

1. Comments to Review of Dr. Mark:

Review of *AI-Track-tive: open source software for automated recognition and counting of surface semi-tracks using computer vision (Artificial Intelligence)*

Chris Mark, 19-May-2021.

The authors present a novel approach to automated fission track counting using artificial intelligence. A number of highly intelligent design decisions are included, particularly the ability of the offline version to detect tracks on any window open on the user's screen, offering maximum flexibility with regard to input (static images, live microscope camera feeds, remote-accessed computers, etc). I congratulate the authors on tackling a critical problem in FT analysis: minimising operator bias in track detection, and thus greatly reducing inter-lab variability. This approach will also lead to considerable time savings, and by increasing throughput may offer the possibility of greatly improving counting statistics. I strongly support this approach and encourage the authors to persevere.

The manuscript itself has already received three reviews by appropriate experts, and I have only minor comments to add (see below). However, neither the online or the offline version of the software is yet ready for release (see detailed bug lists below). I urge the authors to extensively test both versions on a wide range of operating systems and browsers, as well as images acquired from a much wider range of camera-microscope combinations.

SN & JDG: We regret that, according to your experience, neither the online and offline version of the software is ready for release. Your efforts are well-appreciated and to our great surprise it seems that the online software also does not work sufficiently. We used your valuable constructive comments to debug both the on- and offline version of the program.

I also urge the authors to watch the system being tested by at least one, and preferably several, users who have not watched the tuition videos and are working from the on-screen instructions only (these need to be considerably expanded). This will acquaint the authors with the likely mistakes made by casual or unprepared users. I also urge the authors to expand the manual currently included in the supplemental materials – it is far too short. This approach has huge potential, and it would be a pity if community take up was reduced because the program is not yet intuitive.

SN & JDG: we have written a manual for the offline version on <https://aitractive.ugent.be/download> which is much more complicated than the online version. This manual should make it easier for interested users.

Software testing:

When testing the **online version**, a number of issues were encountered. Unless otherwise stated, all tests were performed using the browsers MS Edge, Opera, and Chrome on a PC running Win10 Pro 64-bit, x64 processor.

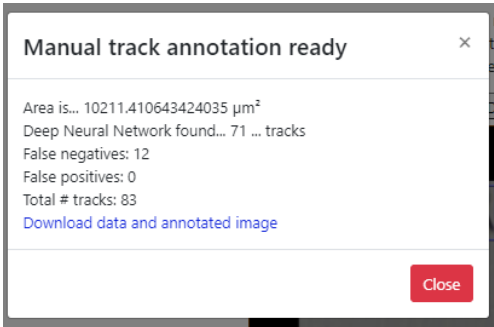
SN & JDG: Thank you very much for providing your settings of your computer's operating system.

- Image widths for the example dataset are not given on the website (that I could see). I assume these are the 117.5 micron width images described in the manuscript text. I recommend stating the widths for the example images on the web app, rather than assuming the user has read the manuscript in detail. Using the example dataset, the online version works ok.

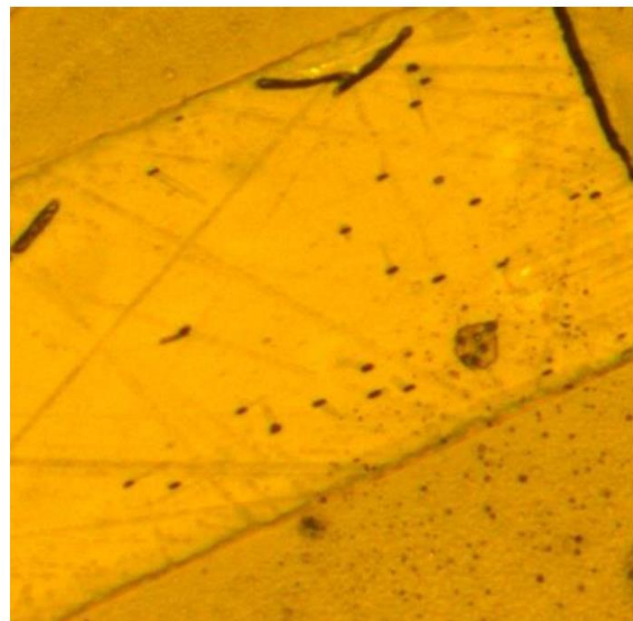
SN & JDG: Indeed, we forgot to include this statement in the zip file. We have added the width in the title of every image, to make it clear.

I strongly recommend stating explicitly on the manual review screen that the results must be downloaded to be viewed – the casual user will expect to see results displayed on the screen after “clicking here when ready” (pressing the button prepares the csv and annotated image file for download – but as the user does not see anything change, it feels as if pressing the button doesn’t do anything at all).

SN & JDG: The user now sees the results of the automatic track recognition process and the manual annotation process when clicking on “click here when ready”. From there, the data can be viewed and subsequently downloaded, as visible in the window below.

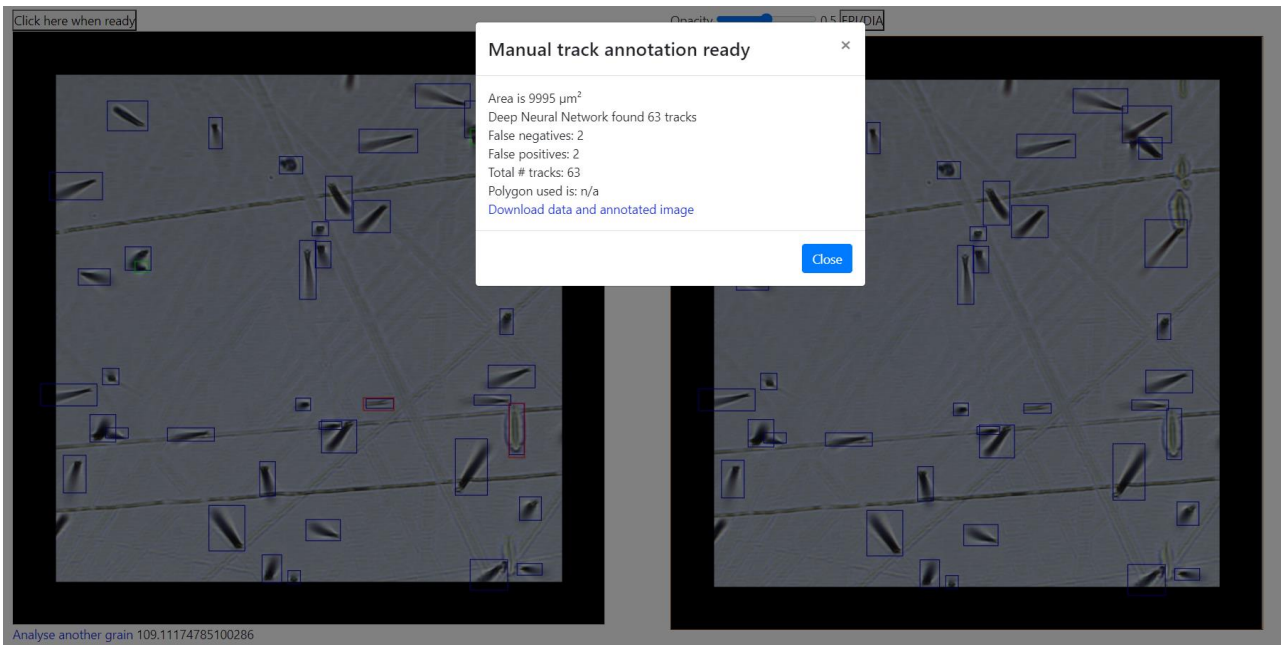


- Using my own transmitted light images (Fish Canyon Tuff apatite), collected in the FT lab at Trinity College Dublin using a Zeiss AxioImager Z1m microscope equipped with an Autoscan automated stage system running Trackworks, no or very few tracks are detected, possibly because of the different colour balancing and contrast in this image. A fixed 70x70 ROI was chosen. A typical example of the images used is shown below (width 127 microns);



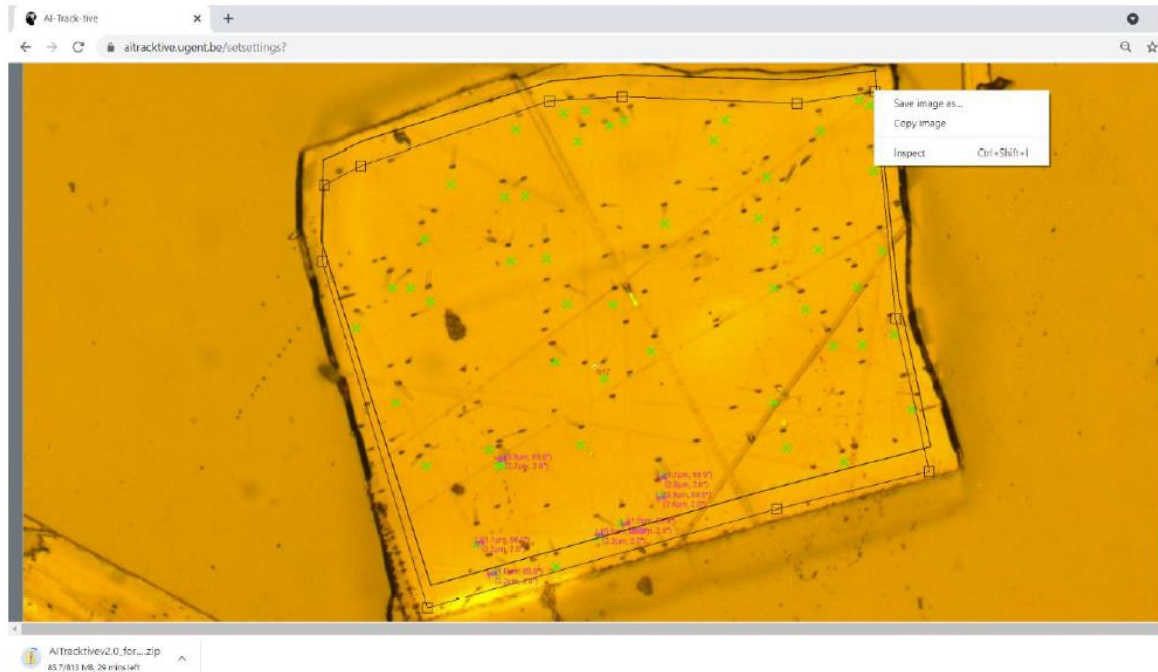
SN & JDG: The Deep Neural Network we are using is trained on a different microscope. These images are indeed very different to the ones from the training and testing dataset. Based on my rather limited experience in different FT systems it is rather a surprise that a transmitted light would look like this. There appears to be a golden surface layer that is hiding the tail next to the fission track etch pits. The etch pit is very good visible, and I assume that this is the purpose of the golden coating, which is also used in

scanning electron microscope samples. The picture below shows a typical picture of our microscope and the new window popping up after the “click here when ready” button is pressed. The image below is an image from our microscope and for that microscope it seems that the DNN works. For your images it should be attempted to make a DNN that was trained on comparable images following the description in the paper.



- The vertices of the interactive ROI generated using the browsers MS Edge, Opera, and Chrome are offset from the click locations. The image below uses an image with overlay from Trackworks to illustrate the problem in Chrome: the vertices defined by boxes are the click locations, and the offset vertices of the second polygon are the AI-track-tive vertices. In Opera and MS Edge the offset seemed worse. There is also the issue that left-clicking an image in Chrome (and other browsers) often brings up a menu, which obscures the grain.

SN & JDG: I could reproduce the “ROI offset problem” error in Chrome and fixed this little error in the JavaScript function. Now it should be solved (see update on website: “25 May 2021: minor JavaScript bug fixed”). For the right mouse click problem, I also found a solution that disables the opening of the menu.



- Pressing the “Start application” button with an interactive ROI defined gives the error message “Input error: An error occurred: no coordinates for the polygon were chosen”.

SN & JDG: Before starting the application, the polygon should be closed by double clicking on left mouse button on your last point of your polygon. I have edited the instructions a little bit to make this further clear.

After encountering the problems listed above, I abandoned testing the online app and downloaded the offline version. I did not test the functionality of the episcopic/diascopic illumination or Z-stack features in the online version.

SN & JDG: Thank you very much for testing the online app.

The **offline version** launched successfully on the same system used for the online tests, and the various fields in the data entry screen could be populated. I strongly recommend that the authors should load the weight and configuration files by asking the user to input a single folder location for AI-track-tive, rather than loading folder addresses from the lead author’s PC as a default and forcing the user to play hunt-the-file in the AI-track-tive folder based on the file extensions.

SN & JDG: We don’t follow the recommendation because only specifying a folder would not allow choosing a neural network by the user. And this is the main idea behind AI-Track-tive: that newer and more efficient neural networks would be developed and used using AI-Track-tive. However, the reviewer points out that the default locations point to my directories and that this is due to the file “savedpathlocations.pkl” that was created by testing the .exe on my computer. This is a mistake and will be corrected in the newest version that I’ll upload soon. There was also a problem with the deep neural networks that were located in another folder (“DNN”) than the INPUT folder, sorry for this.

Running the program in automated track finding mode for apatite opened a new window, which successfully found the grain image (from my own collection) open on my screen. It is not intuitive that the user needs to open their grain image separately – I suggest including more explicit instructions (the design

decision of using live detection in a separate window is really excellent because the program can be used with a live microscope camera feed without the inconvenience of exporting static images – you just need to include more explicit instructions). It is also critical that the grain image is not overlapped by any other windows, or some very strange effects occur.

SN & JDG: For the live semi-track detection I included another feature (live number of tracks calculation). I also wrote down a manual with explicit instructions for the offline app on https://users.ugent.be/~smanacht/download_aitracktivev2.php and <https://aitracktive.ugent.be/download>. This should make it more clear about which instructions to follow.

However, the custom detector window did not then detect anything. Running the program again using one of the demonstration images supplied led to successful detection of tracks, but nothing else happened – no track density output?

SN & JDG: The DNN detecting tracks in a live window is again trained on the typical images that our microscope made. As already mentioned before, it appears that the presented DNN is not successful in the pictures that you have delivered because of the strong coating on top of the samples. I think it should be possible to train another DNN for these samples following the method described in the paper. The DNN detecting tracks in a live window also is not meant to be used for track density estimations, because it is not 100% accurate. When a trained DNN that is smarter than humans is developed in the near future, it could be implemented in another version of AI-Track-tive. For the revised version of this program we programmed a customizable region of interest for live semi-track identification. It is necessary to use two monitors: one for the microscope view and another for the result of the live semi-track identification.

Running the program in manual detection mode caused it to repeatedly close unexpectedly when “continue” was pressed, after one of the demonstration images was loaded; loading one of my own images in manual counting mode repeatedly gave the error of a mismatch in image width (the pixel width I had entered was correct).

SN & JDG: We have been able to reproduce the mentioned error. The program closes automatically because I programmed it to close when a rectangular-shaped image has been provided by the user. The reason is that I only worked with square-shaped images because our camera produces square shaped images (i.e. images with the same width and height). I updated the script and made it possible to analyze rectangular-shaped pictures.

No further tests of the offline version were carried out, and I do not claim that the testing above has been comprehensive, but in my opinion enough bugs have been revealed to discourage the average user from proceeding.

SN & JDG: Yes, we agree, but these software tests are very helpful for us.

I also very strongly encourage the authors to implement interactive ROI selection in the offline version, if possible. For the EDM approach, the ROI is often the whole grain surface, for LA-ICP analysis the ROI is normally the diameter of the laser spot (to avoid having to assume U/Ca homogeneity, which is frequently not the case). So the user will typically want to define their own ROI, and typing in pixel(?) coordinates as currently offered is not very appealing. If you insist on keeping the coordinate approach, then you need to tell the user where the origin is (top LH-corner?).

SN & JDG: I believe that it was not clear that there is an interactive window that opens when one choses for “custom drawn polygon”. I have omitted the entry in which one could paste the coordinates of

the polygon (see figure below). The (erased) entry was meant to paste the coordinate list from a previous analysis.

AI-track-tive v2.1

Enter the name for your sample/grain:

Select the type of sample:

☐ apatite + external detector (EDM)
☐ only external detector (EDM)
☐ only apatite (LA-ICP-MS based FT dating)

Specify your region of interest:

☐ square of 100µm on 100µm
☐ custom-drawn polygon
☐ circular

Circle diameter in µm: (max 100µm)

Select the microscopy images:

Select 1 apatite transmitted light image (or 2 for z-stack)

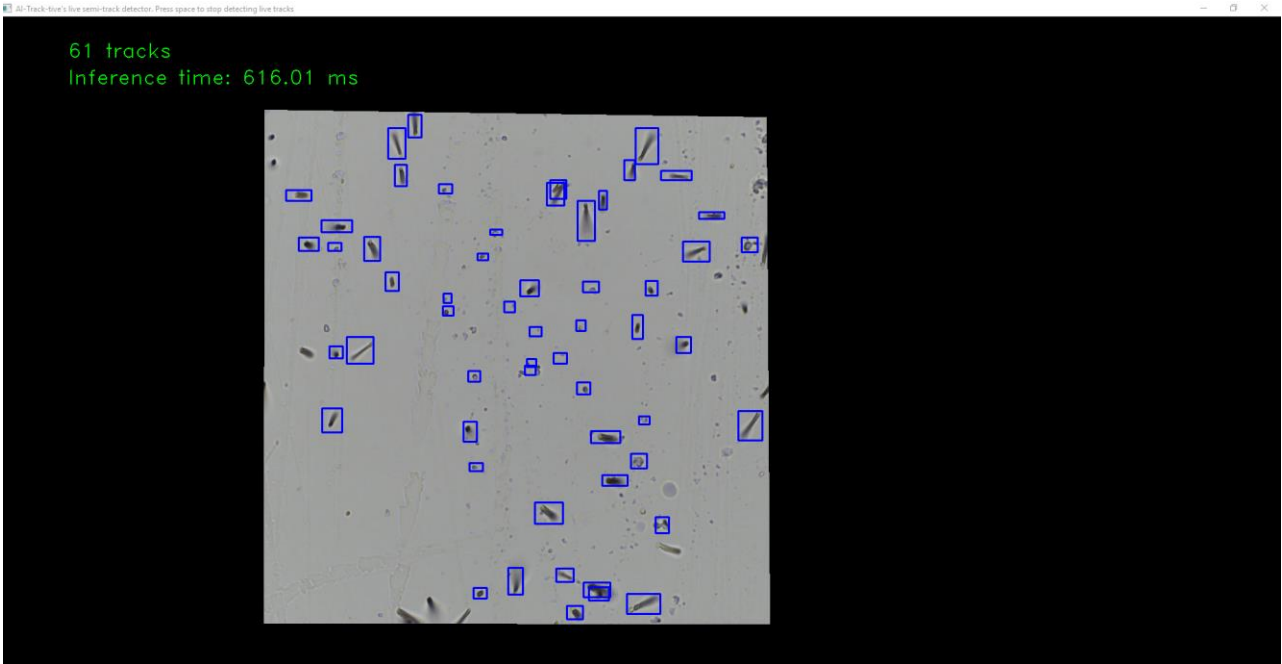
Select 1 apatite reflected light image

Select 1 mica transmitted light image (or 2 for z-stack)

Select 1 mica reflected light image

Continue

SN & JDG: Now, we have also programmed the custom-drawn polygon for live images from a microscope. This will make it possible to have AI-assisted track analysis. See figure below:



Manuscript Comments:

L.19 The thermal dependence of fission track annealing (and thus the potential for thermal history reconstruction) was recognized already by Fleischer & Price (1964, Glass dating by fission fragment tracks, J. Geophys. Res. 69,331-339) and by Fleischer et al (1965, Effects of temperature, pressure, and ionization on the formation and stability of fission tracks in minerals and glasses, J. Geophys. Res. 70, 1497-1502.).

Recognition of thermal dependence explicitly in apatite was discussed in detail by Naeser & Paul (1969, J. Geophys. Res. 74, 705-710). So, long before Wagner 1981. At least one of these refs should be cited.

SN & JDG: Thank you for this correction. I have included two more references and adjusted the first sentences of that paragraph.

L.208 Either U, or uranium.

SN & JDG: It should be uranium in the text now.

L.244 I encourage you to report recall and precision statistics for densities as low as 10^3 - 10^4 , as low-density grains are more common than the literature might suggest. Most FT studies are applied to bedrock, and so suitable (high-U) lithologies such as granitoids are preferentially targeted. However, detrital studies also encounter apatite from unsuitable, low-U lithologies (e.g., metapelites, metacarbonates, metabasites...) for which dating must be attempted nonetheless. See, for example, Ansberque et al (2021, Chemical Geology, doi.org/10.1016/j.chemgeo.2020.119977), and Huyghe et al (2020, EPSL, doi.org/10.1016/j.epsl.2020.116078).

SN & JDG: An adapted version of figure 4 has been drawn and inserted with all data points in between 10^4 and 10^7 tracks/cm². Unfortunately, we have no such samples available. Using 1000x magnification, we cannot go much lower than 7.24×10^3 tr/cm² because 1 detected fission track in a picture of 117.5 μ m on 117.5 μ m is the absolute minimum.

L. 285 You might add that AI-track-tive is also robust because it presumably does not experience changes in visual perception (and understanding) over time, unlike a human operator. This can be corrected for by regularly re-calculating one's zeta, but not many researchers I know actually do this.

SN & JDG: Thank you for another constructive comment. We have included this sentence in the conclusion section.

2. Comments to the editor

Comments to the Author:

Dear Simon,

A new review by Dr. Chris Mark indicates that, whilst significantly improved, AI-Track-tive is still not quite ready for general use by the fission track community. However despite the remaining software issues (which are covered in Dr. Mark's constructive review) I have decided to accept your paper pending minor revisions because:

1. the methodology presented in it is sufficiently novel to be of interest to the geochronology community as a proof-of-concept study, even if the software is still in a 'beta' form;
2. communicating your work with the fission track community will hopefully generate further feedback, which will help you improve your program in the future.

As minor revisions, I request that you:

1. address the detailed comments provided at the end of Dr. Mark's review;
2. add a sentence or two explaining that AI-Track-tive is still under development;
3. invite to the fission track community to test the program and provide feedback.

I strongly encourage you to take on board Dr. Mark's suggestions for the software, but I will not require another round of peer review to verify this. I look forward to receiving a suitably revised version of the paper in due course. Thank you for submitting this important work to GChron. Please let me know if you have any questions.

Pieter

SN & JDG: The detailed comments on the manuscript have been incorporated in the paper. Also, all bugs that Dr. Mark reported are now solved. We added some sentences on the website and on the first screen of the offline app that AI-Track-tive is under constant development and that we would like to receive bug reports in the near future. We will submit an abstract to the Thermo2020 conference and present the software there to the FT community, if possible. Also, we added a sentence in the conclusion to invite the community to use the software and express their thoughts.

Thank you for the flexible editorial handling

Simon Nachtergaele & Johan De Grave