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# Biometric technology for voter identification: The experience in Ghana

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**ABSTRACT**

Our study examines how and why Ghana's first attempt to use biometric technology for voter identification and verification in its 2012 general elections failed. We employ activity theory as the analytical lens and interpretive case study as the methodology. Our findings show that the effectiveness of biometric technology to provide reliable identification does not depend solely on its technical qualities but also on real-time connectivity between registration centres and an electronic national register. Furthermore, the electoral officials need to be trained intensively to operate the machines and given guidance on how to handle situations when breakdowns occur. While biometric technology does introduce powerful capabilities, it is just one piece of a complex human activity system.

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biometric technology; national identification system; voter identification; democratic elections; interpretive case study; activity theory; Ghana

## Introduction

The subject of national identification system continues to attract research interests in information systems (e.g. Mcgrath 2016; Whitley, Gal, and Kjaergaard 2014). As a result, much is known about the objectives, benefits and challenges of creating and maintaining such systems in both developed and developing countries (Mcgrath 2016). However, emphasis on national identification systems research in information system has been on policy, technology adoption, security and privacy issues (Whitley, Gal, and Kjaergaard 2014; Halperin and Backhouse 2008). One significant area that is yet to benefit much from information systems research is biometric voter identification for democratic elections. Research on biometric voter identification is not only relevant but also timely, given the growing social and political discourse on information technology and democratic elections in both the developed and the developing world (Gelb and Diofasi 2016).

Our study analyses Ghana's first attempt to use a biometric technology for voter identification and verification. The overarching research question for this study is how and why Ghana's use of biometric technology in its 2012 general elections failed to achieve the intended outcome. To address this question, the study employs activity theory (Engeström 1987; Engeström 1999) as the analytical lens and interpretive case study as the methodology.

The rest of the paper is organized as follows. The following section reviews the literature on national identification systems and voting. The subsequent two sections discuss information systems activity theory and interpretive case methodology. The next section presents the case description. The succeeding section analyses the findings from the case study. The last section offers concluding thoughts.

## National identification systems and voting

National identification systems associate individuals in a country with a unique set of attributes (Beynon-Davies 2005) that can be used to verify who people claim to be and what they are authorized to do or not (Mcgrath 2016; Zviran and Erlich 2006; Jain, Hong, and Pankanti 2000). Nowadays governments are creating and maintaining electronic registers with a unique identity code for each citizen or legal resident in a country (Whitley, Gal, and Kjaergaard 2014; Martin 2008), which serve as a single reference point for identity verification (Jain, Hong, and Pankanti 2000; Whitley, Gal, and Kjaergaard 2014). National identification systems are useful for preventing crimes such as identity fraud, voter fraud, illegal immigration, and impersonation (Briggs and Thomas 2015; Whitley, Gal, and Kjaergaard 2014; Jain, Hong, and Pankanti 2000). On the other hand, such systems can be susceptible to privacy violation and abuse by public officials (Holden and Millett 2005).

The identification process generally involves three interrelated activities: personal identification (also called

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registration or enrolment), verification (also called authentication or recognition), and authorization (also referred to as access control) (Zviran and Erlich 2006; Jain, Hong, and Pankanti 2000; Jain and Ross 2004). Despite the interrelatedness between identification, verification and authorization, Zviran and Erlich (2006), for security reasons, call for their separation into three stages.

In the first stage, identification, the personal attributes of individuals are captured and associated with a unique number or code, and stored in a database (Jain, Hong, and Pankanti 2000; Jain and Ross 2004). Identification addresses the question who an individual is (Zviran and Erlich 2006). In the second stage, verification, the claimed identity of a person who wants to access a particular service or partake in an activity is authenticated. Verification seeks to match the identity information supplied by the individual with what was captured and stored during identification (Wilson, Brown, and Thatcher 2015; Sullivan 2009; Mcgrath 2016). It addresses the question whether an individual is who he/she claims to be (Zviran and Erlich 2006) in order to accept true claimed identities and reject false ones (Jain and Ross 2004). In the third stage, authorization, what a verified individual is permitted to do is addressed (Zviran and Erlich 2006). Often identification and verification are sufficient. Authorization becomes an issue when people need to access restricted spaces and services or perform specific activities (Zviran and Erlich 2006). For elections, all the three stages are important to ensure credible results.

Three technologies for identity verification commonly discussed in the information systems literature are knowledge-based, object-based (also called token-based) and biometric-based (Zviran and Erlich 2006). First, knowledge-based identification technologies rely on information people know – personal identification numbers (PINs) and passwords (Briggs and Thomas 2015). Its main limitation is that people often forget or unintentionally reveal PINs and passwords to imposters (Jain, Hong, and Pankanti 2000), who can use them to gain unauthorized access (Zviran and Erlich 2006). Second, object-based identity verification relies on physical items such as identity cards, passports, drivers' licenses, and credit/debit cards (Zviran and Erlich 2006; Jain, Hong, and Pankanti 2000; De Luis-Garcã et al. 2003). However, such objects can get lost or stolen (Zviran and Erlich, 2006). They are also subject to forgery (Whitley et al. 2007). The above two are commonly referred to as traditional forms of identity verification (Jain and Ross 2004).

Finally, biometric-based identity verification relies on data captured from the human body or behavior (Zviran and Erlich 2006; De Luis-Garcã et al. 2003; Yadav and Singh 2013; Jain and Ross 2004). Common types of biometric-based identification include fingerprints, iris, hand geometry, signatures and speech patterns (Jain, Hong, and Pankanti 2000; Whitley, Gal, and Kjaergaard 2014; Jain and Ross 2004). Compared to the traditional methods, the biometric-based identification is considered the most reliable means to provide a unique identity (Jain, Hong, and Pankanti 2000; Beynon-Davies 2005). However, there can be errors in data capture and verification due to dirt, poor lighting, and environmental conditions as well as physiological deformities of people resulting from surgery, aging, sickness or accidents (Zviran and Erlich 2006). Even when the data is accurate, biometric technologies do not guarantee100% reliability because of their margin of error, which can lead to false match or mismatch during verification – sometimes accepting wrong identity and rejecting right ones (Zviran and Erlich 2006). Moreover, there tends to be a wanton expansion in the use of biometrics beyond the original intended use and that raises issues of privacy, which can trigger public resistance (Davies 1994).

For a long time, most developed countries have invested in electronic national identification systems to support governance and democracy (Beynon-Davies 2005; Martin 2012; Piccolino 2015; Whitley and Hosein 2010; Mcgrath 2016; Mariën and Audenhove 2010). Unfortunately, most developing countries are yet to establish credible electronic national registers (Mcgrath 2016). Consequently, voter registration and verification in most developing countries is still based on identity cards, amidst problems of errors, fictitious voter registration, and multiple voting (Piccolino 2015; Tilwani, Majumdar, and Bhargava 2013; Maiye and Mcgrath 2010). Given the challenges associated with object-based identification, the biometric technology is seen as a better option for voter identification and verification (Jain, Hong, and Pankanti 2000). Therefore some developing countries have begun exploring biometrics (Piccolino 2015; Yadav and Singh 2013). Yet, not much is known in the information systems literature on the outcomes of such attempts in the developing world.

## Theoretical foundation: Activity theory

Activity theory (Engeström 1987; Engeström 1999) provides a useful analytical lens for our purposes. It was originally developed in psychology based on Vygotsky (1978) and related work to understand the object-oriented and tool-mediated nature of human activity (Miettinen, Samra-Fredericks, and Yanow 2009). The original concepts were activity, subject, object, and tool. These were later extended to include community, division of labor, rules and outcome (Engeström 1987; Engeström

2001). Figure 1 shows the core concepts and the structure of an activity system.

*Subject* refers to an individual or a group of people who undertake an activity with an intention to achieve an object. Generally, the subject is the entity from whose perspective an activity is analyzed (Vakkayil 2010; Karanasios and Allen 2014). Thus, multiple activity systems can be analyzed in a single activity context (Vakkayil 2010; Engeström 1987; Karanasios and Allen 2014). *Object* is the result that the subject intends to achieve and *outcome* is what actually happens. *Tools* constitute the mediating artifacts that are used to perform the activity. *Rules, community*, and *division of labor* constitute the socio-cultural context within which the activity occurs. *Rules* are the regulations and policies that govern the activity system; *community* refers to stakeholder participants, who have interests in the object; *division of labor* refers to the distribution of tasks and power between the subject and the community members.

Three additional constructs from the activity theory literature which are drawn on in this study are: *mediation* (Leont'ev 1978; Kuutti 1996); *hierarchical structure of activity-action-operation* (Allen, Karanasios, and Slavova 2011; Leont'ev 1978; Mursu et al. 2007); and *principle of contradictions* (Allen, Karanasios, and Slavova 2011; Engeström 2001; Kuutti 1996; Issroff and Scanlon 2002; Engeström 1987; Engeström 1999; Korpela, Soriyan, and Olufokunbi 2000). Mediation, represented by the intersecting lines in Figure 1, signifies that performance of an activity or the relations between the subject and the object can be shaped by other elements of the activity structure (Kuutti 1996; Vygotsky 1978; Leont'ev 1978). Mediation is tool-based when the subject-object relationship is mediated by a tool or socio-cultural when the relationship is mediated by laws and division of labor.

The division of labor plays out through a hierarchical structure of activity-action-operation (Table 1). Here

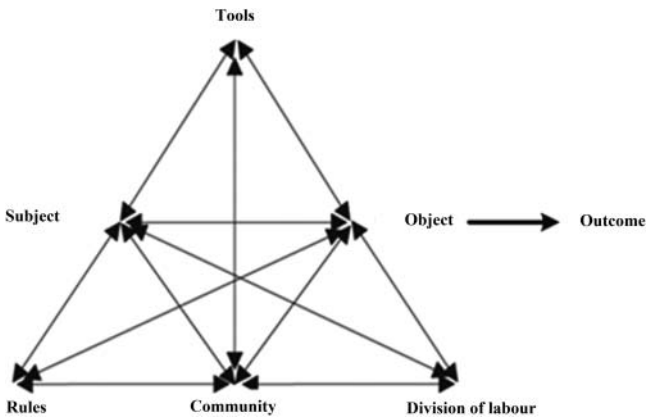


**Figure 1.** Structure of human activity system (Engeström 2001).

**Table 1.** The hierarchical structure of activity after Leont'ev (Based on Leont'ev 1959/81, 1978; table developed by Engeström et al. 1990).

| Unit | Directing factor | Subject |
|---|---|---|
| Activity | Object/motive | Collective |
| Action | Goal | Individual or group |
| Operation | Conditions | Non-conscious |

activity system is seen as a multi-layered composite of activities, actions and operations occurring at different levels.

According to the principle of contradictions, since activity systems are dynamic, they can give rise to inconsistencies or problems within or between activities that prevent the subject from attaining the object. Contradictions can also occur between neighboring activity systems (Engeström 1987; Engeström 1999; Korpela, Soriyan, and Olufokunbi 2000). *Contradictions*, therefore, constitute conflicts that run contrary to the intended outcome (Engeström 1987; 2001; Weeger and Ulrich 2016).

From its origin in psychology, activity theory has been applied in information systems research to investigate varied phenomena, including human-computer interactions, system design and system development (Kuutti 1996; Chen et al. 2013; Korpela, Mursu, and Soriyan 2002); organizational transformation and learning (Ryu et al. 2005; Allen, Karanasios, and Slavova 2011); information systems use patterns (Karanasios and Allen 2014; Wiredu 2014). From interpretive perspective, this study draws on activity theory as a sensitizing device (Klein and Myers 1999; Davidson and Chismar 2007; Flynn and Gregory 2004) to understand the phenomenon of interest. We choose activity theory because it offers rich concepts for understanding the biometric technology use as a socio-technical activity with constituent action.

## Methodology

We conducted a qualitative, interpretive case study. Data gathering for the study occurred over a five-year period from 2012 to 2016. Following the interpretive tradition (Klein and Myers, 1999, Walsham, 1995, 2006), data was gathered from multiple sources, including semi-structured interviews, focus group, and documents. Key informants from the Electoral Commission, political parties and voters were selected through purposeful sampling based on their participation in the 2012 biometric voter registration, verification and voting (Creswell 2013; Davidson and Chismar 2007; Patton 2002).

The total number of interview participants was 51 – 6 electoral officials and 12 party officials at the national level, 11 permanent electoral officials, 9 temporary

electoral officials, and 13 voters at the district level. Participants from both national and district levels were selected because officials at EC's national headquarters and the political parties receive reports from districts, while the actual biometric registration, verification, and voting occurs at polling stations in the various districts.

Focus group had 12 individuals with academia, media, civil society, and ICT (information and communication technology) backgrounds. They were purposefully selected based on their expertise, personal experience, and knowledge of the events that occurred when biometric technology was used in the voting process. The focus group provided a platform not only for discussion of the issues that needed to be interrogated but also for verifying the information gathered from the interview participants.

In addition, documentary sources, including publicly available reports from the media, independent election observers, non-governmental organizations and civil society organizations, were consulted. In particular post-election review reports by the United Nations Development Programme, Ghana Centre for Democratic Development (GCDD), Institute of Economic Affairs and Coalition of Domestic Election Observers provided rich data for analysis. Additional documentary evidence came from newspaper articles, online articles, official documents from the Electoral Commission and legal documents related to the regulation of the elections.

In line with interpretive research principles, data analysis occurred alongside data gathering. Each co-author conducted an independent analysis – reading and re-reading the data from the various sources to identify activity elements, the constituent actions and the contradictions that emerged. The two co-authors met periodically to discuss and develop a consensus on emerging findings. Where necessary, follow-up interviews were made via e-mail or telephone to verify responses or to gather additional data from participants. Data collection and analysis ended when we realized that theoretical saturation had been reached such that subsequent efforts yielded no new findings but repeated earlier ones (Eisenhardt and Graebner 2007; Day, Junglas, and Silva 2009).

## Case description

Ghana has an estimated population of 25 million. Since 1992, it has had democratic elections every 4 years to elect a president and parliamentarians. However, each election has ended with controversies over the credibility of the voters' register and the election results. Until 2008, voter registration and verification had been largely paper-based and manual. EC printed the voters' register and issued photo identity cards. This system was criticized for problems such as multiple registrations, impersonation by minors and foreigners, and multiple voting. In 2012, EC introduced a biometric technology for the voter identification and verification to address these problems. The 2012 election was based on a new law, Public Election Regulations, 2012 (CI 75), which stipulated that only biometrically registered and biometrically verified citizens could vote.

### *Registration*

The biometric registration was done in 6,000 centres in constituencies throughout the country from 24 March to 5 May 2012. The technological infrastructure for the biometric registration consisted of a data centre situated at the EC's headquarters in Accra, the national capital; a satellite data communication station in each district capital; and data capture kits comprising fingerprint scanners, laptops, digital cameras, identity card printers, lamination device, and USB flash disks in each registration centre.

Before registering, each voter was required to provide a proof of citizenship and age (18 years or above). Acceptable proofs at the time included: birth certificate; baptismal certificate; passport; driver's license; national identity card; previous voter identity card; national health insurance card; or any qualified voters as guarantors.

After the identity check, electoral officials captured each voter's biographic data, fingerprints (all ten), and photo. For people with disfigurations of hands and fingers due to accidents, diseases or deformity, only biographic details and pictures were captured. They were labeled as FO (face only) voters. After registration, each voter received a photo identity card with biographic details and a barcode. Periodically, data captured at the registration centres were copied onto USB flash disks, sent to the district satellite communication centres and subsequently transmitted to the data centre at EC's headquarters.

Electoral Commission's ICT team periodically investigated the data for possible multiple registrations. In April 2012, while registration was ongoing, the Electoral Commission announced that it had discovered cases of over 4,000 multiple and illegal registrations involving minors across all the regions in the country. In a forum to educate the public on the biometric registration exercise, the head of EC's ICT team spoke about the emerging issue of multiple registrations and what the commission planned to do:

Persons who were found to have registered more than once would have their names removed entirely from the

register, be arrested and prosecuted to face either a jail sentence or a fine, as the court may please. There is an adjudicating committee looking at those cases. What is important is to establish whether they were done deliberately or some thought their photographs were not nice so they decided to have another registration just that they can have better photographs. The outcome of the investigations should determine what should be done. The EC wants the public to be responsible and vigilant to prevent attempts of double registration.

EC later announced that its officials had gone through a de-duplication process to remove all multiple registrations. However, it could do nothing about registrations by minors since it had no legal powers to remove them. In a media dialogue organized by the Editors' Forum of Ghana on the 2012 election, the EC chairman said:

> Minors captured in the Biometric Voters' Register pose a big challenge to the EC in the conduct of this year's general elections. Nobody knows exactly what to do about these registered minors. It is a very big problem and it does not speak well of us.

EC only appealed to such minors to not to attempt to vote and their parents and teachers to advise them not to vote.

Between May and August 2012, EC corrected data entry errors it had identified. In the words of head of EC's ICT team: "We had to correct errors committed by data entry personnel to have a clean register." In September 2012, EC exhibited the printed provisional register at various centres for registrants to check the accuracy of information and point out any illegal registrations, including registrations of the dead. The exhibited provisional registers, however, provided only demographic information – no biometric information. According to the EC, it used feedback from these exhibitions to correct errors and print the final register to be used for the elections.

Although the biometric registration was generally considered to have been successful, some challenges were reported, including biometric machine breakdown in some centres, non-registration of some legitimate citizens after several attempts due to failure of the biometric machine to capture their fingerprints, and registration of people without approved documents or with unapproved documents such as school identity cards, employee identity cards and examination results by some electoral officials (GCDD 2013). An ICT expert who was interviewed registered his disappointment with the biometric registration as follows:

> We all thought the biometric registration was going to prevent people from double registration as the EC had assured the public. However, the setup did not prevent double registration rather it allowed it before the EC took pains to clean the register by deleting names of those who registered more than once.

## Verification and voting

The actual voting occurred on December 7, 2012 in 26,002 polling centres throughout the country. Election materials supplied to each polling station included copies of printed voters' register for manual verification, biometric verification machines with barcode readers, fingerprint scanner, and display panel for instructions, ballot papers, transparent ballot boxes, and indelible ink.

The verification at the polling stations involved two processes: manual verification and biometric verification. At the manual verification stage, a voter presented his/her photo identity card to an electoral officer. If the details matched the printed voters' register, the voter proceeded to the biometric verification stage, where an officer scanned the barcode associated with the person's details on the printed register. Following the scanning, the voter's photo appeared on the display panel attached to the biometric device. Another check was made to ensure that the displayed picture matched with the picture on the photo identity card and the person's face.

If so, the voter was asked to put one finger on the biometric scanner to be verified. If successful, the biometric machine displayed and announced the message "verified" to the electoral officers and the party representatives at the polling station. If unsuccessful, the person was made to try the remaining fingers successively until all 10 fingers had been exhausted. If still unsuccessful, the person was not allowed to vote. The "face-only" voters had to only go through manual verification.

After the verification, an electoral officer applied indelible ink on the thumb to signal that the voter had cleared the process. This ink mark was meant to prevent any attempt to vote again at that or another polling station. Another officer issued a presidential ballot paper to the voter, who entered a secret booth to place a thumbprint against the picture of the preferred candidate and then proceeded to put it in a transparent ballot box placed in an open space. The voter returned to the electoral desk to collect the parliamentary ballot paper and repeated the process for the preferred parliamentary candidate.

While voting was going on, there were media reports on problems in some polling stations including frequent breakdown of the biometric verification machines, failure of the machines to verify some voters who had successfully undergone the manual verification, and long

queues in some polling stations due to these problems and other delays. By 5 pm when voting was expected to have closed, some people had not been able to cast their votes in places that had such challenges. Consequently, the EC issued a press statement to extend the voting to the next day, 8th of December:

The Electoral Commission directs as follows: at polling stations where the biometric verification of voters could not be completed and as a result, some voters in the queue could not be processed to vote …, polling should continue tomorrow, Saturday, 8th December 2012 to give the opportunity to the affected persons to vote. Presiding Officers should arrange with the police for the safe custody of all ballot boxes and election materials.

Following this directive, voting continued the following day. This was the first time in the history of the country that voting had to be extended. Voting officially closed at 5 pm on the 8th of December. The results were manually countered and the EC chairman declared the incumbent president of the National Democratic Convention Party as the winner. The electoral officials in various constituencies also declared elected parliamentarians as winners.

## Post-election disputes

After the results declaration, the legitimacy of the elected president was questioned given the numerous problems that occurred with the introduction of the biometric technology. Reports from the media and some observer groups showed that, despite the legal requirement that "no biometric verification no vote" there were instances where electoral officials allowed some people to vote without biometric verification. There were also instances where some people could not vote due to machine breakdown or failure in verification of any of their 10 fingers, despite having been manually verified with the printed register.

In 2013, the main opposition party, the New Patriotic Party, challenged the election results in the Supreme Court and asked the court to cancel results in places where violations of the law had occurred, including voting without biometric verification. The opposition party lost the case on a 5:4 majority decision. However, the court proceedings brightened the spotlight on instances of voting without biometric verification, double registration and over voting despite the use of the biometric technology.

In 2015, the opposition New Patriotic Party advocated for a new register for the 2016 elections, pointing to problems such as multiple registrations, registration of minors, and registration of foreigners. It compared Ghana's register with that of neighboring countries and found several people appearing in both. Its analysis of the printed register also showed that pictures of some voters had staple marks. This was presented as evidence that these voters did not go through biometric registration, which would have led to direct printing of the digital photos onto the paper-based register – herein there is no need for staples. The fact that some pictures in the print register had staple marks indicates that they were collected from voters and later smuggled into the printed register. New Patriotic Party's call was supported by most opposition parties but was rejected by the incumbent political party, which instead called for corrections in the existing register. In the same year, EC organized a forum on the problems with the biometric register and the way forward. What became clear was that all stakeholders agreed that the register was not credible but disagreed on how to rectify the situation.

In 2016, a concerned citizen challenged in the Supreme Court the legitimacy of the National Health Insurance as a proof of nationality for voter registration. The basis for the legal challenge was that the national insurance registration was open to not only Ghanaians but foreigners as well. The court ruled in favor of the challenger and declared the use of the national insurance card as illegal. Finally, the court ordered EC to delete the records of all those who registered with the national insurance card from the voters' register and give the opportunity to legitimate citizens to use other acceptable forms of identity to re-register.

## Activity analysis

In our study, election was the focal activity and the associated registration, verification, and voting were the constituent actions. As the institution legally mandated to oversee the election, the EC was the subject. The object was a free and fair election, while the intended outcome was credible results accepted by all stakeholders. The tool was the biometric technology, which was used for voter registration and verification. The rules were the electoral laws that governed the election, which required that only biometrically registered and verified citizens of 18 years age or older could vote.

The primary community members, who directly participated in the election activities, were the electoral officers, voters and political parties. The roles played by the various community groups constituted the division of labor (see Figure 2 for the election activity diagram and Table 2 for hierarchical structure of activity-action-operation for the 2012 elections).

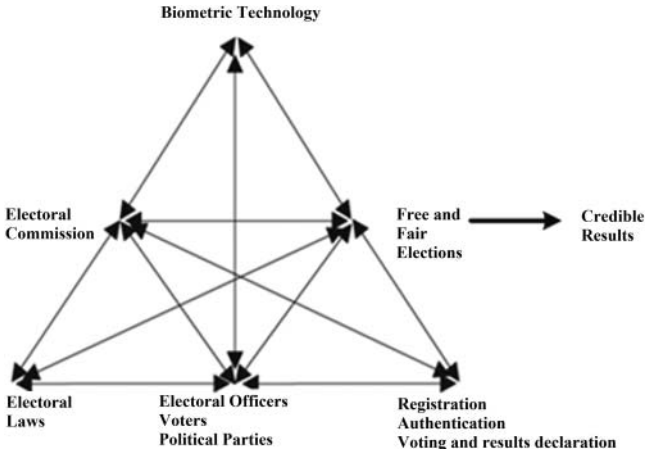


**Figure 2.** 2012 Election Human Activity System.

## Contradictions in registration and verification

The registration process required potential voters to physically present themselves at registration centres to prove their citizenship and legal age before their biographic and biometric details could be captured. The law permitted only the following as acceptable proof of identity: birth certificate; baptismal certificate; passport; driver's license; national identity card; previous voter identity card; national health insurance card; or any two qualified voters as guarantors.

However, the interactions between the biometric system and other systems in the electoral process gave rise to misalignments, which contributed to the failure to attain the desired object. By failing to connect the registration centres to a centralized database to double-check registration attempts in real-time, the verification system allowed people to engage in double registration. Although EC claimed that they went through a procedure to remove the multiple registrations, evidence presented in the court showed that the deduplication was not fully achieved.

Similarly, the absence of a reliable database on citizenship and date of birth made it difficult to prevent minors and foreigners from registering. After analyzing the photos of registrants, EC itself admitted the presence of minors on the register. Additionally, the New Patriotic Party detected that some voters on Ghana's register were also found on the registers of neighbouring countries. Further analysis showed that the acceptance of national health insurance card, which was open to foreigners, as a proof of identity made it possible for some of them to register. In 2016, the Supreme Court ruled that the national health insurance card could no longer be used as proof of citizenship. In effect, EC failed to compile a credible voters' register despite the use of the biometric technology.

## Contradictions in verification and voting

The verification process involved an initial manual verification followed by a biometric verification with a fingerprint. The voter needed to clear both in order to vote. However, some registered voters could not be biometrically verified after successfully going through the manual verification, which confirmed that the person had been registered. In effect, there was a misalignment between the manual registration system and the biometric registration system, giving rise to inconsistencies that undermined the credibility of the election.

Machine breakdowns often created situations such that some legally registered voters could not cast their ballot. Since the law did not stipulate what should be done while the machine is down, the electoral officials had no official guidance on how to proceed – some electoral officers allowed voters to vote without the biometric verification and others prevented them from doing so. Other problems that created similar situations were the freezing of the machine due to harsh weather conditions and failure of the electoral officers to change batteries on schedule.

Looking back, the use of the manual verification process introduced unforeseen complications. When faced with problems with the biometric verification system, manual verification gave electoral officials a rationale to give ballot papers to voters even though they had not been biometrically verified. The use of "face-only" voters

**Table 2.** 2012 Election Hierarchical Structure of Activity-Action-Operation.

| | | |
|---|---|---|
| Election Activity | Motive | Subject |
| • 2012 Election | • Free and fair elections | • Electoral Commission |
| Election Management Actions | Goals | Community Members |
| • Registration management | • Ensure register integrity | • Electoral officers |
| • Verification management | • Prevent illegal voting | • Electoral officers |
| • Voting management | • Credible results | • Electoral Commission |
| Voting Actions | Goals | Community Member |
| • Registration | • Get biometric registration | • Voters |
| • Verification | • Pass biometric verification | • Voters |
| • Voting | • Vote for preferred candidate | • Voters |

who went through the manual but not the biometric verification seemed to further validate this rationale. If the EC had not limited itself to fingerprint verification and also used other biometrics such as iris and face recognition, the problems in the field would have been mitigated.

## Conclusions

Our findings show that biometric technology alone is not sufficient to prevent registration fraud in a distributed environment, especially in developing countries where computer network infrastructure and electronic national voters' registers are limited. Studies in Nigeria have found that the electronic registration technology itself was not enough to ensure credible elections. Its deployment needed to be accompanied with a conscious effort to address disputes, suspicions, power struggles, and uncertainties (McGrath and Maiye 2010; Mcgrath 2016).

This finding suggests the need for more nuance in the information systems literature, where the call has been made for separation between biometric identification and verification activities in order to avert security problems (Zviran and Erlich 2006). While this may be appropriate for computer network access control, our findings show that in a distributed national registration environment, biometric registration and verification should be linked to prevent double and other illegal registration attempts.

Our findings also spotlight the need for real-time communication between registration centres and a centralized national database. This finding resonates with those in India, where Tilwani, Majumdar, and Bhargava (2013) found that in many voting centres, particularly, in semi-urban and rural areas, lax voter verification often results in impersonation and other frauds. They call for a centralized electronic biometric technology to verify voters in real-time before authorization to vote.

Given the limitations of infrastructure in a developing country context, Ghana could have used a biometric kiosk to integrate the verification and the voting activities, similar to how automatic teller machines (ATMs) operate. Voters can then be biometrically verified and authorized to or rejected from voting by touching the digital images of their preferred candidates. Such an approach would have helped to enforce the legal requirement that only individuals with biometric verification be allowed to vote.

In sum, this study advances existing knowledge by offering rich insight into how and why a developing country's first attempt to use biometric technology for an election failed to achieve the intended purpose. The findings show that the effectiveness of biometric technology to provide reliable identification does not depend solely on its technical qualities but also on real-time connectivity between registration centres and an electronic national register. Furthermore, the electoral officials need to be trained intensively to operate the machines and given guidance on how to handle situations when breakdowns occur. In effect, biometric technology is not a silver bullet for the problems that plague elections in developing countries. While it does introduce powerful capabilities, it is just one piece of a complex human activity system.

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