Currently people struggle on repairing torn photos and documents because they need to manually piece broken parts together either by hand or using software that can only read one fragment at a time, then use image processing software like Photoshop to fill the missing pixels by hand. This is very time-consuming, tedious and requires a lot of skill, especially when dealing with photos or documents torn in tens or hundreds of parts. However, there is a groundbreaking way to solve this long existing problem by using this project. Written in C# and Emgu CV using Windows Form Application and Universal Windows App, TornRepair is an innovative and very efficient approach for repairing torn objects. It automatically pieces fragmented 2D objects like torn photos, torn newspaper or torn book pages together.By using this software, people can save at least 80% of the time on repairing torn photos and documents compare to the time spend by using the most efficient technology widely available, so they can have more time doing things that are more important. In addition, there are few software that use even more advanced technology have similar functionalities, and nearly all of them does not have a better performance than TornRepair.

Although it seems that this software might have a very high cost, there are two major versions that target different kinds of users with reasonable prices. Standard version serves for individuals, and it is free for all. It has all the functions pertain in the overview section and will be host on major app stores. Professional version serves for archeologists and provides specific tools that are only needed in that field. Organizations using the professional version need to pay $10,000 per year. Therefore, people can choose the edition they need and only pay the fee required for that function. If they only want to do simple torn pieces repair, they can use this software for free, so this software is even accessible for average people in the least developed countries.

**Overview:**

This program has two features, which are restoring torn or shredded photos and restoring torn or shredded documents. The photo restoration allows user to input source image files with single or multiple fragments of a complete image, and it generates that complete image. The program can fix the torn area of the image automatically, so the resulting image is just like it were not torn before. The document restoration is an OCR for fragmented document. It accepts images of fragmented documents, even if there are multiple fragments in one image file. It then generates the complete document to an editable document file like MS Word using OCR. This tool can also accept fragments from multiple pages, so it can be used to restore a complete book as well.

For torn photo repair, the users can input the torn photo fragments by an input manager implemented in a friendly user interface (UI). The input manager can take different sources of input from cameras, image files and scanners and check if the input is valid for further processing or not. If the input is not valid, the manager will notice the user and wait for a valid input. After the program gets the torn photo fragments, it will extract the edge features of the fragments using the functions provided by Emgu CV. The edge feature of a fragment contains the position, the turning angle, and the color of that edge. The core algorithm of the program then receives the edge features and begins to find out the best matches using two matching parameters: turning angle and color. After some candidate best matches were found, the program will send the output image to an image editor implemented in the program. Users can then use the image editor to choose the most correct one they think and do some manual modification using the tools provided by the editor. After they have their satisfied result, they can export the result image using the output manager of the program. The output manager supports different file formats; in addition, it allows users to output the complete photo directly to online service providers like Facebook and Instagram. If the fragments are from different photos, the output manager also supports automatic album generating. The user can then get an album in PDF.

For torn document repair, the users can input the document using the same input manager as I described in torn photo repair. After the program gets the torn document fragments, it will extract the same edge features as well just like the counterparts in torn photo repair. However, unlike torn photo repair, the core algorithm of torn document repair also takes the characters near the edges as one matching parameter. When the edge feature is extracted, the torn documents are also scanned by an OCR provided by Emgu CV, and the characters of the torn document are interpreted as characters for computer data. After the OCR process is done, the core algorithm will find some best matches and export the outputs to a text editor provided by the program. The users can then choose the most correct one and edit the output text. After they have done the modifications, the output manager will receive the output text. The users can then choose the output file format and output destination like the counterparts for torn photo repair.

Although users need to manually check if the output is correct or not when they begin to use this program, they do not need to do this again after several runs of the program. This program also has a strong machine learning algorithm implemented, so it can take feedback from modifications of outputs and get better matches in future runs. After several runs, the program will know about what kinds of document the user mostly working with, and it will eventually provide a perfect output without user’s intervention if the input follows users’ most frequently kinds of input. In professional version, there are some preset parameters for different professions, so they can get the correct output for a great chance on their first input.

**Economic Potential:**

Recently, people are more interested in discoveries of ancient culture, and they are more aware of the value of preserving human heritages. More people go to museums and more people consider demonstrating their knowledge of ancient culture as a proud thing in their social network. As the result, museums that charge visitors gain more revenue, and free museums gain more fund from governments. However, the archeologists in those museums are struggled to speed up the process of discovery because they have to put the fragments excavated together manually or by using some low-performance software, which is cumbersome and very error prone. If there is no such technology that can do those matching jobs automatically with a high efficiency and accuracy, more funds for more skilled workers would be frivolous.

TornRepair is such a solution that fulfills the technological need very well. In addition to the functionalities described in overview, there are more functionalities that are specialized to the specific working conditions for archeologists and researchers for ancient culture. TornRepair professional version supports different background color of the fragments and extracts the features of the fragments in an accurate way even if the fragments are fuzzy. In addition, for document repair, not only it supports Roman letters, but also it is compatible with different alphabet systems. If archeologists encounter some new alphabet systems people have never seen before, they can manually input the new alphabet system into the software, and the program will work fine as well.

There are some other solutions exist in archeology and other fields, but they only works in one specific purpose. Some solutions provide tools for image processing, and they provides a great deal of convenience to the archeologists for piecing the fragments using computers. However, they does not provide tools for automatically matching. Some solutions provide tools for automatically matching, and they can match the fragments in a very efficient and accurate way even if there are hundreds of fragments. However, they cannot do image processing and automatically OCR the manuscripts from the fragments. There are also some software packages that can perform all the functions pertained in my project, but most of them are private and special purpose software for some museums. TornRepair is a software that combines image processing, automatically matching and multi-alphabet-system OCR, and it is a general purpose software. By using this software, people don’t need to use different software for different purposes, so they can do all the things required in just 1 button click and don’t need to worry about manually transferring documents for different software.

In order to run the business, we will develop the standard version in 2 months. After we post the standard version on major app stores, we will start developing the professional version while modifying our design according to the feedback from app stores. About 2 years from now, we will invite some museums for the alpha test of our software, and if everything goes will we will start a 6-month free beta test for the professional version. We predicts that the professional version of TornRepair will be on the market about 3.5 years from now, and we will cover our cost of development about 5 years from now. After we gain $10 million profit, we will begin our research and development on versions for other professions like providing evidence for lawsuits.

Not only we have a nice prospect of our project, but we are well aware about the risks of this project. One risk is the uncertainty of research and development, and this will ruin our proposed business plan if not handled correctly. We choose to approach our R&D from the easiest case to hardest case, and we think the easiest two cases are standard version and professional version for archeology. The other risk is the actual efficiency increase in archeology because if the archeologists do not find this software is helpful they will stop the subscription. We handle this by careful tests and make sure this software can run efficiently and accurately with minimal human intervention.

**Social Impact:**

TornRepair provides a tool that can fix torn or shredded photo or documents automatically in a very short time, and it can be used in both daily life and professional work. In both versions this software will be beneficial to their own work, and eventually it will benefit the overall quality of living and make a great progress for mankind if this software is used widely in an appropriate way. Since the standard version is free for all people, this software should be accessible to average people in least developed countries. In addition, we sell the professional version of the software in a lower price to the organizations in poor countries. Therefore, this software can mitigate the digital divide in our world. However, it could be used in an illegal way, and the outcome will be disastrous. In order to prevent that, we implement a content check mechanism to make sure this software can only be used legally. .

People may sometimes tear some photos or documents accidentally, or they might want to repair an old torn family photo. This software can recover the original items automatically so that they don’t need to spend too much time and money recover the items manually. As for benefits in professional fields, this project will be very helpful in disciplines depended on historical artifacts because this project will achieve a much higher efficiency in digitizing ancient documents. The archeologists will spend less time on repairing and digitizing a single manuscript, and there will be more ancient artifacts available to general public. If this software is used widely in archeology field, there will be more new discoveries that are available for museums, and people will be more likely to come to museums. As the result, museums will have more incentive to do excavations from different sites, and more human culture will be understood and more human heritage will be preserved. This is also beneficial for forensics because it makes the judges much easier to recover torn material evidences, so that more lawsuits will be judged in a fair way. It is well known that some criminals does not get appropriate punishments from law because they destroy their evidence before arrested. If this software is widely used in court houses, it will be much harder for criminals to destroy their evidence, and people will be less likely to disobey the law.

Not only we are proud that TornRepair can improve productivity, quality of life and accessibility of technologies in least developed countries, but we also realize the potential negative effects related to unethical and illegal uses of our software. One possible bad use is spreading illegal photos. Many online services filter the photos that are inappropriate to children or advocate terrorisms, but they cannot filter the fragments of those photos. Therefore, people who want to bypass this mechanism may tear their photos into tens or hundreds of fragments first, and upload the fragmented photos to online service providers. The receivers download the fragments and use TornRepair to get the original photo back. As the result, the filter used by online service providers is useless against this kind of illegal behavior. In order to address this problem, TornRepair would scan the content of the photos or documents while matching the pieces, and if it finds the content is inappropriate, the output manager will be disabled so that the users cannot see the original image.