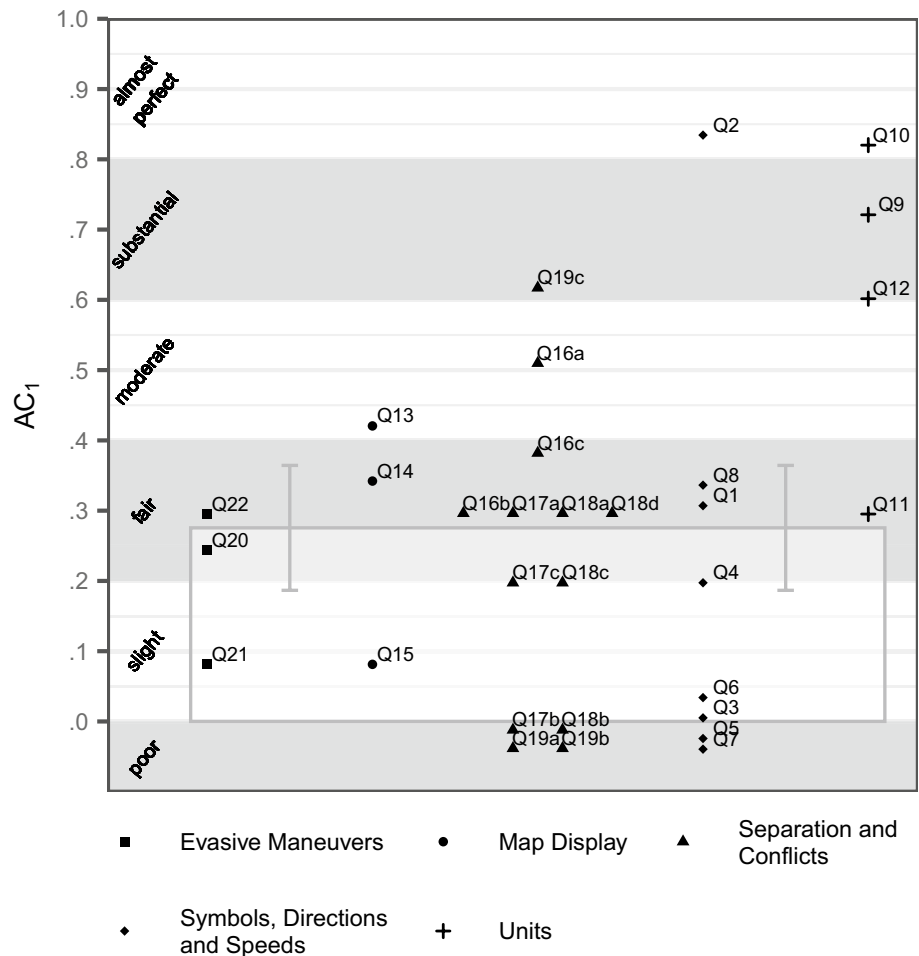
Calculated AC_1 agreement coefficient values for each question are shown in Fig. 3. In addition the global AC_1 average with its 95% confidence interval is illustrated, along with the Landis-Koch benchmark scale [27]. The global average agreement coefficient is $AC_1 = .276$ ($SD = .252$, $p < .001$). On the Landis-Koch benchmark scale there is sufficient confidence at the $1 - \alpha$ level (95.23% chance) that the best-fitting adjective interval for the overall agreement is "fair" or above. The t-test returned significant results with $p < .001$.

Inspecting individual agreement coefficients in Fig. 3, six values show an agreement among the raters with AC_1 exceeding a value of .5. This high level of agreement is reached for the depiction of intruders, use of units for vertical speed as well as vertical and horizontal separation, the indication of vertical separation and for the depiction of time and distance information in the case of a conflict. In contrast, no agreement can be observed regarding seven questions. Raters lack agreement on the depiction of the horizontal or vertical speed of ownship and intruder, the depiction of horizontal separation and the ownship's direction of flight, the use of flashing icons to indicate a conflict, the depiction of CPA information and the depiction of a conflict corridor.

5 Discussion

Globally across all questions, there is only sufficient confidence that agreement between raters is "fair" or higher (95.23% likelihood). The performed t-test shows that the global average AC_1 value is > 0 ($p < .001$). This supports hypothesis 1, since an overall agreement can be observed and hypothesis 1 is retained. However, within the individual agreement coefficients there is some variation ranging from "poor" to "almost perfect" ratings. To derive a design for the traffic display, each rated 2D graphical element is inspected individually. For high-agreement elements, the elements can be directly considered in the design concept. In contrast, for low agreement element the top-rated choices are

Fig. 3 AC_1 agreement coefficient for each question and global average with its 95% confidence interval on the Landis-Koch benchmark scale



examined. Figure 4 shows the proposed heuristic which is used to derive a design for the first implementation of the traffic display. Each AC_1 value is inspected individually. If the AC_1 value is $> .5$ the most preferred design is chosen, while for a lower AC_1 value ($\leq .5$) the most preferred design choices to satisfy at least 75% of users (ordered high to low) are chosen. All design possibilities are collected in a pool of temporary design choices, based on which the elements are reviewed and synergies or design conflicts are identified. These synergies and conflicts are regarded in updates to design choices, by either purging features or adding them.

5.1 User preferred 2D graphical elements

Temporary design choice elements based on the heuristic in Fig. 4 for the depiction of ownship and intruder information are illustrated in Table 3. The review of all elements are performed based on the authors' professional opinions, resulting in selected (underlined>, disregarded (plain text) or user selection-option (dashed) elements for the design for the first implementation. User selection-option elements are either the decision between multiple selectables, like the

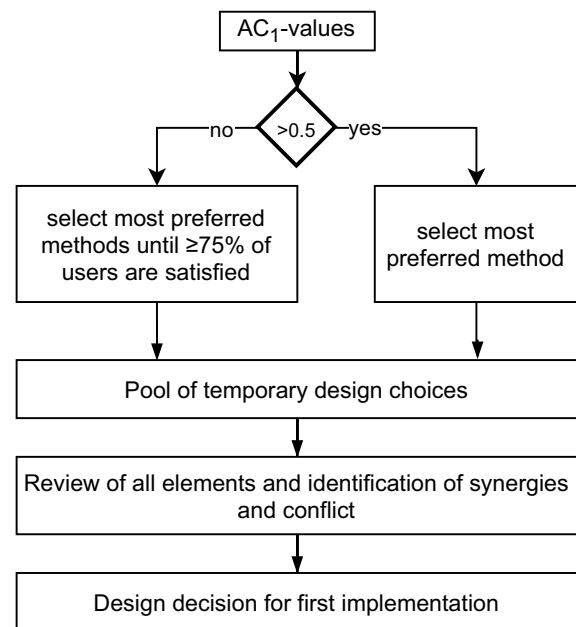
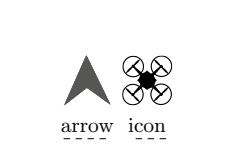
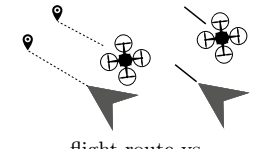
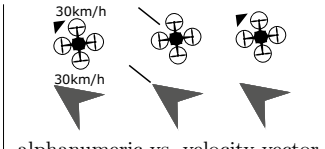
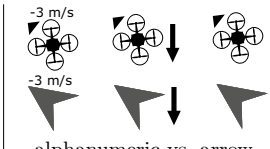
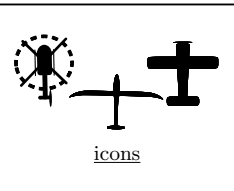
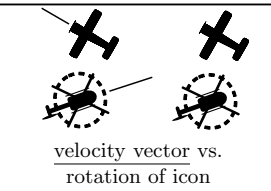
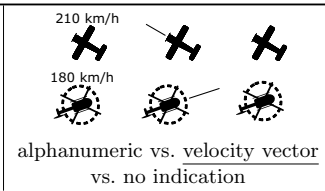
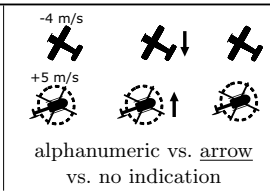


Fig. 4 Heuristic display design

Table 3 Pool of temporary design choices for ownship and intruder. Selected 2D graphical elements after review are illustrated underlined and user selection-option elements are -----


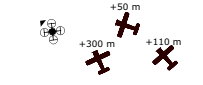






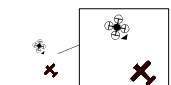
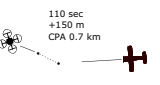
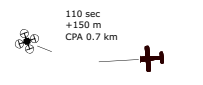
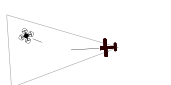


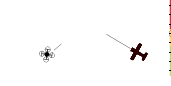



Element	Depiction	Flight direction	Horizontal speed	Vertical speed
Ownship	 arrow icon	 flight route vs. velocity vector	 alphanumeric vs. <u>velocity vector</u> vs. no indication	 alphanumeric vs. <u>arrow</u> vs. no indication
Intruder	 icons	 <u>velocity vector</u> vs. rotation of icon	 alphanumeric vs. <u>velocity vector</u> vs. no indication	 alphanumeric vs. <u>arrow</u> vs. no indication

depiction of the ownship’s position with an arrow or a type-specific icon, or the depiction of additional information like the intended flight-route of the ownship (if available). If user agreement of an element is low ($AC_1 \leq .5$) and individual 2D graphical elements are not identified by the authors to be in conflict with other selected 2D graphical elements, user choice-selection elements can be implemented. If

high agreement of the users is observed or elements are in conflict with others, the best suited design element for the overall design is selected, based on the authors’ professional opinions.

This results in a user choice-selection for the depiction of ownship and the use of type-specific icons for the depiction of intruder. Flight direction and horizontal speed are

Table 4 Pool of temporary design choices for separation, conflicts and evasive maneuvers. Selected 2D graphical elements after review are illustrated underlined and user selection-option elements are -----

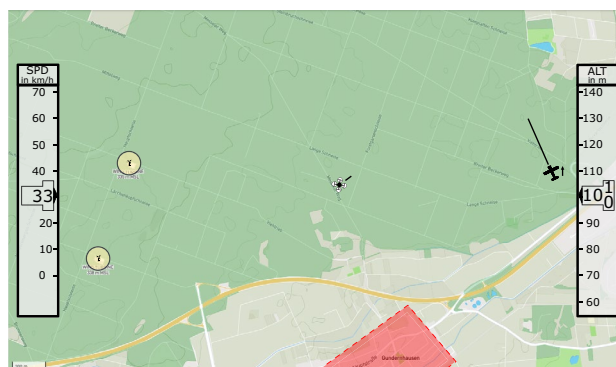
Separation					
vertical			horizontal		
 <u>color coding</u>	 <u>alphanumeric value</u>	 icon size	 <u>color coding</u>	 <u>alphanumeric value</u>	 well clear circle
Conflict					
indication			depiction		
 <u>color coding</u>	 <u>flashing</u>	 pop-up window	 <u>CPA depiction</u>	 <u>conflict info</u>	 conflict zone
Evasive maneuver					
course change		altitude change		hold	
 <u>depiction of save and unsafe courses</u>	 depiction suggested course	 <u>depiction of save and unsafe altitudes</u>	 depiction suggested altitude	 <u>depiction hold maneuver</u>	 depiction hold maneuver icon

illustrated with velocity vectors. Vertical speed is indicated with vertical arrows, which are depicted above a certain threshold of vertical speed. This combination was chosen for both ownship and intruder for the sake of consistency and simplicity.

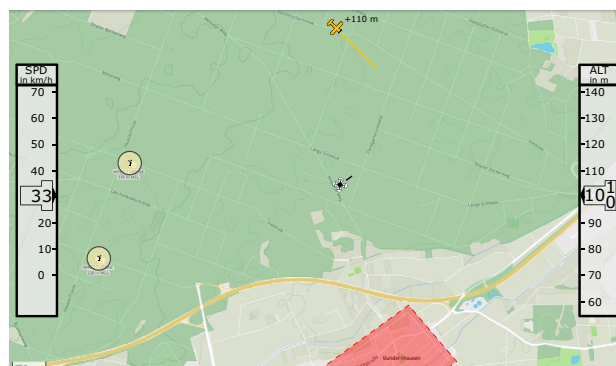
In terms of the use of units in the traffic display, users showed highest agreement. The use of metric units are therefore selected which means distances are shown in km, vertical separation in m, horizontal speed in km/h and vertical speed in m/s.

The preferred background is a simple map and No-Fly-Zones are indicated. In addition, obstacles are displayed and differentiated by their type with an indication of a caution area surrounding the obstacle.

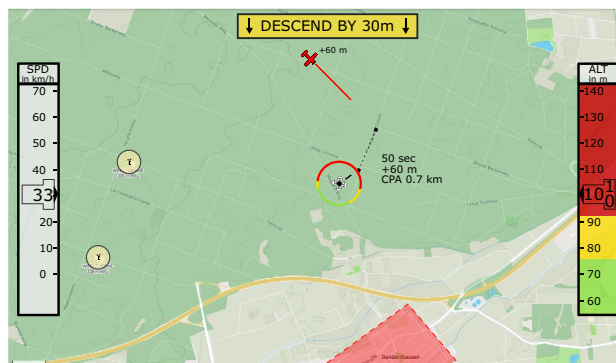
Table 4 shows the temporary design choices for the depiction of separation, conflicts and evasive maneuvers. Similarly to Table 3, selected 2D graphical elements after review are underlined and user-choices are dashed. The use of color coding to illustrate horizontal and vertical separation is selected. Since, vertical separation cannot be identified by the icon position on the display and coloring of the icon, an alphanumeric value is displayed. The alphanumeric value provides information about the relative altitude of the intruder to the ownship. For simplicity, no additional information besides the color coding for the horizontal separation is chosen, since the movement and icon depiction on the traffic display is sufficient for this purpose, based on the authors' professional opinion. Similar to separation, color coding is used to indicate a conflict (making the user aware of a potential conflict). Additionally, users can select flashing icons and/or an auditory warning for conflict indication. High agreement among the raters about the depiction of conflicts is observed. Therefore, information about the closest point of approach (CPA), meaning the shortest predicted slant distance between ownship and intruder is displayed. This information can be given in the form of alphanumeric values (horizontal and vertical distance at CPA and time to CPA). In addition, a user choice-selection of the depiction of the CPA positions for ownship and intruder is provided. Lastly, for evasive maneuvers three different types were included in the survey: a course change, an altitude change or a hold maneuver. Users prefer the depiction of safe and unsafe courses and altitudes, which is why those designs are provided. For a hold maneuver, a textual output is preferred. Since a useful combination of the depiction of safe and unsafe courses and altitudes with a textual output is possible by the authors' opinion, this combination is chosen for first implementation. Although no speed change maneuver was included in the survey, similar depictions as an altitude change can be used.



(a) Traffic display normal mode



(b) Traffic display caution mode



(c) Traffic display avoidance mode

Fig. 5 Proposed traffic display design for first implementation

5.2 Proposed Traffic Display Design

Based on the performed survey and data analysis, a design for first implementation is proposed in this section. In general, the proposed display consists of three modes: normal, caution and avoidance mode. For each mode an example sketch is shown in Figs. 5a through 5b, based on which the overall capabilities of the display are explained.

The position of the ownship is shown in the center of the traffic display with either an icon or an arrow. The horizontal speed is indicated with a velocity vector. As background

serves a map with No-Fly-Zones (red rectangle) and obstacles (e.g. wind power plants with surrounding caution area) shown. Current speed and altitude of the ownship are indicated with tapes on the left and right side. If other traffic is nearby, the traffic's position and horizontal velocity are illustrated with a type-specific icon and a velocity vector. The velocity vector of the ownship and intruder shows the predicted position in a specified future time (e.g. in 30s). If the ownship or intruder perform a climb or descend maneuver with a vertical speed above a specified threshold, an arrow pointing up or down next to the icon is shown (see Fig. 5a).

Figure 5b shows the traffic display in caution mode, meaning that the caution area surrounding the ownship or intruder are predicted to be penetrated. This is determined by the current positions and velocity vectors. In this case, the color of the intruder-icon changes to amber and the current relative altitude is indicated in meters next the icon.

When a loss of separation is predicted, the color coding of the intruder-icon switches to red and information about the conflict is shown: The distance of the CPA (horizontal and vertical) and the time until reaching the CPA. Optionally, the users can decide to depict the positions of the CPAs on the traffic display and if the intruder icon should flash and/or an auditory warning should be issued. In addition, an evasive maneuver is suggested. As preferred by the participants of the survey, altitude change maneuver are shown on the altitude tape by color coding, indicating safe and unsafe altitudes. Similarly, safe and unsafe courses for the current altitude and speed of the ownship are shown through a color-coded circle around the ownship icon. A specific evasive maneuver is provided through a textual message in a pop-up box. With this setup, the user has the freedom to select a conflict-resolving maneuver suitable to his/her mission but receives a specific (simple to apply) instruction through the textual message.

6 Summary and Outlook

This work illustrates a methodology to initiate the user-centered design process to design a traffic display for UAV pilots. While several solutions exist for manned aviation, unmanned aviation lacks standardized traffic displays suitable to avoid other traffic for BVLOS missions. Based on an online survey, user preference data was collected for several 2D graphical elements of the traffic display and analyzed using Gwet's AC_1 agreement coefficient. Overall, a "fair" agreement was observed but individual agreement coefficients varied from "poor" to "almost perfect" agreement for different design parameters. To derive a traffic display design based on the user preferences, a heuristic was introduced to extract a pool of temporary design choices. Based on this, synergies and conflicts of combinations are identified,

resulting in a proposed traffic display design for first implementation. With the implemented display, human in-the-loop experiments may be conducted in the future to obtain objective data and evaluate the proposed display design along with the complexity of the graphical elements used. To make weaker effects easier to be observed, it is planned to conduct the experiments with a larger group of participants. This will also provide an evidence-based cross-check of the design choices that were based on the authors' professional opinion and engineering judgment.

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Declarations

Conflicts of interest The research leading to these results was supported by the German Federal Ministry of Education and Research within the research project "KMU-Innovativ - SAMMIE: Design und Evaluation einer Mensch-Maschine-Schnittstelle für Drohnenpiloten". The authors have no competing interests to declare that are relevant to the content of this article.

Compliance with Ethical Standards All procedures performed in this study were in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants involved in the study.

Data Availability Data sets generated during the current study are available from the corresponding author on reasonable request.

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