Project Summary

Project Overview

The purpose of this Small Business Innovation Research Phase I project is to create an image processing software application for crime scene investigation. The intended user, a forensic scientist, would use the application to upload images of crime scene evidence (e.g. blood stains, debris) and automate the forensic process of bloodstain pattern analysis. Key modules of the project are defined as keywords in the following list:

- A ***mobile application*** for iOS and Android, where the user may upload images from a smartphone camera.
- An ***algorithm*** that outputs an analysis of the image from the input requests of the user, or automatically, when no input is provided.

Intellectual Merit

This Small Business Innovation Research Phase I project will gain most of its intellectual value from the image processing algorithm to be devised. Technical challenges will be faced at each defined project module. Developing an effective algorithm must overcome technical hurdles, because the algorithm must recognize the physical components (e.g. walls, surfaces) of a crime scene in addition to analyzing it. The primary goal of R&D, which is crucial to the innovation of the project, is the effectiveness, usefulness, and accuracy of the algorithm. The high-level plan for R&D is to research effective methods for computer image processing, and to research established forensic image analysis processes that can be automated. Development of the mobile application and infrastructure will require technical knowledge in iOS and Android development, and cross-platform development. As the topics of mobile interfaces and data analytics have received massive attention from businesses and researchers in the past few years, they have become the new standard in application development. Overcoming the aforementioned technical and algorithmic challenges in mobile development and forensic science processes, respectively, will yield a user-friendly application that is effective, lightweight, and useful in analyzing crime scene data.

Broader Impact

This project will yield a useful, automated solution for forensic scientists and other crime scene investigators. Therefore, the proposed application will have potential for commercialization. The proposed application will be used as a tool to compare against forensic results, or it can be used as an unbiased, unambiguous third party in a case analysis. An algorithmic image processing solution will allow crime scene investigators to pursue a deeper analysis of their cases, and it will consequently increase the probability that a case analysis of a crime scene verifies the unequivocal truth. Because it will automate existing forensic processes, the proposed application will allow forensic scientists to spend their time more efficiently by researching and analyzing other data. Furthermore, this project will encourage industry innovators to automate data analysis processes. This approach to data analytics will be helpful in the future because organizations currently have more data than they are able to effectively analyze. To that end, the innovation and commercialization of this project will provide a net benefit to society.

Elevator Pitch

The expected customer of the application is a crime scene investigation professional (e.g. forensic science experts, detectives) who captures or analyzes photos of crime scene evidence. The primary customer need that will be addressed by the application is a demand for automation of existing analysis processes. In the current era, organizations obtain more data than they are able to effectively analyze. The proposed application will automate forensic science processes on a given photo. Therefore, a crime scene investigation organization that uses the application will have a better opportunity to allocate its resources to another project or analysis task. Automation of the forensic analysis process will also provide an unbiased, third-party solution to a criminal case, and thereby increase the probability that the results of a case reflect the truth.

The value of the proposed application will be generated from the innovation of its algorithmic component. Increasing the effectiveness, accuracy, or usefulness of the algorithm will directly increase the benefit of the application to the customer. The application will be as valuable as its ability to apply existing forensic processes. Another key differentiation of the application will be its ability to interface with the user. The application will allow the user to make his or her own decisions in analyzing an image, because the intended user is a professional in the field of crime scene investigation. The user will be able to focus on specific parts of an image, and apply automated processes of his or her choosing.

This application will advance the field of crime scene investigation by applying existing processes to an efficient and lightweight mobile software application. Applying concepts from mobile development, data analysis, and algorithmic problem-solving to the field will allow for deeper analysis of crime scene evidence. Furthermore, this project will encourage industry innovators to explore new approaches to the utility of mobile interfaces, and the automation of data analysis processes. This project will also apply emerging image processing concepts to a field that can benefit greatly from them. In its direct application of new concepts, and in its indirect encouragement of new approaches to solving problems, this project will benefit innovators in the field of crime scene investigation, as well as innovators that seek to apply the same concepts.

Commercial Opportunity

This innovation addresses the market of crime scene investigation solutions, and it will enter the market through a low-cost software application. The major driver in this market is technological innovation. Advancements in technology have greatly influenced the market through innovations such as digital fingerprinting, security video surveillance, and DNA analysis. This project will contribute to the existing technology solutions in the market through its application of both mobile computing and image processing. Due to the compatibility of the software with ubiquitous mobile operating systems (e.g. iOS, Android), the business model for the innovation will be a low-price, high market share model. The targeted customers are law enforcement agencies, particularly those at the state, county, and municipal level. Most federal agencies have sufficient funding for high-cost, advanced solutions for crime scene investigation. Therefore, this proposed innovation will fill the niche of widespread, low-cost mobile solutions for lower-budget agencies.

Because of the low cost of entry into a market for software solutions, the primary competition to this innovation will be other attempts by research groups and firms to apply mobile computing and image processing algorithms to the field of crime scene investigation. After the product has been released as a pioneer to the market, firms will most likely attempt to gain market share by either purchasing the rights to the innovation, or by producing a similar product at a lower cost. The competition can change over time as new innovations develop in the fields of mobile technology and image processing, which can cause the current version and algorithmic component of this innovation to become outdated.

The key risk in bringing this innovation to market is the risk of whether it will adequately fill its market niche to low-budget law enforcement agencies. While this innovation provides a new technological approach, it mainly serves as a low-cost alternative to existing procedures and processes used at the most advanced level of crime scene investigation. Currently, some crime scene investigation organizations already have effective, high-end solutions, albeit at a high cost. The major challenge of bringing this innovation to market is to provide useful solutions to customers that are targeted for their limited budget.

In order to respond to the risks and challenges of the market, the commercialization approach of this innovation will be to build relationships with law enforcement agencies that have a high demand for the innovation. Agencies with a low budget, and agencies with a low return on investment (crime rate vs. department spending per capita) would benefit from the operational efficiency offered by this proposed innovation. For example, New York City, Orlando, Fort Lauderdale, and Washington, DC, rank poorly among police departments for return on investment (Bernardo, 2015). At a price of $1,000 per year, and the 100 lowest-ROI metropolitan police departments are successfully targeted, this innovation could yield a yearly revenue of $100,000.

Societal Impact

The broader societal impact of this innovation is to better determine the truth of criminal investigations, in order to identify suspects, improve clearance rates for homicides, and hold criminals accountable with greater accuracy. This innovation will help law enforcement organizations to act more efficiently, because it is a simple, user-friendly approach to crime scene investigation. Agencies will benefit operationally from this solution, and its widespread use will encourage faster communication and investigation processes. Ultimately, this project aims to benefit society by protecting the public from criminal activity, and the proposed commercialization approach targets law enforcement agencies to have this responsibility.

Regulations should be strongly considered for the widespread use of this innovation. Because law enforcement agencies are accountable to the public, the transparency of this innovation is a key issue. Legislators should decide how much of the documented use, software infrastructure, and algorithmic component should be open to the public. The algorithm is particularly impactful because it may be used to determine the outcome of a criminal case. If the algorithm is hidden from the public, there may be some opportunity for legal corruption. Cases could be falsely determined, while their outcome is publicly attributed to a non-transparent algorithm. However, a full public release of the algorithm could also have problems, because criminals could abuse workarounds in the software, and leave crime scenes unable to be correctly analyzed by the algorithm. In addition to the regulatory considerations of the innovation, cybersecurity standards are also an important issue. If a hacker gains access to the intellectual components of the innovation, they would be able to abuse vulnerabilities in the algorithm. To address this risk, it is important to set a high standard for the security of the system. Because of the massive ethical value of the algorithm in its societal context, legislators should come to an agreement to determine the best use of this innovation.

This innovation can be applied to global issues due to its compatibility with mobile platforms, and its low cost. Law enforcement agencies could benefit from the effectiveness of this innovation, which would help to stabilize governments across the world that would otherwise be too weak to earn credibility. This innovation is relevant to global issues because of its implications to criminal justice, ethics, and society as a whole.

Technical Discussion

There are a variety of technical challenges and risks involved with bringing this innovation to market. Technical challenges include the research and implementation of existing computer vision packages and application frameworks, the development of a generalized system infrastructure, the development of an effective, useful, and accurate algorithm, the integration of the infrastructure with mobile interfaces, and the integration of the application with online web services. This proposed Phase I project will focus primarily on algorithmic development. The other challenges each come with the risk of becoming outdated. After the initial delivery of the product to market, user interfaces and web service providers will be subject to change. However, the integrity of the algorithmic concepts developed during the proposed Phase I project will provide long-term commercial value.

The following technical modules constitute the major aspects of the proposed application.

1. Core image processing and analysis algorithms

At its core, the value of this innovation comes from the intellectual value of its algorithmic components. Many these components may have a variety of purposes for the intended user, and they are designed to be used as automated solution tools. The core image processing tools will be included in the application as a comprehensive toolbar, such that the user may apply them at will. Examples of core image processing tools may include, but are not limited to, bloodstain color analysis - a process to gather information about a bloodstain by its color - and bloodstain wound analysis - by its physical shape and distribution.

The core image processing algorithms will be devised after a thorough research process. Developing the core algorithms will involve two sets of tools: 1) a generalized set of image analysis tools to be applied, and 2) a user-specific set of tools to be utilized by the end user in the final application. For example, a generalized tool might allow a user to freely choose RGB values on which to set a threshold. An application of this for a user-specific tool might include a pre-existing thresholding algorithm that automatically chooses threshold RGB values, based on the average brightness of the image. Researchers will use existing knowledge about computer vision and image processing algorithms, such as color thresholding, edge detection, and image segmentation, in order to develop the generalized set of tools to transform and process images. The intellectual material for user-specific tools will be determined from existing knowledge about forensic science analysis processes. This material will be gathered through existing literature, and through interviews from intended users. User feedback interviews and surveys will ensure that the core analysis tools will accurate and useful, and they will ensure that the application maintains commercial feasibility.

2. Executive control concept and algorithms

In addition to the core image processing tools that will be developed for open-ended analysis, this innovation will implement an *executive control* interface concept. Executive control is defined as an intelligent interface that will make suggestions to the user based on given inputs. In this innovation, executive control will be implemented as a mobile camera interface that will identify bloodstains in the camera view, and suggest to the user to zoom, pan, and capture images at different angles, based on the

bloodstains that appear in the view. The executive control interface will involve its own algorithmic development because it will be designed to present suggestions on the mobile camera interface before an image is captured. This implementation is distinct from the core image processing tools, which will be designed to be used on captured images. While the executive control algorithms will be implemented separately, they will be researched with a similar approach to the core image processing algorithms. Research and development of the executive control algorithms will involve similar existing knowledge of computer vision.

The executive control interface is a particularly innovative aspect of this application because it will apply the concept of an intelligent interface. Mobile interfacing is an area of growing research, and this approach to executive control in a computer vision application will encourage other innovations that utilize mobile cameras to implement new interfacing methods.

3. Mobile Camera interface implementation

In order to successfully implement the executive control algorithms, the development of an effective mobile camera interface will be a key technical objective. Ideally, the mobile camera interface should be developed and maintained for several platforms. The hardware of most mobile cameras allows for this, because most mobile camera hardware includes a *complementary metal–oxide–semiconductor* (CMOS) sensor (Yetisen et. al, 2014). However, because of the higher priorities of this Phase I project, such as the algorithms themselves, mobile development for this application will focus primarily on developing platforms for iOS and Android.

4. Web services and interface

In order to be both effective and commercially viable at a large scale, the infrastructure of this application will require a database and web interface for user accounts. Because this innovation is designed as a mobile application, the final product should be compatible with the platforms for which it is developed. Researchers will determine the appropriate resources that should be allocated for the web server, and they will determine the transition steps that should be taken as the application is delivered to the market. Researchers will communicate with cloud service providers to determine secure, effective, and affordable solutions for web services.

There are a number of key objectives to be accomplished during Phase I research. Developers must research background information on computer vision libraries and packages, and determine the appropriate steps to take for the development of a robust system infrastructure. Developers should also research background information on mobile development; specifically, they should explore existing knowledge on similar image processing applications and mobile camera interfaces. Another key objective in the development of this application is ensuring the accuracy of the algorithm. Over a set of sample images, an algorithm to identify bloodstains should have at least 70% accuracy on average. In order to determine the usefulness of the algorithm, the research team will gather input from sample end-users through focus groups, surveys, and interviews.

The following key questions should be answered to determine the technical and commercial feasibility of the proposed application:

- Which libraries and packages will be implemented in the infrastructure? What are their advantages and disadvantages?
- What constitutes an ideal system infrastructure for this project?
- What elements of the infrastructure are designed to be extended by future additions to the application?
- How should the mobile application be standardized across multiple platforms?
- Which mobile platforms should be prioritized for future changes to mobile operating systems, and to the application itself?
- What constitutes a useful algorithm for the end-user? Is the algorithm of the final product at least 70% accurate according to those standards?
- Would a crime scene investigator use this application?
- Would a crime scene investigation organization purchase this application?

Research and Development Timeline

The following timeline is an overview for the estimated steps to be taken in a 24-week development process. Demonstrations are designed to represent important milestones in developing subsets of the proposed project. This Phase I project will follow an agile software development methodology, because it will continuously develop more complex subsets of the product to be delivered to the market. The research team will run tests on its finalized deliverables throughout the process.

Weeks 1-2
Objective: The developers examine their areas of expertise, and they determine their respective roles in the Phase I project. The developers begin preliminary setup and research and on current computer vision literature, image processing applications, and mobile application design.

Weeks 3-4
Objective: The research team begins development of the application infrastructure, and develops a basic web application to upload images to the server. Mobile application is not required.
Demonstration: By the end of Week 4, the research team should demonstrate the current progress of the infrastructure capabilities.

Weeks 5-8
Objective: The research team develops the infrastructure for the mobile application.
Demonstration: By the end of Week 8, the research team should demonstrate the current progress of the infrastructure capabilities. These capabilities should include a working mobile camera interface that uploads captured images to the database.

Weeks 9-12
Objective: The research team develops a generalized image processing application. The research team hosts interviews and surveys with crime scene investigation experts for input on the end-user experience of the application.
Demonstration: By the end of Week 12, the research team should demonstrate a working image processing application, to be rated satisfactory by a team of crime scene investigation experts.

Weeks 12-16
Objective: The research team should develop and implement the user-specific and executive control algorithms to the application.
Demonstration: By the end of Week 16, the research team should demonstrate a working image processing application, to be rated excellent by a team of crime scene investigation experts.

Weeks 16-24
Objective: The research team runs regression tests and user tests on the application. By the end of week 24, the application should be released to the market on a limited scale.

References Cited

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