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Data Article

Data on the design and operation of drones by both individuals and teams

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ABSTRACT

Human subject experiments are performed to assess the impact of artificial intelligence (AI) agents on distributed human design teams and individual human designers. In the team experiment, participants in teams of six develop and operate a drone fleet to deliver parcels routed to multiple locations of a target market. Among the design teams in the experiment, half of the design teams are human-only teams with no available AI agent. The other half of the design teams, designated as hybrid teams, have drone design and operation AI agents to advise them. Halfway through the team experiment, team structure is changed unexpectedly, requiring participants to adapt to the change. In the individual experiment, participants develop drones based on given design specifications, either on their own or with the availability of a drone design AI agent to advise them. During these experiments, participants configure, test, and share their designs and communicate with their teammates through an online research platform. The platform collects a step-by-step log of the actions made by participants. This article contains data sets collected from 44 teams (264 participants) in the team experiment and 73 participants in the individual experiment. These data sets can be used for

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behavioral analysis, sequence-based analysis, and natural language processing.

Specifications Table

Subject	Engineering
Specific subject area	Configuration design, operation planning, and business strategy
Type of data	Table
How data were acquired	Online research platform called HyForm (https://www.hyform.org)
Data format	Raw data
Parameters for data collection	The team experiment includes four conditions: (1) human-only teams change from an open team structure to a restrictive team structure; (2) human-only teams change from a restrictive team structure to an open team structure; (3) hybrid teams change from an open team structure to a restrictive team structure; (4) hybrid teams change from a restrictive team structure to an open team structure. The individual experiment includes two conditions: (1) individual designers work on their own; (2) individual designers with the availability of a drone design AI agent to advise them.
Description of data collection	In the team experiment, participants in teams of six develop and operate a drone fleet to deliver parcels routed to multiple locations of a target market. In the individual experiment, participants develop drones based on given design specifications. During these experiments, an online research platform, called HyForm, collects a step-by-step log of the actions made by each participant.
Data source location	Institution: Carnegie Mellon University Region: Pittsburgh, Pennsylvania, 15213 Country: United States of America
Data accessibility	With the article as supplementary material Data are also hosted in the public data repository. Repository name: Mendeley Data Data identification number: https://doi.org/10.17632/vcssdpgpfj.1 Direct URL to data: http://dx.doi.org/10.17632/vcssdpgpfj.1

Value of the Data

- These data sets are important to engineering design, psychology, and planning and development since these data sets provide a step-by-step history of problem solving in engineering design, perceived workload of each participant for the design and operation task, and team collaboration and communication in the design and operation process.
- Researchers in engineering design, cognitive science, operations, and business strategy may be interested in these data sets since they provide detailed process information of the design and operation of an engineered system by both individuals and teams.
- These data sets can be used for behavioral analysis, sequence-based analysis, and natural language processing to understand the design and operation process of an engineered system and to assess the impact of AI agents on distributed human design teams and individual human designers, respectively. For example, the individual experiment data could be analyzed to evaluate whether the AI agent has significant impact on the individual performance and total number of design actions, respectively; the content of the team discourse across the different communication channels of human-only teams could be compared with that of hybrid teams to show whether the AI agents increase the total team communication count in the team experiment; since an abrupt team structure reconfiguration is included in the team experiment, the analysis of the team experiment data could reveal participants' responses to the abrupt change.

- These data sets are helpful for future human subject experiment development that couples configurational design, operational planning, and business strategy since many existing experiments focus on configurational design of an engineered system and do not consider operational planning and business strategy of the system.

1. Data Description

The data sets collected from the team experiment and the individual experiment are included in the supplementary material as a ZIP file. The ZIP file has two folders entitled “Team Experiment” and “Individual Experiment”, respectively.

The “Team Experiment” folder contains eight CSV files entitled “Team Experiment Log”, “Team Experiment Design Database”, “Team Experiment Operation Database”, “Team Experiment Business Database”, “Team Experiment Customer Information”, “Team Experiment Pre-experiment Questionnaire Result”, “Team Experiment Mid-experiment Questionnaire Result”, and “Team Experiment Post-experiment Questionnaire Result”, respectively. Descriptions of the column headings for the first five CSV files are provided in Table 1, Table 2, Table 3, Table 4 and Table 5. The column headings for the last three CSV files list the questions and possible answer ranges in the corresponding questionnaire. For example, one column header in the CSV file entitled “Team Experiment Post-experiment Questionnaire Result” is “Mental demand: How mentally demanding was the task? (0–100)”. Each participant is asked that question in the post-experiment questionnaire and chooses a number from 0 to 100 as the answer to that question.

The “Individual Experiment” folder contains four CSV files entitled “Individual Experiment Log”, “Individual Experiment Design Database”, “Individual Experiment Mid-experiment Questionnaire Result”, and “Individual Experiment Post-experiment Questionnaire Result”, respectively. Descriptions of the column headings for the first two CSV files are provided in Table 6 and Table 7. The column headings for the last two CSV files list the questions and possible answer ranges in the corresponding questionnaire.

Table 1
Description of columns in CSV file entitled “Team Experiment Log”.

Column header	Description
Record ID	An integer indicating the identification of the record.
Time	Real time in the format of [YYYY-MM-DD hh:mm:ss.s].
Type	The type of the record, {‘action’, ‘chat’}.
Role	The role of the participant who takes the action or sends the chat, {‘Business’, ‘Ops Manager’, ‘Ops Planner 1′, ‘Ops Planner 2′, ‘Design Manager’, ‘Designer’, ‘Designer 1′, Designer 2′, ‘Experimenter}.
Content	A string containing the content of the action or chat. If the record is an action, the content includes the user interfaces in which the action is taken, the name of the action, the variable associated to the actions, and their corresponding values.
AI Agent	A string indicating whether the team has access to AI agents, {‘AI’, ‘nonAI’}.
Session	An integer indicating the session of the experiment, {1, 2}.
Team Structure	A character indicating the team structure, {‘A’, ‘B’}.
Team ID	A string indicating the team identification, {‘Team_AI_1A-2B_*(1–11)*’, ‘Team_nonAI_1A-2B_*(1–11)*’, ‘Team_AI_1B-2A_*(1–11)*’, {‘Team_nonAI_1B-2A_*(1–11)*’}.
Channel	The channel through which the chat is sent if the record is a chat, {‘All’, ‘Business’, ‘Operations’, ‘Operations 1′, ‘Operations 2′, ‘Designer’, ‘Designer 1′, ‘Designer 2′, ‘Help’, ‘Session’}. There are also cases in which the Experimenter directly talks to a specific role, indicated by the name of the role {‘Operations Manager’, ‘Operations Specialist 1′, ‘Operations Specialist 2′, ‘Design Manager’, ‘Design Specialist’, ‘Design Specialist 1′, ‘Design Specialist 2′}
Discipline	The discipline where the action is taken if the record is an action, {‘design’, ‘operations’, ‘business’}.
User ID	A string indicating the identification of the participant in the team. The first 3 letters of the user ID indicate the name of the database to which the team uploads their design solutions, {‘cmu’, ‘psu’}.

Table 2
Description of columns in CSV file entitled "Team Experiment Design Database".

Column header	Description
Drone Tag	A string indicating the name of the drone
User ID	A string indicating the identification of the participant in the team. The first 3 letters of the user ID indicate the name of the database to which the team upload their design solutions, {'cmu', 'psu'}.
Team ID	A string indicating the team that submits the drone.
Role	The specific role who submits the drone.
Configuration	A string indicating the configuration design of the drone. Please see Section 2.3 for more information.
Payload	An integer indicating the payload that the drone can carry in the unit of pound.
Cost	A float indicating the cost of the drone in the unit of US dollar.
Range	A float indicating the flying range of the drone in the unit of mile.
Velocity	A float indicating the flying velocity of the drone in the unit of miles per hour.

Table 3
Description of columns in CSV file entitled "Team Experiment Operation Database".

Column header	Description
Plan ID	An integer indicating the identification of the plan.
User ID	A string indicating the identification of the participant in the team. The first three letters of the user ID indicate the name of the database to which the team uploads their design solutions, {'cmu', 'psu'}.
Plan Tag	A string indicating the name of the plan created by the participant.
Team ID	A string indicating the team that submits the plan.
Role	The specific role of whom submits the plan.
Scenario ID	An integer indicating the corresponding scenario which the plan is built upon.
Number of Paths	An integer indicating the number of paths included in the plan.
Start-Up Cost	A float indicating the start-up cost of the plan in the unit of US dollar, which is calculated by summing up the costs of all vehicles used in the plan.
Profit	An integer indicating the profit made through this plan in the unit of US dollar.
Food	An integer indicating the weight of food in the unit of pound delivered through this plan.
Package	An integer indicating the weight of package in the unit of pound delivered through this plan.
Number of Deliveries	An integer indicating the number of parcels (both food and packages) delivered through this plan.
Mass Delivered	An integer indicating the weight of parcels (both food and packages) in the unit of pound delivered through the plan in total.
Vehicle-*(1–15)*	A string indicating the name of the vehicle used for the corresponding path-*(1–15)*.
Path-*(1–15)*	A string indicating the path of the corresponding vehicles with customer IDs connected by "-".

2. Experimental Design, Materials and Methods

This section presents overviews of the team experiment and the individual experiment. The grammar string format of drone configuration in log data is also provided. Importantly, participants configure, test, and share their designs and communicate with their teammates in these experiments through an online research platform, called HyForm.[1] The architecture of the platform and the detailed information of the design and operation AI agents integrated in the platform are found in prior research [1].

[1] https://github.com/hyform

Table 4
Description of columns in CSV file entitled "Team Experiment Business Database".

Column header	Description
Scenario ID	An integer indicating the identification of the scenario.
Database	The name of the database storing the scenario, {'cmu', 'psu'}.
Scenario Tag	A string indicating the scenario is the default initial scenario or an updated scenario, {'Initial Scenario', 'updated'}.
Version	An integer indicating the sequence number of the scenario submitted by a team.
57–112 (integers from 57 to 112 indicating the customer IDs)	A Boolean data indicating whether the corresponding customer is included or not in the market scenario, {'TRUE', 'FALSE'}.

Table 5
Description of columns in CSV file entitled "Team Experiment Customer Information".

Column header	Description
Customer ID	An integer indicating the identification of the customer in the market.
Type	The type of parcel ordered by the customer, {'food', 'package'}.
Profit	An integer indicating the profit in the unit of US dollar that can be made if the parcel is delivered to the customer.
Weight	An integer indicating the weight of the parcel in the unit of pound ordered by the customer.
X	A float indicating the location of the customer along the X-axis in the unit of mile.
Y	A float indicating the location of the customer along the Y-axis in the unit of mile.

Table 6
Description of columns in CSV file entitled "Individual Experiment Log".

Column header	Description
Record ID	An integer indicating the identification of the record.
Time	Real time in the format of [YYYY-MM-DD hh:mm:ss.s].
Type	The type of the record, {'action', 'chat'}.
Individual Designer ID	A string indicating the individual designer who takes the actions or sends the chat, including Experimenter.
Content	A string containing the content of the action or chat. If the record is an action, the content includes the user interfaces in which the action is taken, the name of the action, the variable associated to the actions, and their corresponding values.
AI Agent	A string indicating whether the team has access to AI agents, {'AI', 'nonAI'}.
Session	An integer indicating the session of the experiment, {1, 2}.
Set ID	A string indicating the identification of the individual experiment set in which multiple individual designers conduct the experiment at the same time, {'IN_AI_*(1–16)*', 'IN_nonAI_*(1–13)*'}.
User ID	A string indicating the identification of the participant in the individual experiment set. The first three letters of the user ID indicate the name of the database to which the team upload their design solutions, {'cmu', 'psu'}.

Table 7
Description of columns in CSV file entitled "Individual Experiment Design Database".

Column header	Description
Drone Tag	A string indicating the name of the drone
User ID	A string indicating the identification of the participant in the individual experiment set. The first three letters of the user ID indicate the name of the database to which the team upload their design solutions, {'cmu', 'psu'}.
Set ID	A string indicating the individual experiment set during which the drone is submitted.
Individual Designer ID	The specific role of whom submits the drone.
Configuration	A string indicating the configuration design of the drone. Please see Section 2.3 for more information.
Payload	An integer indicating the payload that the drone can carry in the unit of pound.
Cost	A float indicating the cost of the drone in the unit of US dollar.
Range	A float indicating the flying range of the drone in the unit of mile.
Velocity	A float indicating the flying velocity of the drone in the unit of miles per hour.

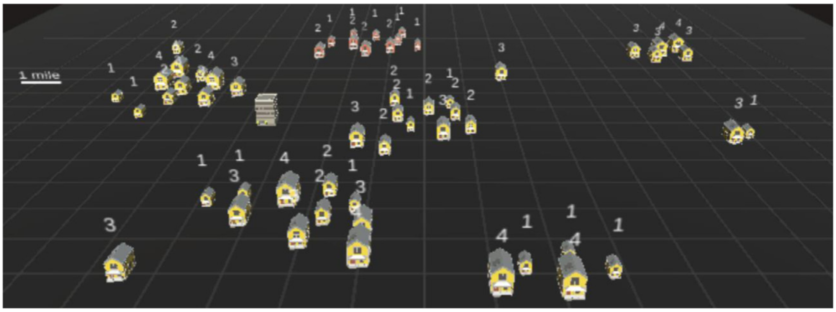

Fig. 1. Initial customer location map.

2.1. Team experiment overview

Each participant belongs to a team of six participants tasked with creating a new company that specializes in package and food delivery using drones. The new company is the first entrant in a market and to be successful must maximize profit by designing and implementing a drone fleet.

An example of an initial customer location map is shown in Fig. 1. The houses represent customer locations. Yellow houses represent package demand, and red houses represent food demand. The number on the top of each house represents the food and package demands in the unit of pounds. The grey building shows the company's new warehouse where the drone system will be managed. Each customer can order either one package or one food order. Each package must be delivered within 24 h, and each food order must be delivered within 4–6 h from the start of the day.

The company has an initial budget of $15,000 to build and operate a drone fleet. As part of the business strategy, the company can choose to provide service to any customers on the map the company wants to acquire. The company will receive $100 in profit per each pound of package delivered and $200 in profit per each pound of food order delivered.

Each participant is assigned a role in the team as either a Design Manager, Design Specialist, Operations Manager, Operations Specialist, or Business Manager. The Design Manager is responsible for managing the design team and communicating its progress. The Design Specialist is responsible for designing drones (with the Design Manager) and submitting completed designs to the operations team. The Operations Manager is responsible for managing the Operations team and communicating its progress. The two Operations Specialists are responsible for developing operation plans by generating delivery routes with designed drones to deliver parcels. The Business Manager is responsible for handling the company budget, choosing the customers, and communicating its progress. The Business Manager can decide to approve or reject the operation plans.

Depending on the role, each participant has access to one of the following three interface modules. More details of each module are found in the prior research [1].

1. The drone design module enables members of the design team to construct drones. Designers can check the drone feasibility, assess the cost, and assess the performance of the design by running a simulation.
2. The operational strategy module enables the operations team to determine an operation plan that aligns with the company's business strategy, and the customers' constraints. This module rapidly evaluates routes and schedules, and provides estimates for time-to-deliver, the number of vehicles required, time on/off station, among others.
3. The business plan module enables the business manager to construct and simulate their market plans. The market plan includes the number of customers for whom service should be provided, the locations of the customers, and the type of incentives each customer requires.

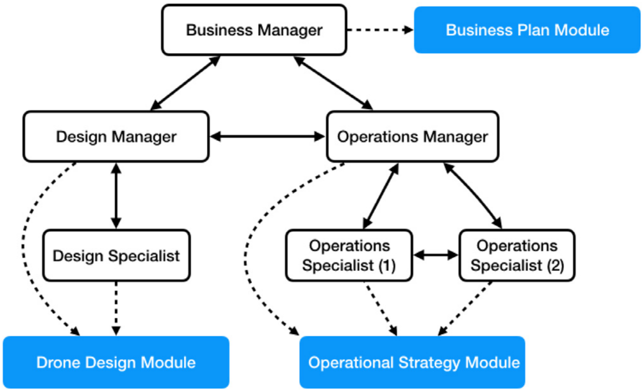

Fig. 2. The open team structure (referred to as Structure A in Supplementary Material). All team members can communicate directly with each other. The solid arrows represent the communication channels between team members. The dash arrows represent the access to interface modules.

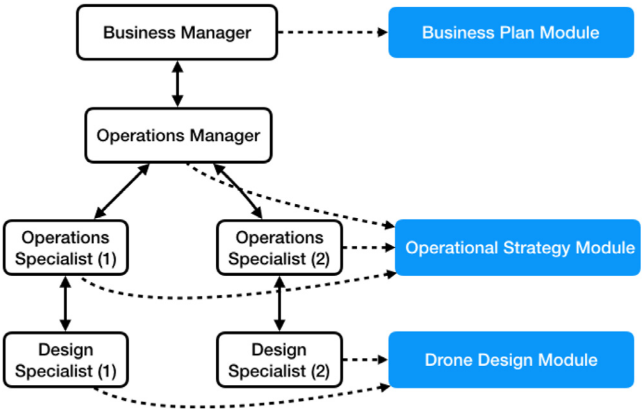

Fig. 3. The restrictive team structure (referred to as Structure B in Supplementary Material). Only particular members can communicate with one another through explicit channels. The solid arrows represent the communication channels between team members. The dash arrows represent the access to interface modules.

In the team experiment, half of the teams are human-only teams with no available AI agent. The other half of the teams, designated as hybrid teams, have drone design and operation AI agents to advise them. Halfway through the team experiment, the team structure is changed unexpectedly, requiring participants to adapt to the change. Two distinct team structures (i.e., the open team structure and the restrictive team structure) are shown in Figs. 2 and 3, respectively. During the team structure reconfiguration, all team members maintain their assigned role with one exception: the Design Manager in the open team structure becomes the Design Specialist in the restrictive team structure. The 2×2 factorial experimental design results in four different experimental conditions (i.e., hybrid teams change from the open team structure to the restrictive team structure, hybrid teams change from the restrictive team structure to the open team structure, human-only teams change from the open team structure to the restrictive team structure, human-only teams change from the restrictive team structure to the open team structure).

The team experiment takes 70 min. Time allocation of the experiment appears in Fig. 4. There are two 20-minute design sessions in the experiment. Each design session simulates one typical

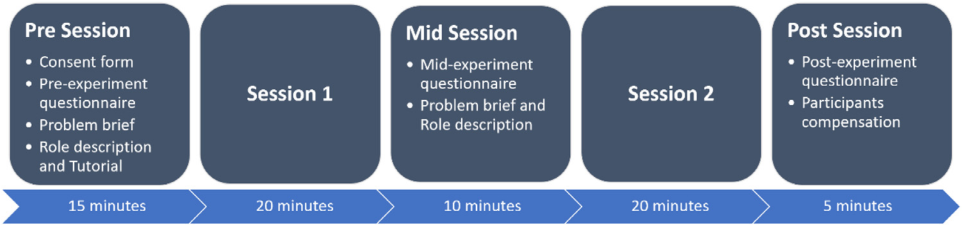

Fig. 4. Time allocation of the team experiment.

Table 8
Objectives for drone design in the individual experiment.

Objective No.	Description
1	Construct a fleet of 4 drones that meet the following parameters: A. One drone capable of flying a total distance of 20 miles B. One drone capable of flying a total distance of 50 miles C. One drone capable of carrying a maximum payload of 10 lbs D. One drone capable of carrying a maximum payload of 20 lbs
2	Construct a fleet of 4 drones that meet the following parameters: All drones must be capable of flying at a minimum speed of 5 mph A. One drone capable of flying a total distance of 15 miles carrying at least 20 lbs B. One drone capable of flying a total distance of 20 miles carrying at least 15 lbs C. One drone capable of flying a total distance of 30 miles carrying at least 10 lbs D. One drone capable of flying a total distance of 40 miles carrying at least 5 lbs
3	Construct a fleet of 3 drones that meet the following parameters: Each drone must individually cost less than $5000 A. One drone capable of flying a total distance of 18 miles carrying 25 lbs B. One drone capable of flying a total distance of 35 miles at 8 mph C. One drone capable of flying a total distance of 20 miles at 10 mph carrying 8 lbs
4	Construct a fleet of 4 drones that meet the following parameters: Each drone must individually cost less than $4000 A. One drone capable of flying a total distance of 18 miles at 10 mph carrying 15lbs B. One drone capable of flying a total distance of 20 miles at 8 mph carrying 8 lbs C. One drone capable of flying a total distance of 30 miles at 6 mph carrying 10 lbs D. One drone capable of flying a total distance of 40 miles at 6 mph carrying 5lbs
5	Construct a fleet of 3 drones that meet the following parameters: Each drone must individually cost less than $3500 A. One drone capable of flying a total distance of 18 miles at 8 mph carrying 15lbs B. One drone capable of flying a total distance of 20 miles at 15 mph carrying 10 lbs C. One drone capable of flying a total distance of 30 miles at 6 mph carrying 20lbs

day (i.e., 24 h delivery time). Each participant fills out a questionnaire at the beginning, in the middle, and in the end of the experiment, respectively.

In sum, 264 participants are recruited from 18 US universities for the team experiment. Participants are engineering undergraduate or graduate students and are over 18 years old. These 264 participants are randomly assigned to 44 teams of six (11 teams for each experiment condition). Each participant receives $20 gift card compensation after the team experiment. Participants are remotely located, anonymously connected only through the HyForm platform.

2.2. Individual experiment overview

Each participant is responsible for designing drones using the drone design module presented in Section 2.1. Participants are required to complete the objectives shown in Table 8 in order of appearance. Participants should not skip to the next objective until all previous objectives have been completed.

Fig. 5. Time allocation of the individual experiment.

There are two experimental conditions in the individual experiment. Half of the participants work on their own. The other half of the participants have a drone design AI agent to advise them.

The individual experiment also takes 70 min. Time allocation of the experiment appears in Fig. 5. There are two 20-minute design sessions in the experiment. Each participant fills out a questionnaire in the middle and in the end of the experiment, respectively.

In sum, 73 participants are recruited from 18 US universities for the individual experiment. Participants are engineering undergraduate or graduate students and are over 18 years old. These 73 participants are randomly assigned as 37 individual designers with no availability of the AI agent and 36 individual designers with the AI agent to advise them. Each participant receives $20 gift card compensation after the individual experiment. Participants are remotely located, anonymously connected only through the HyForm platform.

2.3. Grammar string format of drone configuration in log files

In the experiment log files, each drone configuration is defined by a grammar string, which constrains the placement of nodes and connections between nodes to a rectangular grid pattern, rotated 45 ° from the forward direction. This rotation is applied since a majority of drone configurations use a connection assembly pattern based on this rotation, and positions are more efficiently defined using the rotated grid. Each node includes information about its identifier, component type, position, and size. Each connection between two nodes, called edge, is defined by two ending nodes identified with their respective character identifiers. The grammar allows for any variable number of nodes and connections. Fig. 6 shows an example drone configuration defined by a string, along with its physical representation.

Fig. 7 shows the grammar rules used by the Lark parser[2] that defines a drone configuration. A rule, defined by a non-terminal name prepended with ‘?’, includes a series of non-terminal names and/or terminal symbols (identified using “”, where ‘|’ represents *or* selections of terminal symbols). A non-terminal name is replaced with other non-terminal names until a terminal symbol is reached. The starting rule (?*start*) includes a variable number (identified by the +) of nodes and edges followed by two comma separated numbers, which identify the capacity and controller index, respectfully. Each node must have a starting ‘*’ character, an identifier (*comp_id*), x and z location identifiers (*loc_id*), and component type (“0″-“4″). The optional (identified by the ‘[‘ and ‘]’) size increments follow, where the component size is incremented up for one or more ‘+’ characters and incremented down for one or more ‘-‘ characters. The *comp_id* rule includes a list of available node identifiers (“a”-“z”, followed with “!” “@” “#” “$” “%” “&” “(“ “)” “_””=” “[“ “]” “{“ “}” “<” “>”). The *loc_id* rule includes a list of available position identifiers (“A”-“Z”). Each edge must have a starting ‘^’ character and two node identifiers.

[2] https://github.com/lark-parser/lark

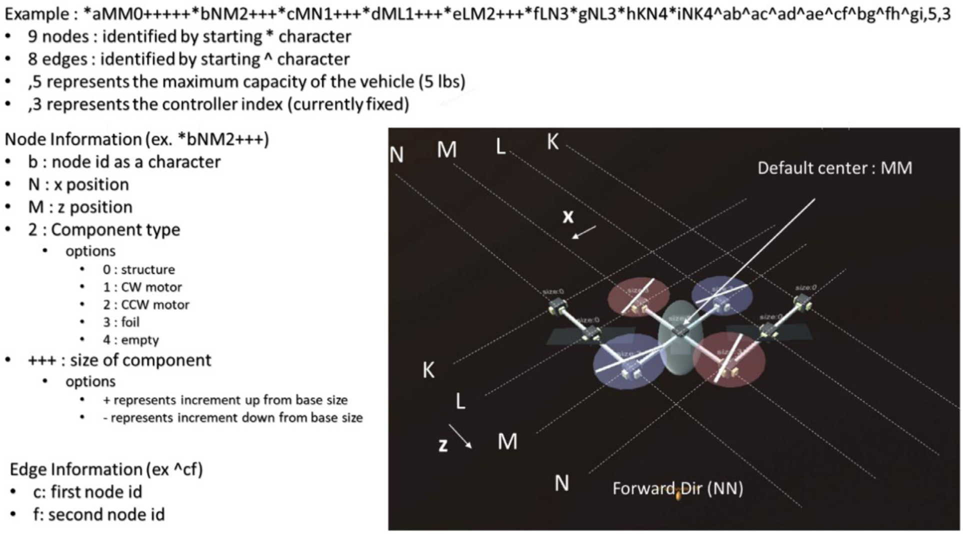

Fig. 6. Example drone configuration defined by a string.

```
?start: vehicle_component+ connection+ "," NUMBER "," NUMBER

?vehicle_component : "*" comp_id loc_id loc_id comp_type [size_increment]
?connection : "^" comp_id comp_id

?comp_id : "a" | "b" | "c" | "d" | "e" | "f" | "g" | "h" | "i" | "j" | "k" | "l" | "m" | "n" | "o" | "p
?loc_id : "A" | "B" | "C" | "D" | "E" | "F" | "G" | "H" | "I" | "J" | "K" | "L" | "M" | "N" | "O" | "P"
?comp_type : "0" | "1" | "2" | "3" | "4"
?size_increment : "+"+ | "-"+
```

Fig. 7. Grammar rules used by the Lark parser.

Ethics Statement

The authors declare that informed consent was obtained for experimentation with human subjects. These human subject experiments are approved by the Carnegie Mellon University Institutional Review Board (IRB) under protocol IRBSTUDY2015_00000042.

CRediT Author Statement

Guanglu Zhang: Experimentation, Writing – Original draft preparation; **Nicolas F. Soria Zurita:** Experimentation, Writing – Original draft preparation; **Gary Stump:** Research platform development, Writing – Original draft preparation; **Binyang Song:** Data curation, Writing – Original draft preparation; **Jonathan Cagan**: Supervision and manuscript editing; **Christopher McComb**: Supervision and manuscript editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

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Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.dib.2021.107008.

Reference

[1] B. Song, N.F. Soria Zurita, G. Zhang, G. Stump, C. Balon, S.W. Miller, M. Yukish, J. Cagan, C. McComb, Toward hybrid teams: a platform to understand human-computer collaboration during the design of complex engineered systems, in: Proceedings of the Design Society: Design Conference, 1, Cambridge University Press, 2020, pp. 1551–1560, doi:10.1017/dsd.2020.68.