bulletanalyzr
USER GUIDE

bulletanalyzr

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INTRODUCTION

BulletAnalyzr is a forensic tool that uses 3D imaging and advanced algorithms to compare bullets and determine if they were fired from the same gun. The application scans bullet surfaces at high resolution and automates much of the comparison process, while still giving forensic examiners intuitive controls to review and adjust the results.

- **Interactive Visualization:** Upload and view 3D renderings of your bullet scans (x3p format) and examine crosscut profiles with adjustable parameters

- **Automated Analysis:** The software automatically processes your bullet scans, identifying crosscut locations, removing grooves, extracting signals, and measuring similarities between signals.
- **Manual Refinement Controls:** Fine-tune automated decisions using intuitive sliders at each step of the analysis
- **Comprehensive Reporting:** Generate and export detailed comparison reports in a professional, shareable format
- **Free and Open-Source:** BulletAnalyzr is open-source and free to use.

BulletAnalyzr bridges the gap between sophisticated algorithmic analysis and practical forensic workflows, making advanced bullet comparison techniques easily accessible to examiners.

INSTALLATION

You will need to install R, RStudio, BulletAnalyzr, and supporting R packages.

Install Software

Total Estimated Time: 20-30 minutes

- **Install R** from https://cran.r-project.org/
- **Install RStudio** from https://posit.co/download/rstudio-desktop/
- **Download BulletAnalyzr** from GitHub
    - Go to https://github.com/CSAFE-ISU/bulletAnalyzr
    - Click the green Code button and select Download Zip (Figure 1)
    - Double-click on the downloaded file to unzip it. You may save the unzipped folder anywhere on your computer. By default, the unzipped folder will be named "bulletAnalyzr-main". You may rename the folder.

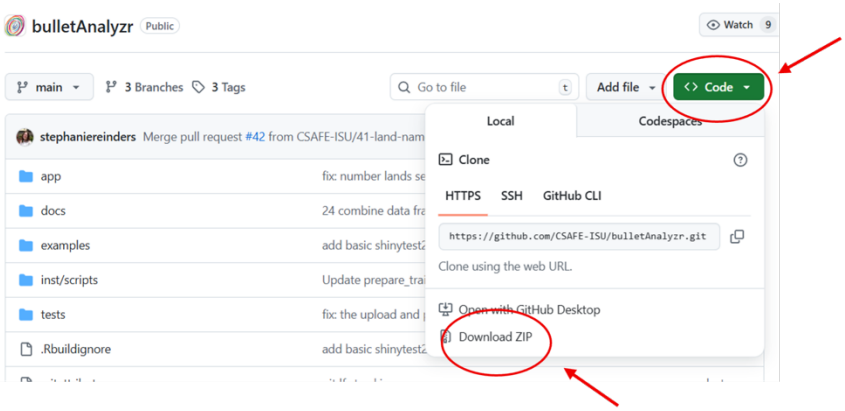


Figure 1. Click Code and then Download ZIP on the BulletAnalyzr GitHub page to download BulletAnalyzr.

Install R Packages in RStudio

Total Estimated Time: 45-50 minutes

Install packages from the Comprehensive R Archive Network (CRAN) and GitHub.

- Open RStudio.
- Navigate to the RStudio Console. (Figure 2)
- Copy and paste the following lines of code into the Console after the ">" symbol. (Figure 2)

```
# Install packages from CRAN
cran_packages <- c("bsicons", "bslib", "curl", "devtools", "dplyr", "DT", "ggplot2", "pagedown",
                   "randomForest", "rgl", "sessioninfo", "shiny","shinyBS",
                   "shinycssloaders", "shinyjs")
for (pkg in cran_packages) {
  install.packages(pkg)
}

# Install packages from GitHub
github_packages <- c("heike/bulletxtrctr", "heike/x3ptools")
for (pkg in github_packages) {
  devtools::install_github(pkg)
}
```

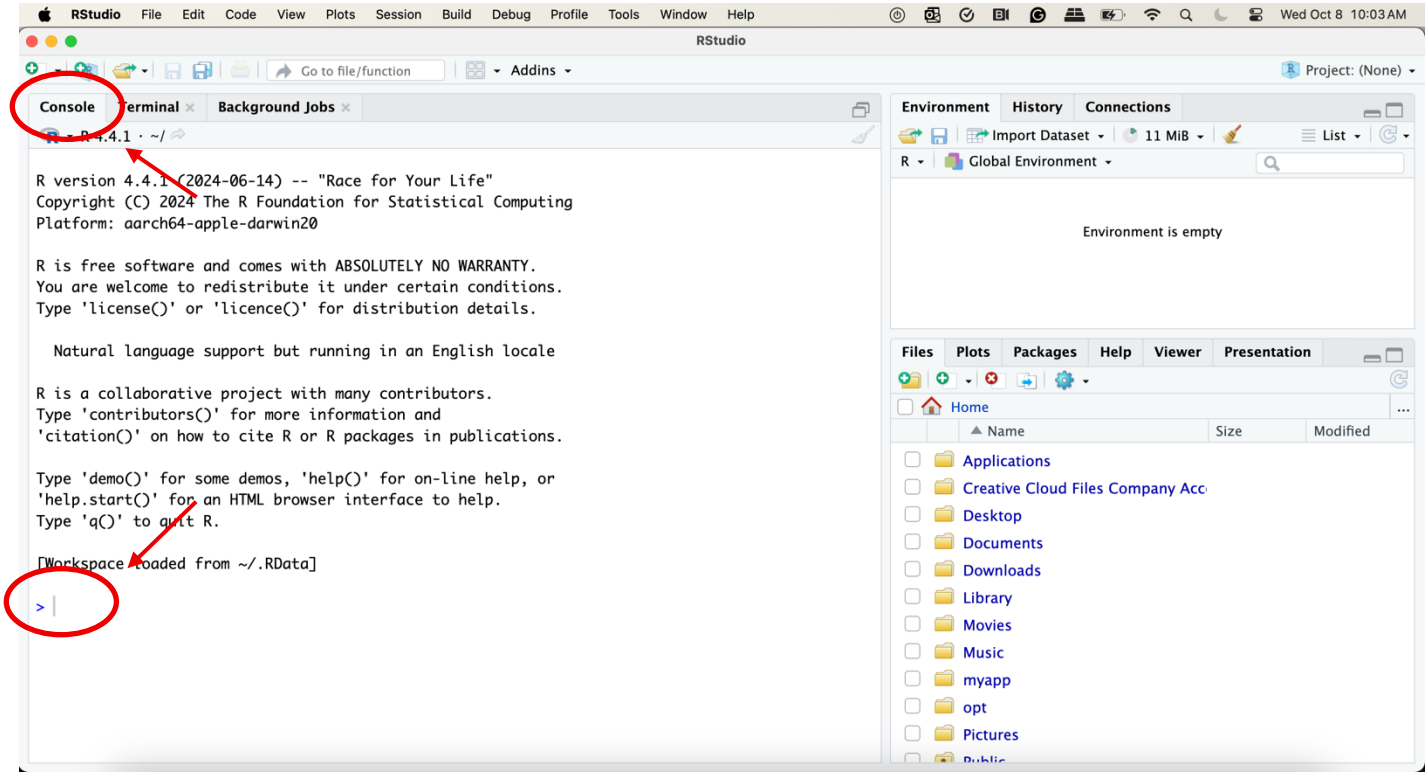


Figure 2. The Console in RStudio.

WALKTHROUGH

Total Estimated Time: 15-20 minutes

BulletAnalyzr includes 3d scans from the Hamby-Brundage bullet set #44 provided by CSAFE, so you can practice the workflow.

Launch BulletAnalyzr

- Navigate to the BulletAnalyzr folder that you downloaded and unzipped during installation.
- Double-click on the file named *rstudio.Rproj* to open BulletAnalyzr in RStudio.
- If, for some reason, the previous step did not work. You can also open BulletAnalyzr from within RStudio.
    - Open RStudio
    - Click Open Project in the top-right corner.
    - Select the bulletAnalyzer folder that you unzipped during installation.
    - Select the RStudio project File named *rstudio.Rproj*.

- Once BulletAnalyzr is open, navigate to the Files tab and double-click the app folder to open it. (Figure 3)
- Click the *server.R* file to open it in RStudio's main window. (Figure 4)
- Click Run App in the main window to launch the app. (Figure 4)
- Click Begin on the BulletAnalyzr home screen. (Figure 5)

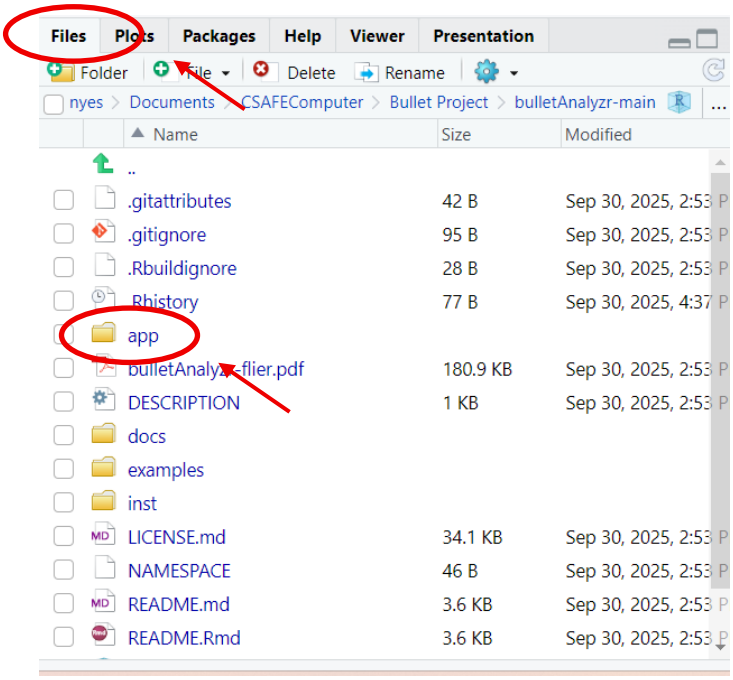


Figure 3. Find the Files tab in RStudio. Then open the app folder.

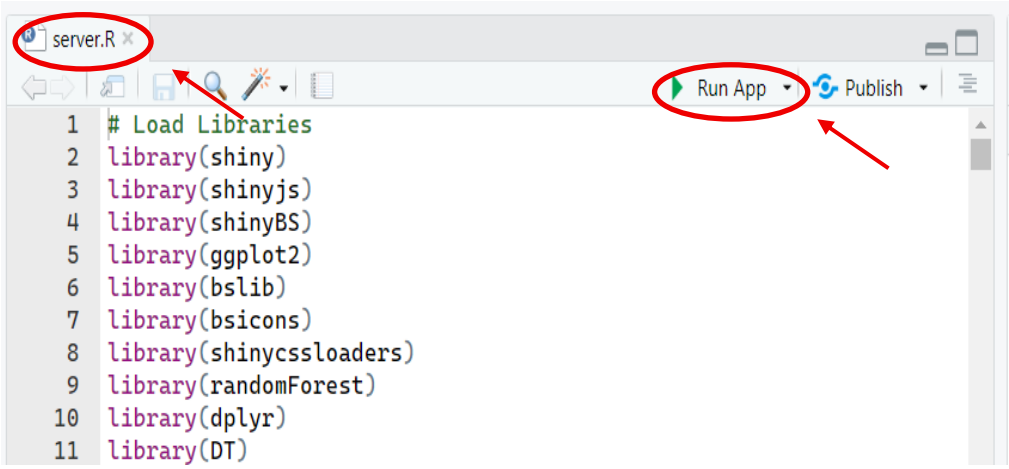


Figure 4. Click Run App in the server.R file to launch BulletAnalyzr.

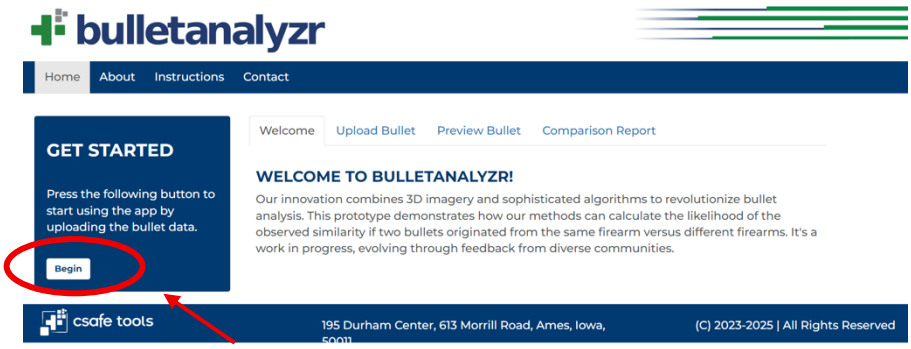


Figure 5. Click Begin on the BulletAnalyzr home page to get started.

Upload the bullets

- Upload the first bullet.
    - Click Browse and navigate to the BulletAnalyzr folder. Then go to examples > Hamby-44 > Barrel 1 > Bullet 1.
    - Select all 6 files in this folder. Each x3p file is an image of a bullet land engraved area. (Figure 6)
    - Give the bullet a name (e.g., Bullet 1). (Figure 6)
    - Add it to the Comparison List. (Figure 6)
    - A preview of each land is shown in the main window. Rotate and zoom the lands for different perspectives. (Figure 6)
- Upload the second bullet.
    - Repeat the same process for the Bullet 2 images: examples/Hamby-44/barrel 1/Bullet 2.

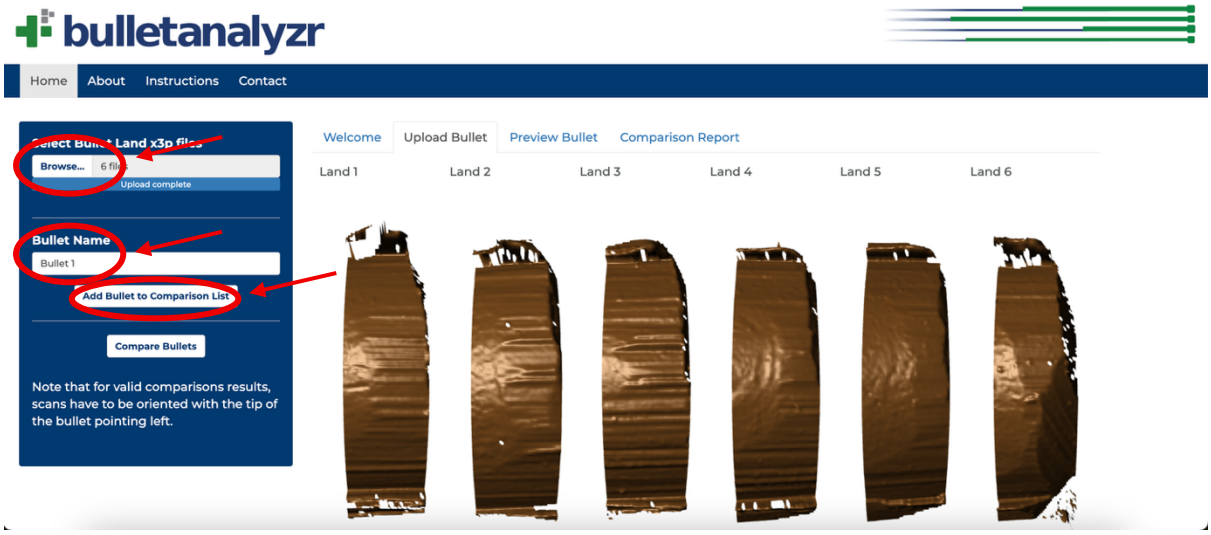


Figure 6. Click Browse to upload the scans from the first bullet. Give the bullet a name. Click Add Bullet to Comparison List.

Adjust the crosscut locations

BulletAnalyzr attempts to identify suitable crosscut locations. The crosscuts are displayed as light grey lines on the lands.

- Adjust the crosscuts for Bullet 1.
  - Select Bullet 1 from the drop-down menu if it isn't already selected.
  - Use the sliders to adjust the crosscuts if needed.
  - Click Finalize Crosscut when satisfied.
- Adjust the crosscuts for Bullet 2.
  - Select Bullet 2 from the drop-down menu.
  - Use the sliders to adjust the crosscuts if needed.
  - Click Finalize Crosscut when satisfied.
- When both bullets are ready, click Compare Bullets.

Adjust the groove placements

In order to capture the full land, the scans also contain parts of the grooves. BulletAnalyzr needs to remove the grooves before further processing. The app attempts to locate the grooves on the crosscut profile, but manual adjustment is sometimes required.

- Adjust the groove on land 1 of Bullet 1. (Figure 7)

- Select Bullet 1 and Land 1 from the drop-down menus.
- The vertical red lines on the crosscut profile plot indicate the left and right groove locations. Everything to the left of the left groove line and everything to the right of the right groove line will be discarded.
- Adjust the groove locations using the slider bars to keep as much of the land as possible.
- Click Save Grooves when satisfied.

- Repeat for all lands on both bullets.
- Once grooves are defined, click Next Step.

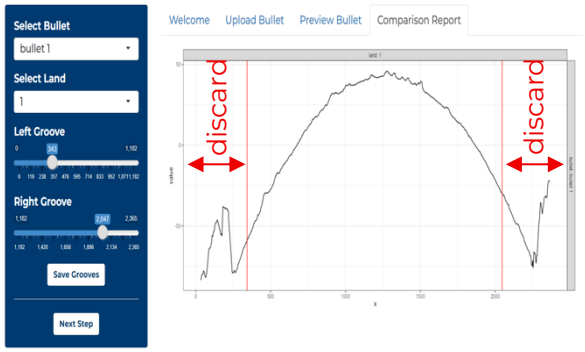


Figure 7. The profile plot of Bullet 1 Land 1. The red lines indicate the current location of the grooves. The profile between each groove and the side of the plot will be discarded.

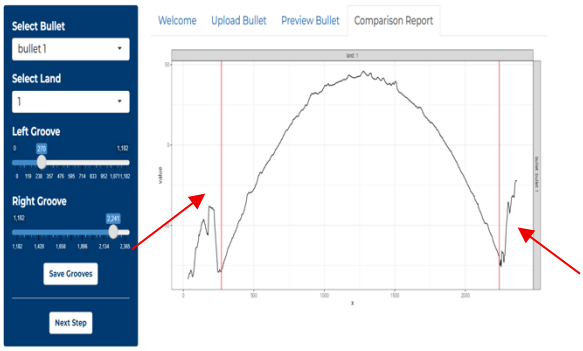


Figure 8. The profile plot of Bullet 1 Land 1 after the grooves are moved.

Comparison results report

Behind the scenes, BulletAnalyzr extracts signals from the lands. Each signal from Bullet 1 is compared to each signal from Bullet 2 by measuring features such as consecutive matching straie.

- The output page displays the comparison results.
- Click Download Report to download a copy of the report.

- The phase test score and the probability of false identification are displayed at the top of the page (Figure 9). For the example bullets, the probability of a false identification is less than 1 in 10 million.
- The bullet-to-bullet score matrix shows the similarity score between Bullet 1 and Bullet 2 (Figure 10). Scores range from 0 to 1, with 0 indicating no similarity and 1 indicating perfect similarity. Bullets 1 and 2 have a similarity score of 0.9, indicating similarity. The phase test score and the probability of false identification give more information about the interpretation of the similarity score.
- BulletAnalyzr measures the similarity between each land in Bullet 1 and each land in Bullet 2 (Figure 11). The land-to-land score matrix shows the similarity score for each pair of lands. Each possible alignment of lands between the two bullets is called a *phase*. Bullets with six lands have six phases. The average similarity score is calculated for each phase, and the highest average similarity score is the bullet similarity score. The land-to-land matrix shows dark boxes around the cells in phase corresponding to the bullet score.
- The crosscut profiles are plotted before the grooves are removed (Figure 12).
- The raw and LOESS-smoothed signals are plotted after the grooves are removed (Figure 13).
- Each section at the bottom can be expanded to show more detailed information about specific land-to-land comparisons (Figure 14). The land-to-land comparisons with the highest similarity scores are shown in order from highest to lowest. The feature values (Figure 16), crosscut profiles with grooves (Figure 15), and aligned signals are presented (Figure 16).

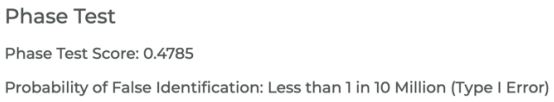


Figure 9. The phase test score and the probability of false identification.

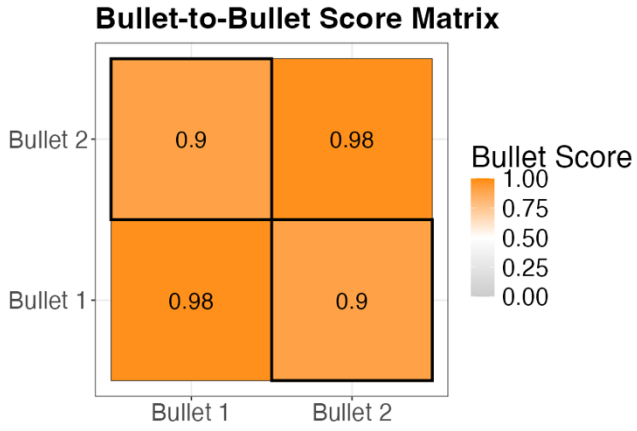


Figure 10. The bullet-to-bullet score matrix.

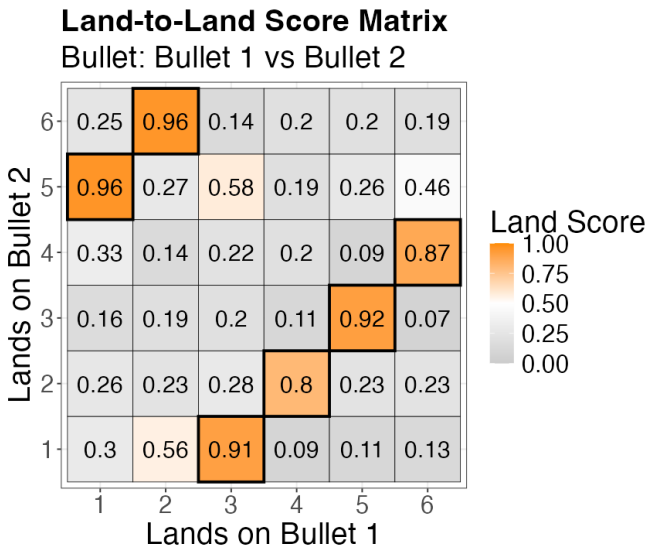


Figure 11. The land-to-land score matrix.

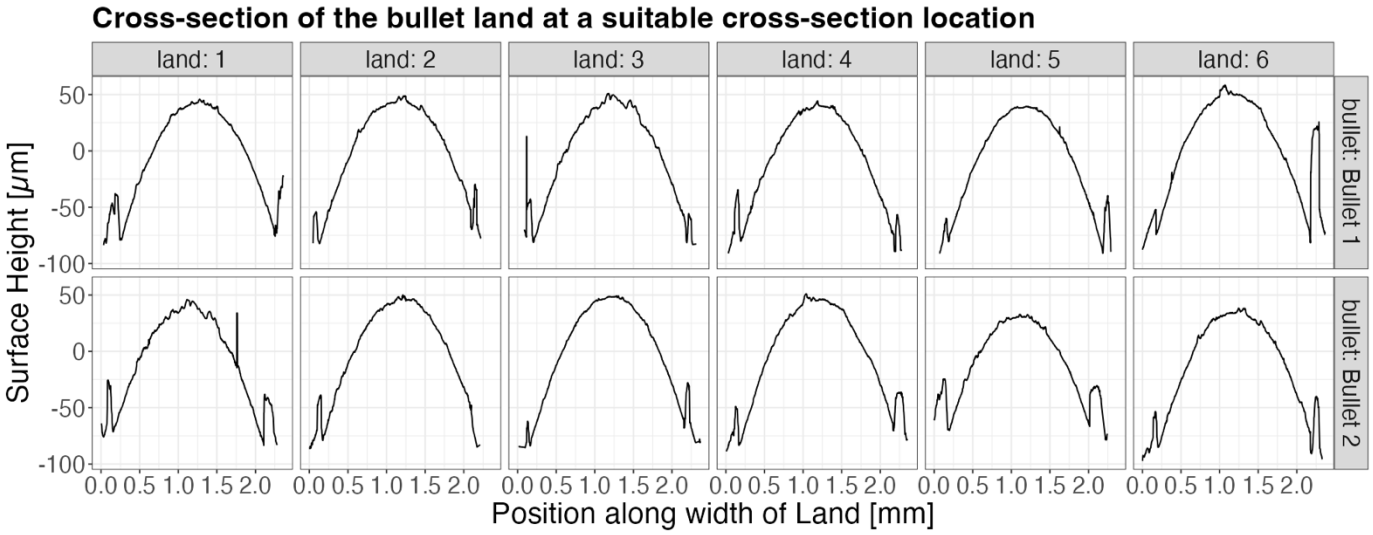


Figure 12. Crosscut profile plots from Bullet 1 and Bullet 2. The grooves have not been removed from the profiles yet.

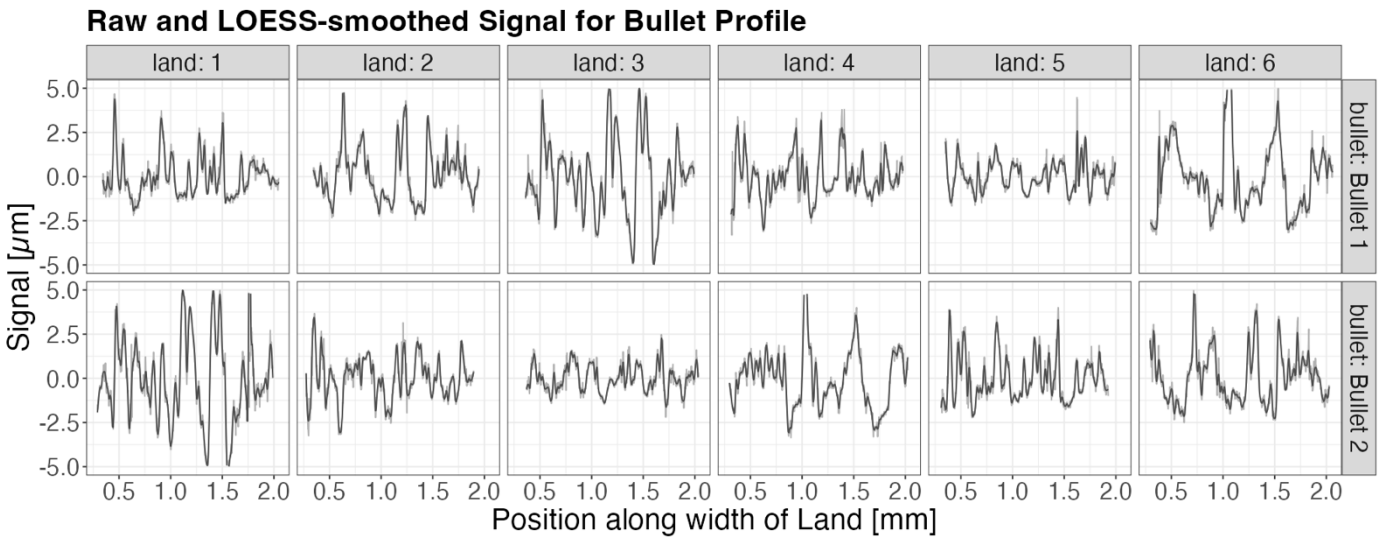


Figure 13. Signal plots for Bullet 1 and Bullet 2. The raw signal is displayed as a grey line and the LOESS-smoothed signal is displayed as a black line.

Bullet 1-1 vs Bullet 2-5 (RF Score = 0.96)

Bullet 1-2 vs Bullet 2-6 (RF Score = 0.9567)

Bullet 1-5 vs Bullet 2-3 (RF Score = 0.9167)

Bullet 1-3 vs Bullet 2-1 (RF Score = 0.9133)

Bullet 1-6 vs Bullet 2-4 (RF Score = 0.8733)

Bullet 1-4 vs Bullet 2-2 (RF Score = 0.8033)

Bullet 1-3 vs Bullet 2-5 (RF Score = 0.58)

Bullet 1-2 vs Bullet 2-1 (RF Score = 0.56)

Bullet 1-6 vs Bullet 2-5 (RF Score = 0.4567)

Figure 14. Collapsible sections containing additional details of the highest land-to-land scores.

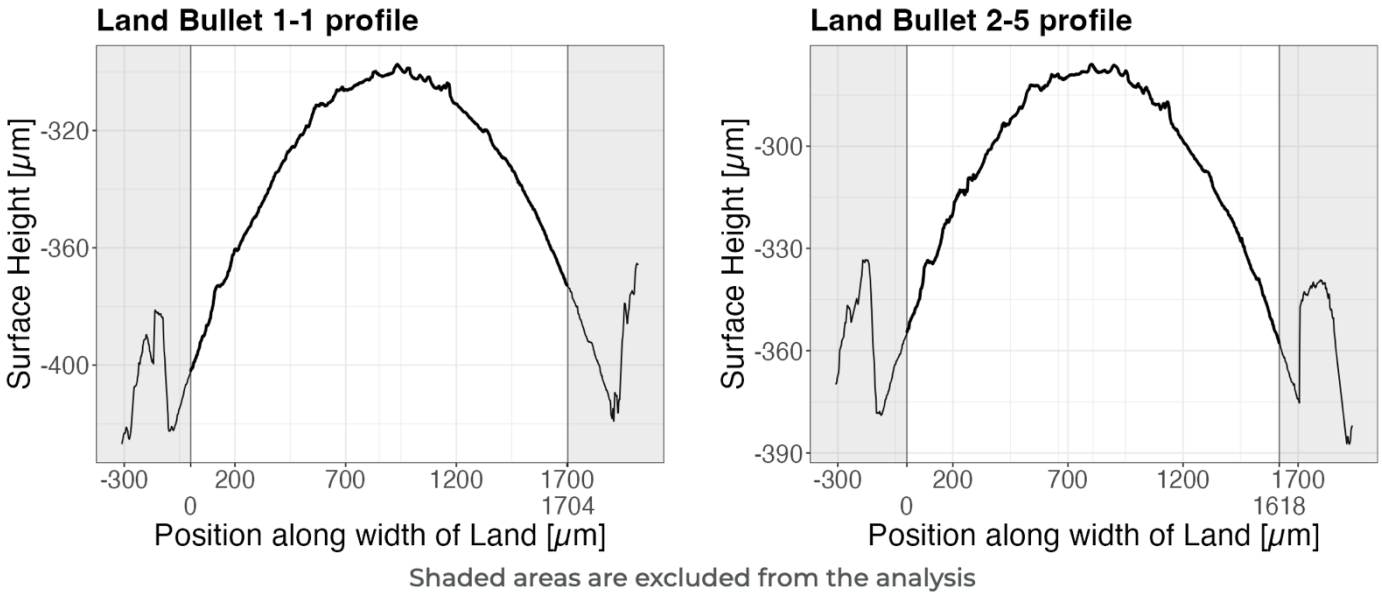
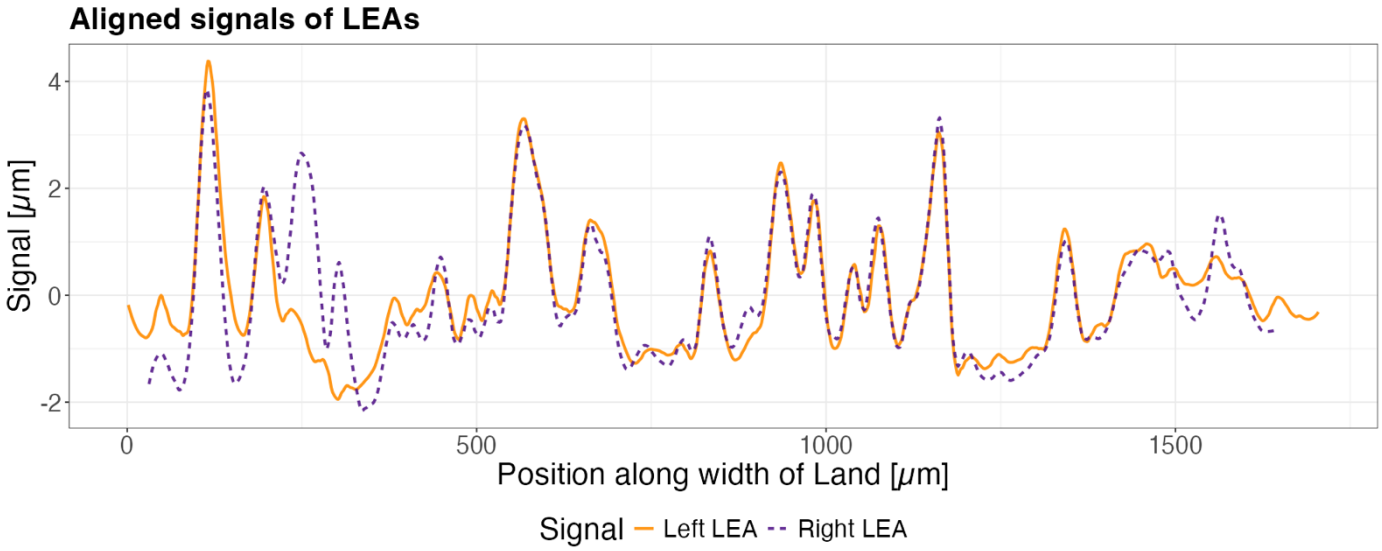


Figure 15. The crosscut profile plots of Bullet 1 Land 1 (left) and Bullet 2 Land 5 (right). The gray shaded areas indicate sections discarded before the signals are extracted.



Feature	Value
Left Land File	Barrel_1-Bullet_1-Land_1.x3p
Left Land MD5	25712f1edfbfd8647cdbbc33c36e7dca
Left Land Instrument (resolution [µm/px])	Sensofar (1.5625)
Right Land File	Barrel_1-Bullet_2-Land_5.x3p
Right Land MD5	67a6429ae1430ed3ce87276a8943dd6c
Left Land Instrument (resolution [µm/px])	Sensofar (1.5625)
Cross Correlation Function	0.846
Mean Distance btw Signals [Âµm]	0.021
Signal Length [mm]	1.619
# Matching Striae Per Millimeter	12.355
# Mis-Matching Striae Per Millimeter	0.618
CMS Per Millimeter	11.737
Non-CMS Per Millimeter	0.618
Peak Sum	24.838

Figure 16. The features table for Bullet 1 Land 1 and Bullet 2 Land 5.

LICENSE

BulletAnalyzr is released under the GPL-3 license, allowing free use, modification, and distribution of the software.

CITATION

If you use BulletAnalyzr in your work, please cite the following publications:

Eric Hare, Heike Hofmann, Alicia Carriquiry. Algorithmic approaches to match degraded land impressions, *Law, Probability and Risk*, Volume 16, Issue 4, December 2017, Pages 203–221, https://doi.org/10.1093/lpr/mgx018

Eric Hare, Heike Hofmann, and Alicia Carriquiry. Automatic Matching of Bullet Land Impressions, *The Annals of Applied Statistics*, Volume 11, Number 4, 2017, pp. 2332–56. JSTOR, http://www.jstor.org/stable/26362188.