THE UTILIZATION OF A3S INFORMATION-INFERENCING FUSION METHOD FOR NATION DEFENSE

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ABSTRACT

Decision-making is the most critical phase in Observe, Orient, Decide, and Act (OODA) defense decision cycle. If the decision made is correct regarding the current situation, then it can minimize the possibility of loss. The contradiction situation will occur if the incorrect decision is made. The correctness of the decision depends of the quality on information delivered from Orient(ation) phase that will be used as the basis for decision-making. Meanwhile, in defense applications the process of decision-making plays a very important role especially if the time is the most affecting factor. Such an application is nation defense system in defending our country's nation sovereignty in air, sea, and land. Therefore, the faster the decision is made, the earlier the system can perform anticipations to any nation defense intrusion. For this purpose, in this paper we address the utilization of A3S (Arwin-Adang-Aciek-Sembiring) information-inferencing fusion for accelerating the information processing and obtaining good comprehensive information quality that will be used as the basis for strategic decision-making for nation defense.

Keywords: A3S, information-inferencing fusion, nation defense, OODA, strategic decision-making

1. INTRODUCTION

Nation defense is a value that cannot be negotiated at all. Of important things in nation defense is the decision-making process that is based on collected information gathered by Intelligence, Surveillance, and Reconnaissance (ISR) apparatus of the strategic environment. The more complete and accurate information that is gathered the more precise the decision that can be made by the decision maker. The process of decision-making becomes complicated along with the increasing of the complexity of the collected information.

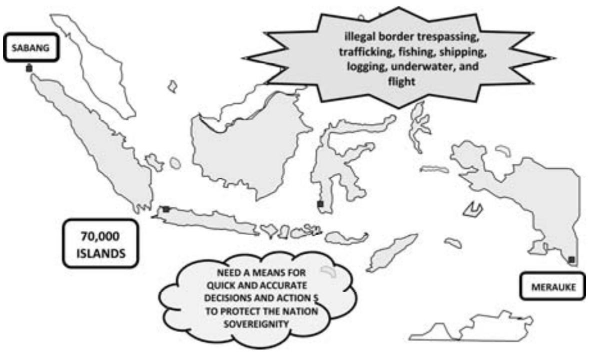

Figure 1. Our nation sovereignty

Our country, the Republic of Indonesia as depicted in Figure 1, is an archipelagic nation which consists of more than 70,000 islands that spread from Sabang, the most west island to Merauke, the most east city at the most east island of Indonesia. Most of the Republic of Indonesia area is covered with waters that connect one island to another. This circumstance brings vulnerabilities that can occur in one or more locations at the same time. These vulnerabilities include illegal border trespassing, illegal trafficking, illegal fishing, illegal logging, illegal underwater shipping, and illegal flight. These vulnerabilities will directly affect the nation defense in economy, culture, defense, and security aspects (Ahmad & Sumari, 2008b).

Imagine that in some different locations occur nation defense intrusions at the same time. Knowing this complex situation, the commanding officer who is responsible for nation defense has to make decisions followed by actions to cope with the situations. On the contrary, he has take into consideration the capacity of his forces before deploying them into the alert locations. He has to count the situations carefully and thoroughly the number of personnel, equipment as well as the budget to support the missions to each location simultaneously. This process will be extremely requiring comprehensive information in order to obtain the most appropriate mission plans. Therefore, he can make the correct decision in a quick manner.

In this paper we address the utilization of A3S (Arwin-Adang-Aciek-Sembiring) information-inferencing fusion method for obtaining good comprehensive information quality for decision-making in Observe, Orient, Decide, and Act (OODA) defense decision-making cycle framework. The focus is in Orient phase where the gathered information in analyzed before it is delivered to the decision maker as the basis for decision-making.

The arrangement of the paper is as follows. The background of the paper is covered in Section 1. In Section 2 and Section 3 we subsequently deliver an introduction to OODA decision cycle and a brief on the concept of A3S information-inferencing fusion method. A simple example of the utilization of A3S method on nation defense will be presented in Section 4. The paper will be summarized with concluding remarks in Section 5.

2. OODA DECISION CYCLE

In order to obtain correct and quick decisions, there are some models that we can adapt, whether for military or civilian domain such as John Boyd's OODA (U.S. DoD, 1996), US Army's Military Decision Making Process (MDMP) (U.S. Army, 1997), Recognition Primed-Decision (RPD), and Integrated Sensor and Decision Support (ISDS) (Senne & Condon, 2007). The most common model that has been used in military domain is OODA decision cycle that was introduced by Colonel (USAF) John Boyd in 1950s. In general, there are four phases which have to be followed in order to win the battle as depicted in Figure 2.

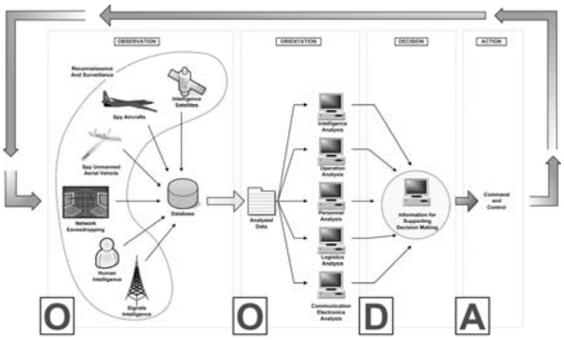

Figure 2. OODA decision cycle (Sumari, 2008a)

2.1 Observ(ation) Phase

In the observation phase, the commanding officer's staffs gather information from the Intelligence, Reconnaissance, and Surveillance (ISR) apparatus and from local authority officials and people. The observation in order to collect information is not only carried out by human and man-controlled apparatus, but also carried out by self-governing or intelligent vehicles.

The use of intelligent is to ensure that the missions for information collection can be done deeply to the very risky locations. The collected information is delivered to command and control center to be further processed by the expert staffs in the form of intelligence information.

2.2 Orient(ation) Phase

In the orientation phase, information about the environment situation is then analyzed in some perspectives such operation, personnel, and logistics in order to obtain the most appropriate plan to support the mission. The information that is received from observation phase most of the time is not in standard formatted form. Therefore, there will be pre-processing step that has to be done at the first place before it can be apprehended by the commanding officer's staffs.

Based on this analysis, the commanding officer will make an assessment of the "reality" of the operational area. The results of analysis also give the commanding officer a situation awareness regarding the current situation and he can select the most relevant alternatives presented by his staffs as the most appropriate decision.

2.3 Deci(sion) Phase

In this phase, the commanding officer will make decisions based on the assessment of the "reality" of the operational area. The decision made by him is not only based on the alternatives presented his staffs' analysis, but also affected by his previous knowledge and experience regarding the same situations he has ever had before.

The decisions made will be communicated to mission commander to execute the mission according the alternative selected by the commanding officer.

2.4 Act(ion) Phase

The mission commander will cause the commanding officer's decisions to become actions that impact the "reality" of the operational area. During the engagement, the commanding officer always stays alert by observing all information apparatuses, so he can perform command and control to his forces.

2.5 The Time Interval of Decision Cycle

OODA is a repeatedly process that moves from Observation phase to Action phase and so forth that forms a cycle. The transition from one phase to another will affect the speed of decision-making process. The most spending-time phase is the Orient(ation) phase where the gathered information is analyzed and decision alternatives are produced to be presented to the commanding officer. Therefore, by reducing the Orient phase, the OODA time-interval loop can be shortened, i.e. the decision can be made in a very quick manner without leaving its correctness.

3. A3S INFORMATION-INFERENCING FUSION METHOD

In this section we present the essential of A3S information-inferencing fusion method. A3S method originated from our observation on the mechanism occurs in human brain in obtaining new knowledge from information gathered by his/her sensory organs. The brain fuses all information to obtain inferencing and the combination of information-inferencing and previous knowledge creates new knowledge regarding the observed environment.

3.1 History of the Origin of the A3S Information-Inferencing Fusion Method

A3S information-inferencing fusion method departs from two engineering fields, Information Fusion and Artificial Intelligence (AI). As depicted in Figure 3, the former field, even though it also departs from the observation of how living things make predictions or estimations from fused information delivered by their sensing organs, the intelligence itself is not explicitly revealed.

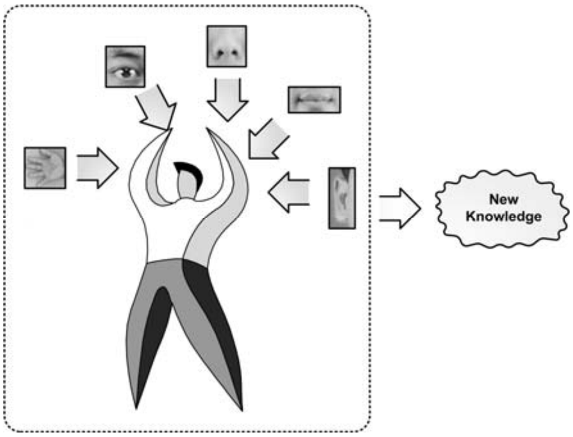

Figure 3. Human information fusion system (Sumari et.al., 2009b)

With the result of that, the applications of the information fusion field are mostly associated with target tracking and target predictions and estimations. The complete explanation regarding the concept of information fusion can be referred to (Ahmad & Sumari, 2008a).

On the other hand, AI field seeks to find approaches for emulating human intelligence to be applied to computing systems. Whatever the definition of AI is, its main aim is creating computer-based systems that carry human intelligence characteristics (Sumari et.al., 2009a). The aims in AI are classified into four classes namely (a) systems that think like humans; (b) systems that act like humans; (c) systems that think rationally; and (d) systems that act rationally (Russel & Norvig, 2003).

In order that a system can think humanly, it has to have an automated reasoning capability, which means it uses the information stored in its memory to answer questions and to draw new conclusions based on given information. The new conclusion is called as inferencing and the process of drawing new conclusions is called as inference.

We did some investigations on the relationship between information fusion and AI which was initiated in 2006. We found that there is an intelligence mechanism in information fusion in obtaining new knowledge as depicted in Figure 3. In the initial research, we devised a new information fusion method called Maximum Score of the Total Sum of Joint Probabilities (MSJP) method, see (Sumari, 2008a) and (Sumari & Ahmad, 2008).

Started from this good start, we then go forward to elaborate the MSJP method to become A3S (Arwin-Adang-Aciek-Sembiring) information-inferencing fusion method in 2008 (Sumari, 2008b). Hence, we coined a new term "Information-Inferencing Fusion" that is defined as a method of fusing information inferencing done by many computation agents to become single comprehensive inferencing (new knowledge) (Ahmad & Sumari, 2008a).

3.2 A3S Information-Inferencing Fusion Method

The A3S information-inferencing fusion method is presented in Equation (1) and Equation (2).

$$\boldsymbol{P}\left(\boldsymbol{A}_i \boxplus \boldsymbol{B}_j\right) = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m}\boldsymbol{P}\left(\boldsymbol{A}_i \mid \boldsymbol{B}_j\right)}{\boldsymbol{j}} \qquad (1)$$

$$\boldsymbol{P}\left(\boldsymbol{A}_i \boxplus \boldsymbol{B}_j\right)_{estimated} = \max_{i=1,\ldots,n}\left(\boldsymbol{P}\left(\boldsymbol{A}_i \boxplus \boldsymbol{B}_j\right)\right) \qquad (2)$$

where $i = 1,\ldots,n$ is the number of hypothesis and $j = 1,\ldots,m$ is the number of indication. The $\boldsymbol{P}\left(\boldsymbol{A}_i \boxplus \boldsymbol{B}_j\right)$ notation means as "joint (fused) probabilities" of all a posteriori probabilities from the same hypothesis. The "estimated" or just "est" term in Equation (2) means the selected hypothesis is the most likely hypothesis from all available hypotheses given indications. $\boldsymbol{P}\left(\boldsymbol{A}_i \boxplus \boldsymbol{B}_j\right)_{estimated}$ is the largest value of $\boldsymbol{P}\left(\boldsymbol{A}_i \boxplus \boldsymbol{B}_j\right)$ or we call is as Degree of Certainty (DoC).

The illustration of the information-inferencing fusion mechanism is depicted in Figure 4. For the detailed explanation regarding this method, interested readers may refer to (Ahmad & Sumari, 2008a).

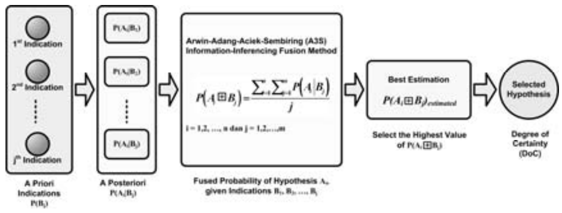

Figure 4. The illustration of A3S information-inferencing fusion mechanism (Sumari, 2008b)

Table 1. The computation mechanism in A3S information-inferencing fusion method (Sumari, 2008b)

A_i		Hypotheses, A_i				
B_j		1	...	i	...	n
Indications B_j	1	$P(A_1 \mid B_1)$	...	$P(A_i \mid B_1)$	...	$P(A_n \mid B_1)$
	2	$P(A_1 \mid B_2)$	...	$P(A_i \mid B_2)$	...	$P(A_n \mid B_2)$
	...	...	...	...	...	...
	j	$P(A_1 \mid B_j)$	...	$P(A_i \mid B_j)$	...	$P(A_n \mid B_j)$
	...	...	...	...	...	...
	m	$P(A_1 \mid B_m)$	...	$P(A_i \mid B_m)$	...	$P(A_n \mid B_m)$
A3S		$\frac{\sum_{i=1}\sum_{j=1}^{m} P(A_1 \mid B_j)}{j}$		$\frac{\sum_{i=i}\sum_{j=1}^{m} P(A_i \mid B_j)}{j}$		$\frac{\sum_{i=n}\sum_{j=1}^{m} P(A_n \mid B_j)}{j}$
A3S + Maximum Score		$\frac{\max_{i=1,\dots,n}\left(\sum_{i=1}^{n}\sum_{j=1}^{m} P(A_i \mid B_j)\right)}{j}$				

4. A SIMPLE EXAMPLE OF A3S UTILIZATION FOR NATION DEFENSE

In defense perspectives, the whole nation's area is divided into four defense regions as illustrated in Figure 4. Each region is under ISR apparatus surveillance for 24 hours non-stop. The task of the nation defense's information system is to obtain comprehensive information based on the information delivered by the ISR apparatus to the decision maker as the basis for decision-making.

Figure 5. The illustration of the defense regions

Assume the ISR apparatus of the defense system detect intrusions to our country's borders in several locations at the same time. The list of detected intrusions is presented in Table 2. The "Detected" term means that the ISR apparatus detects any activity related to one or more types of intrusion listed in the table, while the "Not Detected" term presents the opposite situations. The activity of the ISR apparatus in gathering information regarding intrusion activities is called Observ(ation).

The information listed in Table 1 is delivered to the command post to be further processed in Orient(ation) phase. The information processing in Orient phase has to be done in a very quick manner so the decision maker can make the decision in a quick manner as well. The information delivered by the system is used by the decision maker to decide the forces distribution to each region. The distribution is depended on the number and kind of intrusion reported from each region.

Table 2. List of Detected Intrusions on Each Defense Region

Type of Intrusion	*Defense Region (Detected = +, Not Detected = -*			
	1	*2*	*3*	*4*
Illegal Fishing	-	-	+	+
Illegal Logging	+	+	+	+
Illegal Flight	+	-	+	+
Illegal Trespassing	-	+	-	+

4.1 A3S Computation

In this section we present a simple example on how to apply A3S for obtaining estimation values. Before the applying the A3S method to the information presented in Table 2, we have to preprocess it to become a matrix of binary-form sequences. This can be done by converting the '+' sign to binary '1' and the '-' sign to binary '0' as presented to Table 3.

Table 3. Binary-form Sequences Representing the Information in Table 2.

Type of Intrusion	*Defense Region (Detected = 1, Not Detected = 0*			
	1	*2*	*3*	*4*
Illegal Fishing	*0*	*0*	*1*	*1*
Illegal Logging	*1*	*1*	*1*	*1*
Illegal Flight	*1*	*0*	*1*	*1*
Illegal Trespassing	*0*	*1*	*0*	*1*

To obtain the a posteriori information like the one displayed in Table 1, we use a special case in probability theory namely Bayes method. It is not a common matter to use it to process binary-form sequences. This is the reason why we call this preprocessing mechanism as binary Bayes computation. The results of the computation are listed in Table 4.

4.2 A3S Results

The outputs from the preprocessing section will be used as the inputs for A3S method. The computation mechanism follows the red-line box shown in Table 1 and it will be done to all columns in parallel-processing manner. After applying Equation (1), we will get the values in the lowest line of Table 4.

In order to apprehend what the most critical violation and the most vulnerable location related to the current situation, we must apply Equation (2) to obtain the estimation values as follows.

Table 4. The A Posteriori Probabilities of Situation Presented in Table 2.

Type of Intrusion	*Defense Region (Detected = 1, Not Detected = 0*			
	1	*2*	*3*	*4*
Illegal Fishing	*0*	*0*	*0.5*	*0.5*
Illegal Logging	*0.25*	*0.25*	*0.25*	*0.25*
Illegal Flight	*0.333*	*0*	*0.333*	*0.333*
Illegal Trespassing	*0*	*0.5*	*0*	*0.5*
A3S	*0.146*	*0.188*	*0.271*	*0.396*

$$P\left(A_i \boxed{+} B_j\right)_{est} = \max_{i=1,\ldots,4}\left(0.146, 0.188, 0.271, 0.396\right) = 0.396 \quad (3)$$

The results after applying A3S information-inferencing fusion can be viewed from two perspectives. The first result delivers the comprehensive information regarding the regions intrusion DoCs of all defense regions as presented in Table 4 and the result in Equation (3). The second result delivers the comprehensive information regarding the DoCs of the types of intrusion to all defense regions.

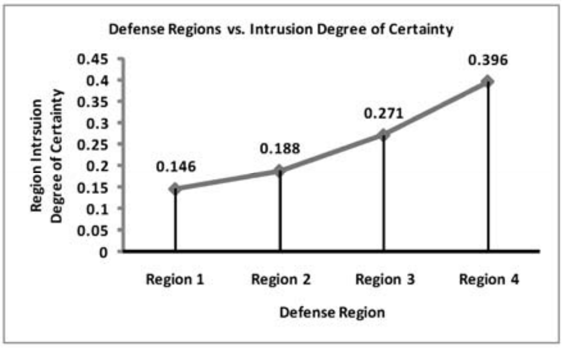

Figure 6. The DoCs of all defense regions intrusion

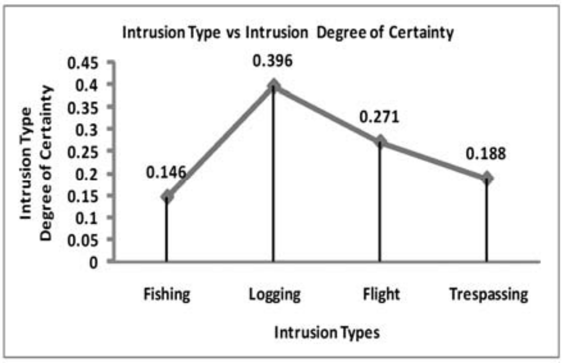

Figure 7. The DoCs of the types of intrusion to all regions

Figure 6 and Figure 7 subsequently depict the A3S results for the two views. In Figure 6 we can observe that Region 4 is the region with the most often violated by any kind of intrusion followed by Region 3, Region 2, and Region 1. In the same manner, in Figure 7 we can also observe that the most often intrusion occurs is illegal logging followed by illegal flight, illegal trespassing, and illegal fishing.

4.3 Inferencing of the A3S Results

We take Region 4 as the example. In general, we can assess why Region 4 has the highest intrusion alert. As we can see in defense region distribution as depicted in Figure 5, Region 4 has many "defense holes" such vast ocean on the north and south areas, extensive forested area, vast air area, and a very long border with a neighbor country.

After apprehending the situations presented in Section 4.1, the decision maker instructs his supporting staffs to devise an operation plan in order to cope with the situations. As the example is Region 4. The decision maker can instruct to deploy more air and sea forces to cover the air and sea areas in Region 4. The task of the air and sea forces is not only cover the areas, but also anticipate and face all possible situations that use air and sea areas as the access way to violate our country's sovereignty.

5. CONCLUDING REMARKS AND RECENT WORKS

In defending the Republic of Indonesia sovereignty against all possible violations, the decision maker who responsible for nation defense system has to have a means to accelerate the information processing and be able to obtain comprehensive information as the basis for him to make decisions in accurate and quick manner.

Accelerating the information processing has to be done in Orient(ation) phase of OODA defense decision-making cycle while obtaining good comprehensive information quality. For this purpose we have utilized A3S (Arwin-Adang-Aciek-Sembiring) information-inferencing fusion method. The results of the utilization of A3S method as already presented in a simple example on nation defense problem shows that the information processing can be accelerated and the products of the information-inferencing fusion can give comprehensive information as the basis for decision-making.

The utilization of A3S method ensures that the OODA defense decision-making cycle can be reduced into minimum especially in Orient(ation) phase. Therefore, it can guarantee that the decision can be taken in a very quick manner so that any country's sovereignty whether it is on the land, sea, or air can be anticipated as soon as possible with the correct forces distribution.

OODA defense decision-making cycle is a dynamic cycle that cycles repeatedly. The A3S method is prepared to handle this dynamic situation. For dynamic environment, the first cycle result becomes previous or prior information that will be combined with new information to obtain new knowledge.

In our recent works, we have developed A3S method so it now it can handle continuous information delivery from the sensors. The developed A3S is called as Observation Multi-Time A3S or OMA3S that is aimed to be applied as the knowledge growing method for Knowledge Growing Systems (Sumari, 2009).

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REFERENCES

Ahmad, A.S., and Sumari, A.D.W. (2008a). *Multi-Agent Information Inferencing Fusion in Integrated Information System*. School of Electrical Engineering and Informatics, Institut Teknologi Bandung, Bandung, Indonesia: ITB Publisher, ISBN 978-979-1344-31-9.

Ahmad, A.S., and Sumari, A.D.W. (2008b). Information Fusion in C4ISR Framework: Concep and Application to Nation Defence (IFiND). *Proceedings of the International Seminar on C4I Research 2008*, Ajou University/ROK Joint Chiefs of Staff, 13 November, Seoul, South Korea, pp. 67-180.

Senne, K.D., and Condon G.R. (2007). Integrated Sensing and Decision Support. *Lincoln Laboratory Journal*, *16*(2), 237-243.

Sumari, A.D.W. (2008a). Design and Implementation of a Multi-Agent Information Fusion System for Decision Making Support in Air Operation Planning, *Magister Teknik (M.T.) Thesis*, Institut Teknologi Bandung, Bandung, Indonesia, March. (in Indonesian)

Sumari, Arwin D.W. (2008b). Mathematical Modeling of A3S (Arwin-Adang-Aciek-Sembiring) Information-inferencing Fusion Method, *Technical Report*, Institut Teknologi Bandung. (in Indonesian)

Sumari, Arwin D.W. (2009). The Modeling of Knowledge Growing System based on Observation Multi-Time A3S (OMA3S) Method, *Technical Report*, Institut Teknologi Bandung. (in Indonesian)

Sumari, A.D.W., and Ahmad, A.S. (2008). Design and Implementation of Multi Agent-based Information Fusion System for Supporting Decision Making (a Case Study on Military Operation), *ITB Journal of Information and Communication Technology*, *2*(1), May, Institut Teknologi Bandung, Bandung, pp. 42-63, ISSN 1978-3086.

Sumari, A.D.W., Ahmad, A.S., Wuryandari, A.I., and Sembiring, J. (2009a). Information-Inferencing Fusion and Intelligence, *Prosiding* SENTIA09, Politeknik Negeri Malang, Malang, pp. F7-F11, ISSN 977-208-5234-00-7.

Sumari, A.D.W., Ahmad, A.S., Wuryandari, A.I., and Sembiring, J. (2009b). Collaborative Agents-based Information Fusion System for Strategic Missions, *Prosiding* SENTIA09, Politeknik Negeri Malang, Malang, pp. F67-F72, ISSN 977-208-5234-00-7.

US Army, Military Decision Making Process (MDMP). Accessed on March 30, 2009 from http://www.ncoschoolcom/dl/train/slide-shows /Operations/Military%20Decision%20Making %20Process%20(MDMP)%201%20-%20 Receipt%20of%20Mission.ppt.

US Department of Defense (1996). *Joint Doctrine for Command Control Warfare (C2W). Joint Publication 3-13.1*. Accessed on March 30, 2009 from http://www.iwar.org.uk/rma/resources/c4i/ jp3_13_1.pdf.