Supplementary Materials for

An autonomous drone for search and rescue in forests using airborne optical sectioning

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- Section S1
- Figs. S1 to S5
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Other Supplementary Material for this manuscript includes the following:

- Movies S1 to S4
Supplementary Sections

Section S1. Average Precision Curve
The AP (fit) curve in Fig. 3 shows a fit of the average precision (AP) scores over all scenes with N as a parameter (data in Tab. 1). The curve is a hyperbolic function of the form
\[ AP(N) = \frac{aN}{b+N}, \quad (3) \]
with parameters \( a = 0.943 \) and \( b = 0.516 \). The parameters were computed with a least-squares optimizer using the SciPy Python library, and we penalized positive residuals (estimations below the data points). The mean-squared error between the fitted curve and the data points in Tab. 1 is 0.0005.

Supplementary Figures

Figure S1. Test sites. Satellite images and example drone (RGB) images of the test sites: Broadleaf forest site for test flights F2, F9, F13, F14, F15, F24, and F25 (A). Mixed forest site for test flights F3, F21, F22, and F28 (B). Conifer forest site for test flights F6, F12, F14, F15, F23, F26, and F27 (C). Second mixed forest site for test flights F16, F17, F18, F19, and F20 (D). Note that flights F14 and F15 covered both the conifer and the broadleaf sites.
**Figure S2. Predefined search experiments.** Integral images and classification results for the test flights presented in Tab. 2 (except F16, which is shown in Fig. 4C). Black boxes indicate where persons are present, and green boxes are classified as containing persons. The red box in F12 indicates a false classification.
Figure S3. Adaptive Search Experiment. Remaining detection and re-sampling cases from Tab. 3 (except F20 and F21, which are shown in Fig. 5B,C). Digital elevation models overlaid with sub-areas. Pink stars indicate detections made. They are confirmed to be correct (green box) or incorrect (red box) classifications in the resampled integral images II. Re-sampled SAs and fast flight segments without sampling are indicated by dashed and dotted black lines, respectively. Black triangles, the orientations of which illustrate the flight direction, mark positions of computed integral images.
Figure S4. Offline registration enhancement. Results of the offline registration enhancement for all correct people detections (PF) in Tab. 3. Integral image computed in real time from GPS and IMU data on the drone (odd rows). Despite substantial misregistrations, person classification was successful. After automatic registration enhancement of the selected region of interest (bounding box of the classification result) as explained in (62), visual image quality is improved (even rows). Computation time was approx. 2-3 minutes on a standard PC with Nvidia GTX 1060 GPU, for 30-39 integrated samples and a region of interest with a resolution of 60 px × 60px.
Figure S5. Visualization of long-endurance prototype (acronym: *Christophorus X*). The basic system is a Stromkind STR-series with Boxer (STR-35) or Wankel (STR-50) engine, 75-80 kg empty weight, 150 kg maximum take-off weight, 3-6 h endurance, and Flettner intermeshing rotor ([https://www.stromkind.com](https://www.stromkind.com)). It is planned to be extended by an AOS sensor, person classifier, autonomy path planning, identification system, (satellite) communication, and flight termination system (possibly also by available collision detection and avoidance mechanisms and a radio signal localization sensor).

**Supplementary Movie Legends**

**Movie S1. Autonomous drone supporting search and rescue missions.** Video footage of our prototype drone and sample test site (D in Fig. S1).

**Movie S2. 1D synthetic-aperture classification performance.** Video footage illustrates the improvement in classification performance with increasing number of samples (N) for 4 sample test flights (broadleaf, conifer, mixed forest, and empty broadleaf forest). Shown are ground-truth labels (black boxes), true positives (green boxes), and false positives (red boxes).

**Movie S3. Predefined search.** Video footage illustrating test flight F16 (Fig. 4). The white pyramid indicates the field of view and the camera positions of the predefined flight path. Single images and computed integral images with classification results are shown (green boxes: persons correctly found). Close-ups show the locations of persons in the integral image.

**Movie S4. Adaptive search.** Computed flight path (with re-sampling in the case of detections) for flight F21 (shown in Fig. 5A and B). The initially provided probabilities are color-coded. For visited cells, the color-coding is removed. Dashed white lines indicate scanned SAs within 30 m × 30 m cells. Dashed blue lines represent resampled SAs. Dotted white lines indicate fast flight segments without sampling. Black triangles illustrate the orientations of flights and mark positions of computed integral images. In the case of resampling, the corresponding integral images are shown. Note that the flight is stopped after a person has been detected in the resampled integral image.