

# Photo Sleuth: Combining Collective Intelligence and Computer Vision to Identify Historical Portraits

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## 1. INTRODUCTION

Identifying people in photographs is a critical task in a wide variety of domains, from national security [7] to journalism [14] to human rights investigations [1]. The task is also fundamentally complex and challenging. With the world population at 7.6 billion and growing, the candidate pool is large. Studies of human face recognition ability show that the average person incorrectly identifies two people as similar 20–30% of the time, and trained police detectives do not perform significantly better [11]. Computer vision-based face recognition tools have gained considerable ground and are now widely available commercially, but comparisons to human performance show mixed results at best [2,10,16].

Automated face recognition techniques, while powerful, also have constraints that may be impractical for many real-world contexts. For example, face recognition systems tend to suffer when the target image or reference images have poor quality or resolution, as blemishes or discolorations may be incorrectly recognized as false positives for facial landmarks. Additionally, most face recognition systems ignore some salient facial features, like scars or other skin characteristics, as well as distinctive non-facial features, like ear shape or hair or facial hair styles.

This project investigates how we can overcome these limitations to support person identification tasks. By adjusting confidence thresholds, users of face recognition can generally expect high recall (few false negatives) at the cost of low precision (many false positives). Therefore, we focus our work on the “last mile” of person identification, i.e., helping a user find the correct match among a large set of similar-looking candidates suggested by face recognition. Our approach leverages the powerful capabilities of the human vision system and collaborative sensemaking via crowdsourcing to augment the complementary strengths of automatic face recognition. The result is a novel technology pipeline combining collective intelligence and computer vision.

We scope this project to focus on identifying soldiers in photos from the American Civil War era (1861–1865). An estimated 4,000,000 soldiers fought in the war, and most were photographed at least once, due to decreasing costs, the increasing robustness of the format, and the critical events separating friends and family [17]. Over 150 years later, the identities of most of these portraits have been lost, but as museums and archives increasingly digitize and publish their collections online, the pool of reference photos and information has never been more accessible. Historians, genealogists, and collectors work tirelessly to connect names with faces, using largely manual identification methods [3,9]. Identifying people in historical photos is important for preserving material culture [9], correcting the historical record [18], and recognizing contributions of marginalized groups [4], among other reasons.

## 2. SYSTEM DESCRIPTION

Our novel person identification pipeline builds on the foundation of Civil War Photo Sleuth, a website we are developing for sharing and discussing Civil War-era portraits. The site contains basic features such as the ability to upload, tag, share, and comment on photos. It also allows users to connect photos

to profiles of Civil War soldiers with detailed records of military service. Currently, our reference database contains over 15,000 identified Civil War soldier portraits and military service records from public sources like the US Military History Institute [18] and the US National Park Service Soldiers & Sailors Database [19], as well as private collections.

A user begins the photo identification process by uploading an unidentified portrait to Civil War Photo Sleuth. All user-uploaded photos, regardless of whether they are immediately identified, are added to the reference database, subject to moderator review. This means that every search enriches the database, and could potentially help identify future uploads.

**Step 1: User Tags.** The user will tag the uploaded photo with visual clues in categories provided by the system, including the uniform, insignia, equipment, and weapons (Fig. 1). Due to our recruiting strategy, many of our initial users have expertise in these areas, but the interface also provides example images of each of these features to help less experienced users choose appropriate tags. It also allows users to specify features outside the categories the system provides; for example, distinctive facial hair or a photography studio prop.

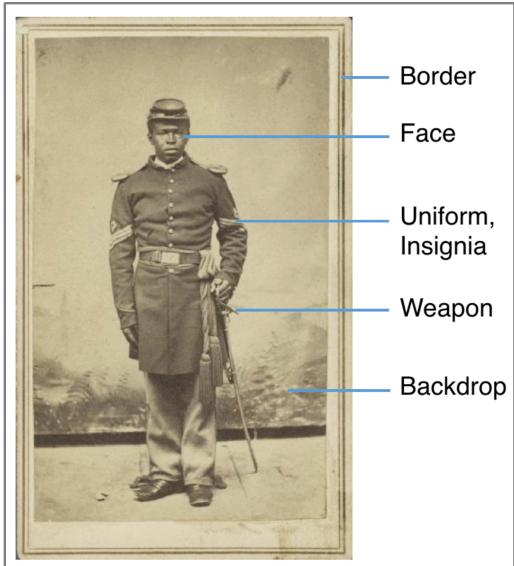


Fig. 1. Categories of visual clues in a portrait of a Civil War soldier (Dandridge Meekins).

**Step 2: Search Filters.** The system draws upon schematized domain knowledge of Civil War portraits to convert the user's tag selections into suggested search filters. For example, if the user tagged a hat insignia of a hunting horn and a frock coat, the system will recommend the “Infantry” filter, whereas if the user tagged a hat insignia of crossed swords and a shell jacket, the system will recommend “Cavalry.” After the system gives suggestions, the user can refine the final selection of filters.

**Step 3: Face Recognition.** Next, the system performs the search. The filters leverage service records to narrow down the pool. For example, if a user tagged the rank insignia of a captain, we know the soldier served as a captain at some point during the war, so the system excludes all reference photos of soldiers who, according to their service records, never held that rank. After this initial filtering, the system applies face recognition to the results, sorting by similarity to the unknown photo. We have tested several commercial face recognition APIs and found Microsoft's to be most powerful and flexible, so our current prototype utilizes

Microsoft's Face API [20]. Our tests show that with Civil War soldier photos, this API yields poor precision, but near-perfect recall at a 0.50 confidence threshold, so we can safely assume most search results include any correct matches.

**Step 4: Crowd Tags.** The system launches tasks via Amazon Mechanical Turk [5], the most popular paid crowdsourcing platform. For each task, a crowd worker compares the unknown photo with a similar photo from the search results and completes two steps. First, the worker tags the unknown photo with two types of features: *user-defined* features (e.g., a unique beard) and *system-defined* features generic to facial recognition (e.g., hair, eyes, nose, jawline, etc.). These tags can later be bootstrapped for subsequent searches [6]. Second, the worker provides an overall similarity score for the two photos on a 4-point scale. Three workers tag and score each photo pair, and the results are aggregated using a majority vote rule.

**Step 5. User Review:** Finally, the system displays the search results to the user as thumbnails (Fig. 2), sorted by a weighted combination of face recognition confidence and crowdsourced tags and scores. The user can click any thumbnail to view the high-resolution photo and detailed service record for that soldier. The user can view the crowdsourced feature tags to help in deciding if the photo is a match. If the user identifies a match, he or she can click a button to link the unknown photo with the identified reference photo. If the photo cannot be identified from the current reference database, the user can request an automatic notification if future user contributions or reference database additions suggest a possible match.

Thus, our hybrid pipeline offers compelling advantages over purely automatic face recognition. The user's initial observations visual clues, linked to military records, eliminate many possibilities. Face recognition narrows them down even further, while sorting by confidence. The power of collective intelligence, via crowdsourcing, is applied to the final result set to find distinct features among the best candidates, generating reusable tags as a byproduct. This method allows users to identify unique features on-the-fly, an advantage over related crowdsourcing approaches that seek to train classifiers [12]. The powerful capabilities of human vision systems allow crowds to consider hair styles, ears, skin characteristics, and other unique attributes [15]. These features augment the face recognition results, applying the more costly crowdsourcing method in a targeted manner.

### 3. PRELIMINARY RESULTS AND NEXT STEPS

We successfully debuted our Photo Sleuth prototype at a large annual gathering of Civil War photo historians and collectors in Gettysburg, Pennsylvania, USA, and the software has already enabled the identification of many soldier portraits (e.g., [8]). We are currently planning several formal evaluation studies. One study will explore how effectively crowds can tag user-defined features and make similarity judgements. A second study will compare our hybrid crowdsourcing pipeline to face recognition-only results. A third study will compare how well our photo identification system helps expert users compared to their current, largely manual approaches. We will recruit historians, genealogists, and collectors to serve as experts. We are in the process of launching CivilWarPhotoSleuth.com, a public website where anyone can contribute to identifying soldier portraits. The site also provides a public RESTful API to facilitate interchange with the digitized collections of libraries and museums.

### 4. ACKNOWLEDGEMENTS

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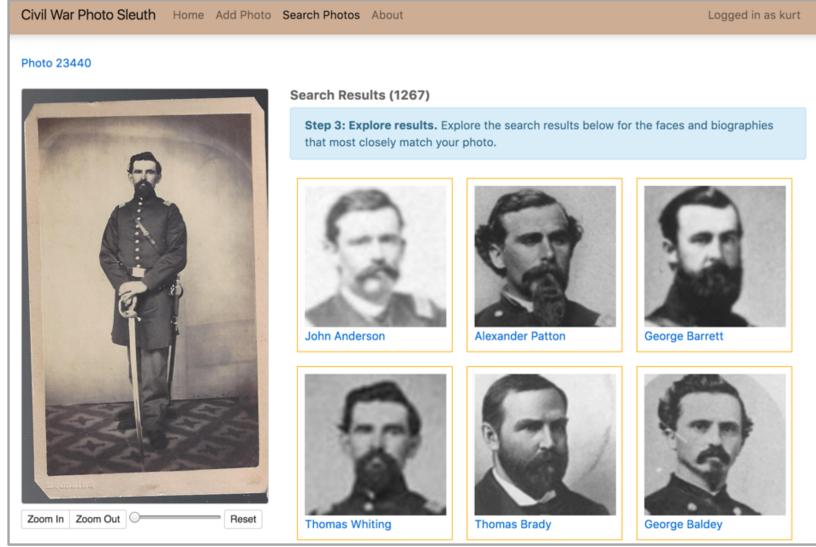


Fig. 2. Photo Sleuth software prototype showing real face recognition results from the Microsoft Face API. Note that due to differences in image quality, even an exact duplicate (Thomas Whiting) is not the top result.

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