ASPEN

Case study title: ASPEN: Autonomous Systems for Forest Protection

Description

Forest protection is essential to mitigating climate change, and a major objective of the Forests and Climate Leaders' Partnership established at COP27. The ASPEN project aims to develop an integrated framework for the autonomous detection, diagnosis and treatment of tree pests and disease. While recent research reveals the potential benefits of forest health monitoring using remote sensing and drones combined with machine learning, these technologies are absent from current government forest-protection strategies. Furthermore, the potential for autonomous systems to fulfil forest-protection roles beyond surveillance and P&D detection remains underexplored, as are their trustworthiness, safety, legal and ethical implications, and their societal acceptance. ASPEN will advance the state of the art by: (1) undertaking proof-of-concept research in relation to the technical aspects of these roles of autonomous systems, (2) exploring their contextual governance (regulation, legal and ethical norms, impact on wildlife, and stakeholder perspectives), and (3) evaluating the feasibility of their practical use. Specifically, our project will prototype an integrated multidisciplinary framework for trustworthy autonomous-system capabilities in tree health that comprehensively describes their broad functional potential whilst identifying key knowledge gaps, and technological and governance needs.

The DJI Phantom 4 Multispectral RTK drone will be used in this project. It is equipped with a RGB camera and multispectral camera. Currently ASPEN, and specifically the drone's inclusion, is being considered in two use cases. The first use case is a forest management team is tasked with inspecting a whole forest area, however it would be ideal if the workload of the human experts (which is a vastly limited resource) can be minimised. The deployment of drones can cover a forest and only alert the experts to specific trees of interest. Second use is acquiring a sample (be it a physical sample, such as soil or branch, or an image of the tree) which can be dangerous to a human expert. The dangers include uneven terrain, climbing the tree, and the P&D themselves can be harmful to humans. The project is also planning on prototyping a sampling tool which will cut a branch off, specifically the DeLeaves Tree Canopy Sampling Tool.

ASPEN is investigating not just commercial but public forests as well. Therefore great care must be considered when concerning citizens who may be in the forest during any drone operation.

Stage of Development (Technical contributor)

Aiming to be PROTOTYPE and PROOF-OF-CONCEPT

Expert info
Expertise of the stakeholders involved in devising the SLEEC rules
Number of stakeholders writing the rules

Stakeholder names	Expertise
TS-1	Safety analyst
N-TS-1	Social Psychology
N-TS-2	Moral Psychology, Law
TS-2	Engineer/Goal Modelling

1. **Normative requirements**
    a. **Normative requirements in natural language**

    Normative requirements in natural language, in blue the corrected requirements after using N-Tool.

rule id	rule	impact	label(s) (social, legal, ethical, empathetic, or cultural)	stakeholder expertise	authors identifiers
1	If an encounter with a human occurs, make sure to inform the purpose of the monitoring. - Ensure the human speaks the same language and understands what the drone is trying to convey.	T+, SR+	Social, ethical	Psychology, ethics	N-TS-1
2	If an encounter with a human occurs, identify the activity they are performing and determine if the activity is related to forest monitoring or not. - If the activity is unrelated to forest monitoring, avoid storing data related to it.	P+, T+	Social, ethical	Psychology, ethics	N-TS-1

3	If humans are nearby, warn them if a dangerous environmental condition is close (bad weather, dangerous terrain ahead, etc).	S+	Social, ethical	Psychology, ethics	N-TS-1
4	~~Prior to deploying drone, ensure that:~~ ~~- targeted area is not otherwise under the control of Indigenous tribes~~ ~~- the drone has sufficient battery life, storage, and that it is not damaged so it is able to make the return journey to base~~ ~~- Flight conditions are good enough~~ ~~- Deployment should be clearly allowed in relevant Treaties with impacted tribes~~ Prior to deploying drone, check whether: - the targeted area is under the control of Indigenous tribes - the drone has low storage or battery, or that it is damaged so it is unable to make the return journey to base - flight conditions are dangerous - that a land treat is not in place In this case, do not deploy the drone	A+ CS+ N+ S+	Social Ethical Legal Cultural	Psychology, Law	N-TS-2
5	Record and monitor role of trees, soil, etc. in relevant food and shelter priorities for local humans and animals	B+ N+ S+	Ethical	Psychology Law	N-TS-2
6	Ensure drone activity and obtaining physical samples do not adversely interfere with local ecosystem and wildlife	N+	Ethical	Engineer/Goal Modelling	TS-2
7	Delineate and keep updating	A+	Legal	Psychology	N-TS-2

	private vs. public territory jurisdictions to ensure drone is not trespassing - Data must include land delineations as well as airfields	P+ S+		Law	
8	Continue monitoring carbon footprint resulting from ASPEN infrastructure to inform missions - Carbon footprint should not be higher than benefits reaped as a result of ASPEN	+B +N	Legal Social	Psychology Law	N-TS-2
9	If irrelevant to mission, photos and videos taken by camera must not be stored - Ensure human subjects in photos and videos are deidentified	+B +N +T +P	Legal Ethical Social	Psychology Law	N-TS-2
9b	If any photos or videos are deleted, add this action to the log and notify the user of deletion.				
10	Prior to implementing ASPEN recommendations, ensure they do not interfere or contradict with pre-existing jurisdictional protections - If they do, inform user	+T +A +E +SR	Legal Cultural	Psychology Law	N-TS-2
11	When the environmental conditions become unsafe for the drone to fly in (lightning, high windspeed etc.), then return to base and inform keeper of return - If conditions are too dangerous to fly in then drone must ground itself and inform keeper of its location	+S +N	Legal	Engineer/Goal Modelling	TS-2
12	When encountering wildlife, the drone must maintain its distance and refrain from any interaction	+N +S	Legal Ethical Empathetic	Engineer/Goal Modelling	TS-2

	- If interaction is unavoidable, exit the area as fast as possible and inform keepers - If wildlife is disturbed by the drone's presence (animal flees, exhibits defensive behavior etc.), the drone must back up				
13	~~Prior to deploying the drone, ensure that the drone has sufficient battery life, storage, and that it is not damaged so it is able to make the return journey to base~~	+S +N +E	Legal	Engineer/Goal Modelling	TS-2
14	If the drone has: - Damages - Low battery - Low storage during the mission, inform keeper of condition and location and discontinue flight, preferably by returning to the base	+S	Legal	Engineer/Goal Modelling	TS-2
15	If the drone identifies anything unusual or unknown during the mission, it should take pictures for further examination	+B +T +E	Legal	Engineer/Goal Modelling	TS-2

Concerns	
c1	When there are damages to the drone prior to deployment, deploy the drone
c2	When the battery of the drone is low prior to deployment, deploy the drone
c3	When the drone has been deployed and it becomes damaged, the drone must not ground itself within 5 minutes
c4	When the drone has been deployed and the battery becomes low, the drone must not ground itself within 5 minutes
c5	When flight conditions are dangerous prior to deployment, deploy the drone
c6	When the drone has been deployed and flight conditions become dangerous, the drone must not ground itself within 5 minutes
c7	When deleting pictures, the drone must not inform the keeper within 5 minutes
c8	Prior to implementing ASPEN recommendations, if it is discovered that the drone interferes or contradicts with pre-existing jurisdictional protections, the keeper must not be informed within 5

	minutes
Purpose	
p1	The drone must be able to collect samples
p2	Territories must be delineated and updated on private vs. public territory jurisdictions to ensure drone is not trespassing
p3	The drone must be able to delete pictures
p4	When preparing the drone and there are damages, the drone must be able to be deployed eventually
Impact keys: A = autonomy, PH = psychological health (non-maleficence), P = privacy, E = explainability, T = transparency, CS = cultural sensitivity, SR = social requirement, B 'beneficence' (doing good), N 'non-maleficence' (preventing/avoiding harm), and S 'safety'. ''+" and "-" for positive and negative impacts respectively.	

1. **Rules in the SLEEC DSL**
   The stakeholders corrections after analyzing the well-formedness of the rules using our N-Tool are commented and in blue.

```
def_start
        event EncounterHuman
        event HumanNearby
        event IdentifyActivity
        event InformHuman
        event InformKeeper
        event BackUp
        event ExitArea
        event PreparingDrone
        event DeployDrone
        event GroundDrone
        event ReturnHome
        event MonitorLand
        event MonitorCarbon

        event CollectSample // Separate event from DeployDrone because not all deployments may result in
        sample collection
        event AvoidInterference
        event EncounterWildlife
        event UpdateTerritories  // Data must include land delineations as well as airfields
        event DeletePictures
        event TakePictures
        event StoreData
        event AnonymizeHuman
        event ImplementASPEN
        event EnsureCompliance // Does not interfere or contradict with pre-existing jurisdictional protections
        //** resolve concern c7, add event for logging robot actions
           event LogDroneAction
         //**********************
```

```
        measure sameLanguage: boolean
        measure humanUnderstands: boolean
        measure unrelatedActivity: boolean
        measure environmentDangerous: boolean // Bad weather, dangerous terrain ahead, etc
        measure onIndigenousLand: boolean
        measure landTreatyInPlace: boolean
        measure relevantLand: boolean // In relevant food & shelter priorities for local humans and animals
        measure privateTerritory: boolean
        measure humanIdentified: boolean
        measure carbonFootprint: scale{low, medium, high}
        measure benefits: scale{low, medium, high}
        measure flightCondition: scale{dangerous, unsafe, safe, ideal}
        measure wildlifeDisturbed: boolean
        measure wildlifeInteractswithDrone: boolean
        measure unKnownObject: boolean
        measure damages: boolean
        measure battery: scale(high, medium, low)
        measure store: scale(high, medium, low)

def_end

rule_start
        R1 when EncounterHuman and ({sameLanguage} and {humanUnderstands})
        then InformHuman

        R2 when EncounterHuman then IdentifyActivity

        R2_1 when IdentifyActivity and {unrelatedActivity} then not StoreData

        R3 when HumanNearby and {environmentDangerous} then InformHuman

        R4 when PreparingDrone and {onIndigenousLand} then not DeployDrone
                unless {landTreatyInPlace} then DeployDrone

        //**********  resolve situational conflict 1 (MERGE R4 and R13 in R4b)
        // comment R4 and  R13, uncomment R4b
        // R4b  when PreparingDrone and (({onIndigenousLand} and (not {landTreatyInPlace})) or
        //                 (({battery} = low) or ({storage} = low) or {damages}))  then not DeployDrone
        //                  unless {landTreatyInPlace} and  then DeployDrone
        //********** resolve concern 5 (Refine corrected and merge rule R4b) *******
        // comment R4b and uncomment R4bb
          // R4bb when PreparingDrone and (({onIndigenousLand} and (not {landTreatyInPlace})) or
          //         (({battery} = low) or ((({store} = low) or {damages}) or
          //           ({flightCondition} = dangerous))))  then not DeployDrone
            //*********************************************************************

        R5 when DeployDrone and {relevantLand} then MonitorLand

        R6 when CollectSample then AvoidInterference

        R6_1 when DeployDrone then AvoidInterference

        // Prior to deploying the drone, ensure territory jurisdictions updated
        R7 when PreparingDrone then UpdateTerritories
```

```
// If area is private territory, then don't deploy drone
R7_1 when PreparingDrone and {privateTerritory} then not DeployDrone

// If drone somehow still stumbles onto private territory
R7_2 when DeployDrone and {privateTerritory} then ExitArea

R8 when DeployDrone then MonitorCarbon

R8_1 when DeployDrone and ({(carbonFootprint} > low) and  ({benefits} < medium)) then InformKeeper

R9 when TakePictures and {humanIdentified} then AnonymizeHuman
unless {unrelatedActivity} then DeletePictures


//********** resolve concern c7 (ADD two rules and an event)
// uncomment R9b1 and R9b2
// R9b1 when DeletePictures then  InformKeeper
// R9b2 when DeletePictures then  LogDroneAction
//*****************************************************************

R10 when ImplementASPEN then EnsureCompliance

//********** resolve C7  (ADD a rule 10b)
// uncomment R10b
// R10b when EnsureCompliance then InformKeeper
 //*****************************************************************

R11 when DeployDrone and ({flightCondition} < safe) then ReturnHome
unless ({flightCondition} = dangerous) then GroundDrone

R11_cont when ReturnHome then InformKeeper

R11_cont_1 when GroundDrone then InformKeeper

R12 when EncounterWildlife then AvoidInterference
unless {wildlifeDisturbed} then BackUp immediately
unless {wildlifeInteractswithDrone} then ExitArea within 1 minute

R12_1 when EncounterWildlife and {wildlifeInteractswithDrone} then InformKeeper

R13 when PreparingDrone and (({battery} = low) or ({storage} = low) or {damages})
then not DeployDrone

R14 when DeployDrone and {damages} then InformKeeper

//Resolve redundancy, comment r14

R14_1 when DeployDrone and {damages} then GroundDrone

R15 when DeployDrone and {unKnownObject} then TakePictures

rule_end
concern_start
```

```
        c1 when PreparingDrone and {damages} then DeployDrone
        c2 when PreparingDrone and ({battery} = low) then DeployDrone
        c3 when DeployDrone and {damages} then not GroundDrone within 5 minutes
        c4 when DeployDrone and ({battery} = low) then not GroundDrone within 5 minutes
        c5 when PreparingDrone and ({flightCondition} = dangerous) then DeployDrone
        c6 when DeployDrone and ({flightCondition} = dangerous) then not GroundDrone within 5 minutes
        c7 when DeletePictures then not InformKeeper within 5 minutes
        c8 when EnsureCompliance then not InformKeeper within 5 minutes
concern_end
purpose_start
        p1 exists CollectSample // Separate event from DeployDrone because
                                // not all deployments may result in sample collection
        p2 exists UpdateTerritories  // Data must include land delineations as well as airfields

        p3 exists DeletePictures

        p4 exists PreparingDrone and {damages} while DeployDrone eventually

purpose_end
```