

Collaboration intelligence based on shared process with process flow control

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In information systems development, there have been consistent efforts to reduce human involvement which causes time, cost, and error in many cases. However, this is difficult and often impossible to do so. With the increasing importance of collaboration, we proposed the concept of collaboration intelligence to measure the level of capacity required to achieve a given task while collaborating with each other. We defined four kinds of intelligence which are human, machine, interface, and system intelligence to represent the cooperative impact of human and machine elements in your system. To that end, we developed a mathematical model and analyzed the characteristics of collaboration intelligence. We also performed a simulation analysis for various situations. According to mathematical model and comparison, we address design guidelines in this paper.

Keyword: - collaboration intelligence, shared process, process flow control, B2B, supply chain management, supply chain integration, simulation

1. Introduction

With the thriving applications of World Wide Web, “collaboration” over the Web or other media is a broad area of research (Brickley 2004). Applications are wide enough to cover most of business transactions such as supply chain management (SCM), Business to Business (B2B) e-commerce and globalization in manufacturing and service. As well as enterprise level applications, you can find specific applications for collaboration. For examples, a role model has been studied in software engineering (Kendall 2000) and a small group design meetings is studied in human computer interaction (Olson 1992) to achieve a higher level of collaboration. We will focus on business transaction in this paper.

In the mean time, there have been consistent efforts to reduce the amount of human involvement in integration in information system development (Pollock et al. 2004a), because the less human resource we use, the less cost we need and the more control we have. In many cases the amount of human involvement directly causes more cost, time and error. However, it has rarely been an easy job to remove the role of human in sophisticated functions and it will not be achieved in the near future. Therefore it is worthwhile to consider the effect of human involvement in a company’s transaction.

If we need a larger amount of human involvement, it means we require more information to be processed by humans. Similarly, if we need a larger amount of machine involvement, we require more information to be processed by the machine. Now, the requirement of processing more information either for human or machine demands a higher level of intelligence.

We proposed a concept of the level of collaboration intelligence or intelligence for brevity (Park et al. 2003a) (Park et al. 2003b). There have been a variety of definitions and usages of intelligence depending upon different fields of study (Albus 1991) (Weiss 2001). The major characteristic of intelligence is capacity to achieve a goal (Albus 1991) (Mifflin 2001a) (Mifflin 2001b). On the other hand, the interactions between human operators and control room equipment were investigated from an information theoretic approach to man-machine interface complexity evaluation (Kang et al. 2001).

In this paper, we chose a comprehensive definition to incorporate various types of intelligence such as human, machine, and system. Our definition of level of intelligence is to represent the capability to acquire and apply knowledge we require to process a given task while collaborating with other parties. Also we will show the level of intelligence is different depending on the degree of human involvement by both mathematic analysis and simulation. Also difference in the degree of human involvement causes differences in the level of intelligence required for communication in a software changes as well as the cost, cycle time and maintenance (Pollock et al. 2004b).

The following characteristics can be identified for jobs requiring a high level of intelligence to be finished.

- More time required to finish.
- More complex to finish
- More resources needed, such as manpower and money

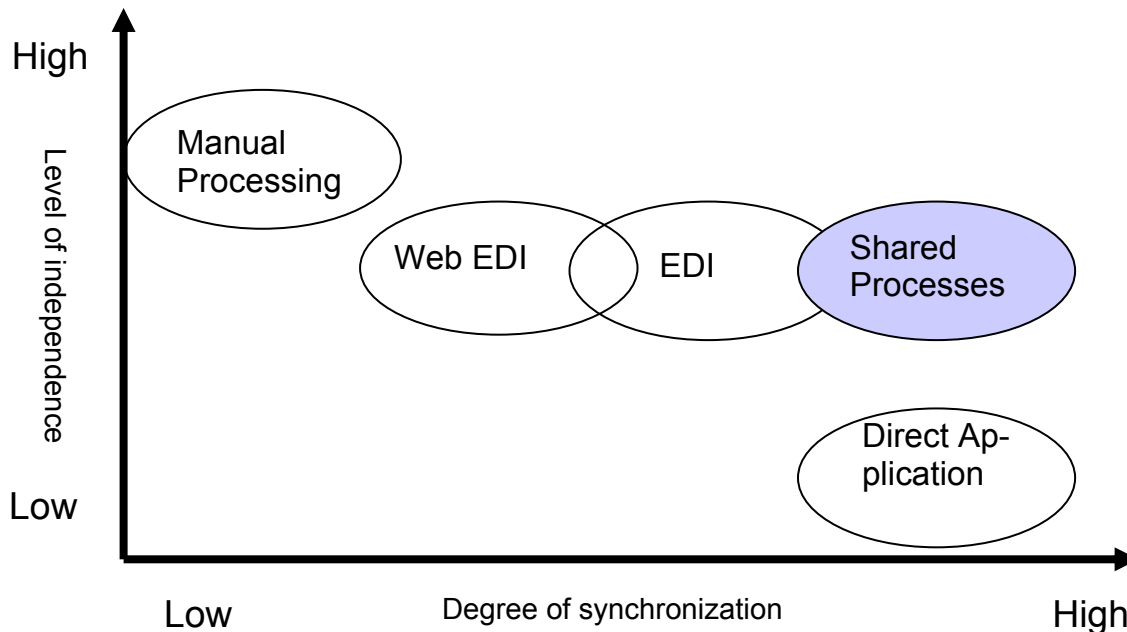


Fig. 1. Comparison of modes in terms of different intelligence level, (Park 2002) (Olsen 2000)

We considered three cases in terms of the degree of automation. As one can assume we design three cases according to the criteria that the more automated, the less human work needed. Three cases are:

Case MP: Manual processing (minimally supported by information system)

Case EDI: Electronic data interchange (EDI) usage (semi supported) or other semi-automated software

Case SP: Shared process with process flow control (PFC) (fully supported) (Park et al. 2003c) (Park 2003) (Park et al. 2003d) (Park 2002).

Especially we have been studying the role of PFC in B2B (Park et al. 2003d) (Park 2002). The role and architecture of PFC for e-business are described in (Park et al. 2003c) (Park 2003) (Park et al. 2003d) (Park 2002).

In terms of independence and synchronization, we position each case in Fig. 1 which is developed from (Park 2002) and (Olsen 2000). Web EDI is added for the purpose of comparison in our simulation.

A. ADVANTAGES OF SHARED PROCESSES

Modern enterprises are facing more challenges of coping with highly distributed working environment (Ghosh 2004). By highly distributed, it does not necessarily mean physically separated, it means more in terms of easiness and frequency of communication (Dix et al. 1993). Even though they are separated geographically, it is not really highly distributed if they can communicate with each other without difficulty. Therefore the degree of distribution is a matter of not a distance between two parties but the degree of easiness in communication.

How to communicate and coordinate in this distributed setting has been a non-trivial task (Ghosh 2004). One of the good examples which demonstrate these difficulties is in the area of product development (Ghosh 2004). In this area, there have been good amount of endeavor to solve these problems both technically (Ghosh 2004) (Linpack 1997) and non-technically (Ghosh 2004) (Anschuetz 1998). By technical solving, they mean the application of information technology and by non-technical solving, they do cultural approach. In this paper, we will focus on the adoption of information technology, shared processes following what we have done so far (Park et al. 2003d) (Park 2002) (Nof 2000) (Nof 2003).

In terms of intensiveness and extensiveness of sharing, firms have greatly benefited from effectively sharing their data within their organization. However, there are clear limitations in sharing data only. When a process changes, this change will not be efficiently reflected into the new system unless human administrator actually specifies the process. We can overcome this obstacle and collaborate much better by employing the concept of shared processes. (Wise et al. 2000) addresses a pressing need for standardization, beyond-profit, yet streamlined transactions for successful B2B.

Even though we can easily conjecture the benefit of employing a fully automated middleware when communications between two parties are necessary, there is no quantified measure in terms of the level of intelligence we need.

One could argue why we should analyze collaboration intelligence. Without the careful analysis of collaboration intelligence, we could waste financial resources on unnecessary investments. Having no criteria on collaboration intelligence, we cannot forecast how much resource we should put in terms of the relationship between investment and benefit. By observing the behavior of collaboration intelligence, we tried to find basic characteristics, thus providing criteria for investments.

In this paper, we formulated each case by considering the assignment relation between a task and amount of intelligence and provided a guideline for the level of intelligence in information system design. We also verified those results by simulation.

B. COMPARISON OF COMPLEXITY

To appreciate the advantage of a shared processes approach in terms of complexity, we provided a simple example from e-business. In this example, you will see how a shared process approach becomes more desirable in reducing the complexity of collaboration, as the scale of business grows.

1) Conventional way:

Let us suppose two organizations A and B are collaborating with each other in an industry. If A needs to introduce another supplier C into the collaborating community, they need to set up new communication channels (Fig. 2). If new member C has a different business process as well as a different data format for transaction, then they need to set up another two different channels of communication. The number of communication channels grows exponentially as the number of participant into the community increases, such as in B2B. When we look at the Fig. 2, we can see a combinatorial expansion of communication channels.

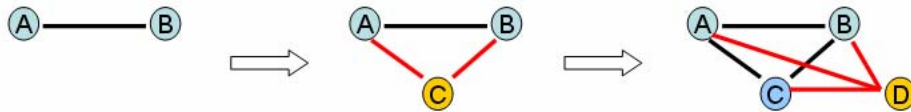


Fig. 2. Complexity of conventional way of collaboration

2) Shared process approach:

For the same situation shown in Fig. 2, they need only one additional communication link as a new participant is introduced (Fig. 3). Thus we can apply the system repeatedly no matter how many participants are introduced. Therefore, our approach has a clear advantage when the number of participants into the collaborating community is increasing with the complexity required remained constant.

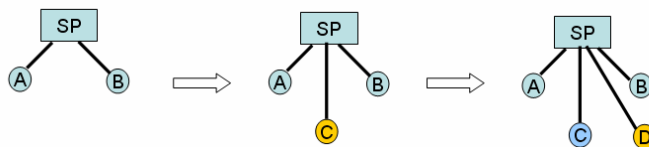


Fig. 3. Complexity of collaboration for shared processes

Therefore, we can high potential of shared process approach over conventional way for large scale enterprise information system in terms of applicability and scalability as the number of participants increases.

At the later sections, we build a mathematical model and validate it. Mathematical analysis provided concrete and accurate criteria for analysis of collaboration intelligence. Also one will see a simulation analysis and the same result as in the mathematical modeling.

2. Mathematical Analysis of Collaboration Intelligence

Our earlier analysis for mathematical modeling appeared in (Im et al. 2005a). To have a mathematical formulation, we defined necessary parameters and variables as follows. First, let's suppose we have n sets of sub-processes.

$$T = \{T_1, T_2, \dots, T_N\}$$

Also, we define an assignment matrix for all n subprocesses,

$$A = \begin{bmatrix} a_{1m} & a_{2m} & \dots & a_{n-1,m} & a_{n,m} \\ a_{1h} & a_{2h} & \dots & a_{n-1,h} & a_{nh} \end{bmatrix}^T \quad (1)$$

Where

$$a_{im} = \begin{cases} 1 & \text{if (sub)process } i \text{ is performed by computer system} \\ 0 & \text{if Otherwise} \end{cases}$$

$$a_{ih} = \begin{cases} 1 & \text{if (sub)process } i \text{ is performed by human} \\ 0 & \text{if Otherwise} \end{cases}$$

$$a_{im} + a_{ih} = 1 \quad \text{for all } i, 1 \leq i \leq n$$

a_{im} and a_{ih} are typical binary variables showing the choice of model. The sum of a_{im} and a_{ih} is always 1 because each sub process can either be assigned by human or machine, not by both at the same time.

Now we need to define how we can represent the amount of intelligence required to execute T_i ,

$$\tau = [\tau_1, \tau_2, \dots, \tau_n]^T$$

Here, we assume τ_i for human is bigger than τ_i for machine, which is reasonable and realistic assumption because nobody tries to reduce human involvement otherwise.

We also need to define interface complexity parameters and the amount of data transfer as follows.

C_{hm} : interface complexity measure from human to machine

C_{mh} : interface complexity measure from machine to human
 f_{ih} : amount of data transfer between two processes i, j

To represent intelligence of human, machine, and total system, we define variables as follows. I_H represents intelligence of human while I_M and I_{SYS} each represents that of machine and total system.

Human represents those components operated by people. Machine represents hardware, and software. For the case 3 it could be middleware.

$$I_H = \sum_{i=1}^n a_{ih} \tau_i + C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im} a_{jh} f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih} a_{jm} f_{ij} \quad (2)$$

$$I_M = \sum_{i=1}^n a_{im} \tau_i \quad (3)$$

In (2), we define operational intelligence as $\sum_{i=1}^n a_{ih} \tau_i$ and interface intelligence (I_f) as

$$C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im} a_{jh} f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih} a_{jm} f_{ij} .$$

Similarly, in (3), we define operational intelligence as $\sum_{i=1}^n a_{im} \tau_i$.

Operational intelligence represents the intelligence required to be operated purely by human in (2) and by machine in (3). Interface intelligence represents the intelligence required when we need to hand over tasks from human to machine or vice versa. We include interface intelligence in human intelligence because most of the interface task is performed by human.

In (2) of case C, we don't need to consider both second and third term because it has no human component associated with it and there is no interface accordingly.

A. Comparison of operational intelligence and interface intelligence

Both in human and machine intelligence, operational intelligence is significantly bigger than interface intelligence in practice. If we could think about a copier that require us to take significant amount of time for set up, it is not critical whether we can get a high speed copier machine or not. Rather we would try to reduce time for set up. However, in a real business situation, a person in charge in an organization would not allow this situation to keep happening. If we need to take more time interfacing with machine component(s) then the operation time for the machine, we can easily sense that there is something wrong. We will take an immediate action or we would reconsider introducing machine component in our system.

$$\begin{aligned} I_{SYS} &= I_H + I_M \\ &= \sum_{i=1}^n a_{ih} \tau_i + C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im} a_{jh} f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih} a_{jm} f_{ij} + \sum_{i=1}^n a_{im} \tau_i \end{aligned} \quad (4)$$

We considered three cases in terms of the level of intelligence required or the degree of human involvement (Recall section I). We will take a closer look on each case from now on.

Case MP:

For the case MP, from equation (2), we divide $\sum_{i=1}^n a_{ih} \tau_i$ in detail into two parts. The former would be the component that it will stay as manual, while the latter being automated in the future. For example, if there is a company that performs its purchasing process completely manually at the current stage. Assume both the collecting of documents and purchasing decision are being done by human workers. Since the collecting of documents is routine and simple job, the company could make a decision that it should be automated in the near future with insignificant expense. However, to make a purchasing decision is not a trivial job and it will cost considerable money for the company to introduce DSS (Decision Support System). Thus in most cases, making a purchasing decision would still be done by the human expert. Therefore we can represent the reality if we divide our model into two parts. In addition, we will see another benefit later in that it would be helpful in comparing the amount of intelligence needed among three cases.

Case EDI:

$$\begin{aligned} I_{SYS} &= I_H + I_M \\ &= \sum_{i=1}^n a_{ih} \tau_i + C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im} a_{jh} f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih} a_{jm} f_{ij} + \sum_{i=1}^n a_{im} \tau_i \end{aligned} \quad (5)$$

$$I_M = \sum_{i=1}^n a_{im} \tau_i \quad (6)$$

This case we can see no change from the general formula defined in (2), (3) and (4). In this case, we need to consider both I_H and I_M to get I_{SYS} . I_M stays the same as the general formula in (3).

Case SP:

In this case, intelligence of total system is nothing but the intelligence of machine, which is easily expected. We completely got rid of the need for human intelligence even though it is highly unlikely in practice. Also, just like in case MP, interface intelligence will be 0 since no interface is required.

$$\begin{aligned} I_{SYS} &= I_M \\ &= \sum_{i=1}^n a_{im} \tau_i \end{aligned} \quad (7)$$

3. Mathematical analysis - comparison of intelligence among each case

From the manipulation of the formula, we can obtain the following results which do not contradict our intuition. For convenience we call the case MP, EDI and SP as case A, B and C each in this section.

Let's compare the amount of intelligence for case A and that for case B, each denoted by I_{SYS}^A and I_{SYS}^B . From (5) we can say,

$$\begin{aligned} I_{SYS}^A &= \sum_{i=1}^n a_{im}^A \tau_i + \sum_{i=1}^n a_{ih}^A \tau_i \\ &= \sum_{i=1}^n a_{im}^A \tau_i + \sum_{\substack{i=1 \\ i \notin k}}^n a_{ih}^A \tau_i + \sum_{\substack{i=1 \\ i \in k}}^n a_{ih}^A \tau_i \end{aligned} \quad (8)$$

since second and third terms are zero in case A.

Like we mentioned before, we divided the term, $\sum_{i=1}^n a_{ih}^A \tau_i$ into two new terms whether it will be automated or not in the future as in (9).

$$\sum_{\substack{i=1 \\ i \notin k}}^n a_{ih}^A \tau_i \quad \text{and} \quad \sum_{\substack{i=1 \\ i \in k}}^n a_{ih}^A \tau_i \quad (9)$$

Where, $k = \{i \mid a_{im}^{Af} = 1, a_{im}^{Ap} = 0\}$,

And

$$a_{im}^{Af} = \begin{cases} 1 & \text{if subprocess } i \text{ is performed by computer} \\ & \text{system in the future in case A} \\ 0 & \text{if Otherwise} \end{cases}$$

$$a_{im}^{Ap} = \begin{cases} 1 & \text{if subprocess } i \text{ is performed by computer system now in case A} \\ 0 & \text{if Otherwise} \end{cases}$$

We expanded our definition of a_{im} in (1) into a_{im}^{Af} and a_{im}^{Ap} . Again, the former represents whether the subprocess is performed by computer system or not in the future and while the latter represents the same for now.

Here, k means those i tasks that are manually processed currently but will be automated in the future as depicted in (9).

On the other hand, we also know from (5),

$$I_{SYS}^B = \sum_{i=1}^n a_{im}^B \tau_i + \sum_{i=1}^n a_{ih}^B \tau_i + C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im}^B a_{jh}^B f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih}^B a_{jm}^B f_{ij} \quad (10)$$

Now from (8) and (10), we can compare I_{SYS}^A and I_{SYS}^B , if we calculate I_{SYS}^A subtracted from I_{SYS}^B , we will get a positive value when $\sum_{\substack{i=1 \\ i \in k}}^n a_{ih}^A \tau_i$ is bigger than the sum of $\sum_{i=1}^n a_{im}^B \tau_i$ and

$$C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im}^B a_{jh}^B f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih}^B a_{jm}^B f_{ij}$$

- which is the case most of the time because of the assumptions that τ_i for human is bigger than τ_i for machine and that interface intelligence is significantly smaller than machine intelligence - because $\sum_{\substack{i=1 \\ i \notin k}}^n a_{ih}^A \tau_i$ is equal to $\sum_{i=1}^n a_{ih}^B \tau_i$.

(It is obvious that $\sum_{i=1}^n a_{im}^A \tau_i$ is zero.) Therefore, from the formula we showed I_{SYS}^A is bigger than I_{SYS}^B .

Now, let's compare the amount of intelligence of human for case A and B, each denoted by I_H^A and I_H^B . From (2) we can say,

$$\begin{aligned} I_H^A &= \sum_{i=1}^n a_{ih}^A \tau_i + C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im}^A a_{jh}^A f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih}^A a_{jm}^A f_{ij} \\ I_H^B &= \sum_{i=1}^n a_{ih}^B \tau_i + C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im}^B a_{jh}^B f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih}^B a_{jm}^B f_{ij} \end{aligned} \quad (11)$$

The first term of A can be divided into two terms as in comparison of system intelligence, which is

$$\sum_{i=1}^n a_{ih}^A \tau_i = \sum_{\substack{i=1 \\ i \notin k}}^n a_{ih}^A \tau_i + \sum_{\substack{i=1 \\ i \in k}}^n a_{ih}^A \tau_i.$$

Note the facts that $\sum_{\substack{i=1 \\ i \notin k}}^n a_{ih}^A \tau_i$ is the same as $\sum_{i=1}^n a_{ih}^B \tau_i$ and that the value of

$$C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im}^A a_{jh}^A f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih}^A a_{jm}^A f_{ij}$$

equals always zero. Therefore if we subtract I_H^B from I_H^A , we will obtain

$$\sum_{\substack{i=1 \\ i \in k}}^n a_{ih}^A \tau_i - \left(C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im}^B a_{jh}^B f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih}^B a_{jm}^B f_{ij} \right).$$

From our assumption that operational intelligence is significantly bigger than interface intelligence, we can conclude that this value is positive. Therefore I_H^A is bigger than I_H^B .

In an extreme case, it will be possible that I_H^B is bigger than I_H^A if the interface intelligence in case B is significant bigger than human intelligence in case A. However, it does not have much practical meaning, since we assume that τ_i for human is larger than τ_i for machine and that $\sum_{i=1}^n a_{im} \tau_i$ is significantly bigger than interface intelligence in any cases. Also, we can easily conclude that I_M^A is smaller than I_M^B . (In fact I_M^A is zero.)

Now let's compare between case B and case C to make our comparison complete. For the comparison of I_{SYS} 's, we can do a similar manipulation as in (8). From (4) we can again say,

$$I_{SYS}^B = \sum_{i=1}^n a_{im}^B \tau_i + \sum_{i=1}^n a_{ih}^B \tau_i + C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im}^B a_{jh}^B f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih}^B a_{jm}^B f_{ij}.$$

On the other hand, since

$$\sum_{i=1}^n a_{ih}^C \tau_i = 0$$

and

$$C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im}^C a_{jh}^C f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih}^C a_{jm}^C f_{ij} = 0.$$

$$\begin{aligned} I_{SYS}^C &= \sum_{i=1}^n a_{im}^C \tau_i + \sum_{i=1}^n a_{ih}^C \tau_i + C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im}^C a_{jh}^C f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih}^C a_{jm}^C f_{ij} \\ &= \sum_{i=1}^n a_{im}^C \tau_i \end{aligned} \tag{12}$$

Now, we can easily see that I_{SYS}^B is bigger than I_{SYS}^C from the assumption that τ_i for human is larger than τ_i for machine not to mention the interface portion of I_{SYS}^B . It may become clearer if we divide $\sum_{i=1}^n a_{im}^C \tau_i$ into two parts, first being the parts it was performed by machine and second being the parts was performed by human in EDI cases. This is a similar way as in (8).

Let's compare the amount of human intelligence between B and C. From (2) we can again say,

$$\begin{aligned}
I_H^B &= \sum_{i=1}^n a_{ih}^B \tau_i + C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im}^B a_{jh}^B f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih}^B a_{jm}^B f_{ij} \\
I_H^C &= \sum_{i=1}^n a_{ih}^C \tau_i + C_{mh} \sum_{i=1}^n \sum_{j=1}^n a_{im}^C a_{jh}^C f_{ij} + C_{hm} \sum_{i=1}^n \sum_{j=1}^n a_{ih}^C a_{jm}^C f_{ij}
\end{aligned} \tag{13}$$

Similar reasoning as in comparison of I_H^A and I_H^B , we can conclude that I_H^B is greater than I_H^C . (In fact, I_H^C is zero.)

Now, compare the amount of machine intelligence between B and C.

$$\begin{aligned}
I_M^B &= \sum_{i=1}^n a_{im}^B \tau_i \\
I_M^C &= \sum_{i=1}^n a_{im}^C \tau_i
\end{aligned} \tag{14}$$

I_M^C includes those terms performed by human and machine under EDI. It is clear that I_M^C is bigger than I_M^B .

From the above analysis, we have the following result in conclusion.

$$\begin{aligned}
I_{SYS}: MP > EDI > SP \\
I_H: MP > EDI > SP \\
I_M: MP < EDI < SP
\end{aligned} \tag{15}$$

When we make a setting for our simulation, it will be better to get a real value for C_{hm} and C_{mh} from the industry if we want to see more realistic figures. However, it is more important to consider relative figure rather than the absolute magnitude of the I_H , I_M , and I_{SYS} .

4. Simulation Analysis

We have shown the details of our mathematical model and analyzed the representation for each case. After we compared our model for each case mathematically, we will also see the same result by simulation experiments. Simulation analysis is regarded as a reliable and effective method in studying the dynamic nature of manufacturing and production systems (Huang et al. 2003) (Baykoc et al. 1988). A good example of simulation analysis can be found in (Huang et al. 2003). A simulation model is built for the assembly line with a discrete event system simulator in (Huang et al. 2003). Our primitive simulation analysis appeared in (Im et al. 2005b).

Our simulation consists of two main scenarios. The first scenario is basic and is composed of SP, EDI and MP. The second scenario is more realistic and includes variations in practice. Both scenarios have following analysis.

- Graphical comparison
- ANOVA for 5, 10, 15 subprocesses

- Case study between EDI and SP

The main process consists of subprocesses to get a task done. Table 1 shows a composition of subprocesses in each case in our simulation. H represents a subprocess performed by human operator and M represents those by machine.

TABLE 1
SUBPROCESSES FOR SIMULATION

Number of Subprocesses	5	10	15
Cases			
Shared Process	M M M M M	M M M M M M M M M M	M M M M M M M M M M M M M M M M
EDI	M M H H M	M M H H M M H H M H	M M H H M M H H M H M H M H M H
Manual Processing	H H H H H	H H H H H H H H H H H H	H H H H H H H H H H H H H H H H H H

A. BASIC SCENARIO

In Table 3., we showed processing time for SP, EDI and MP. Originally they were obtained based on the survey data (especially rate of means). After a number of preliminary simulations, we obtained the parameters of significance in Table 3. We assume the rework rate as Table 2:

TABLE 2
REWORK RATE OF PROCESSING TIME DISTRIBUTIONS IN BASIC SCENARIO

	Maximum Rework for human	Maximum Rework for machine
SP		Rework: 1% of the mean
EDI	Rework: 10 % of the mean	Rework: 1% of the mean
MP	Rework: 10 % of the mean	

Please note that SP and EDI have the same distribution for machine subprocesses and MP and EDI have the same distribution for human subprocesses. Random numbers from uniform distribution are generated, depicted as (minimum, maximum). Here, the units do not matter as long as they are used in a consistent and comparable manner.

TABLE 3
PROCESSING TIME DISTRIBUTION FOR SIMULATION IN BASIC SCENARIO

<Processing Time Distribution for simulation> (Random numbers from Uniform distribution generated)

	ProcessA(Human)			ProcessB(Machine)			Interface		
		mean	variance		mean	variance		mean	variance
SP	0	0	0	(0.54,0.66)+(0,0.06)	0.6	0.06	0	0	0
EDI	(2.6,3.4)+(0,0.3)	3	0.4	(0.54,0.66)+(0,0.06)	0.6	0.06	(0.04,0.08)	0.06	0.02
MP	(2.6,3.4)+(0,0.3)	3	0.4	0	0	0	0	0	0

1) For 5 subprocesses

Let us take a look at the one for 5 subprocesses. We are going to compare human intelligence, machine intelligence and system intelligence for SP, EDI and MP. For basic scenario, only EDI has positive value of interface intelligence, thus we can't really compare interface intelligence to other cases. For SP and MP, interface intelligence is zero since there is no need to interface between human and machine, or vice versa.

Let us begin with human intelligence. In the following Fig. 4, we can clearly see MP requires the highest level of human intelligence and next EDI, and lastly SP as we expected. In Table 4, we can also see that we confirmed their significant difference from each other through ANOVA test. It is clearly significant from checking *p*-value. Also from Table 5, we made sure the significant difference between any two cases by Fischer's least significant difference (LSD) method.

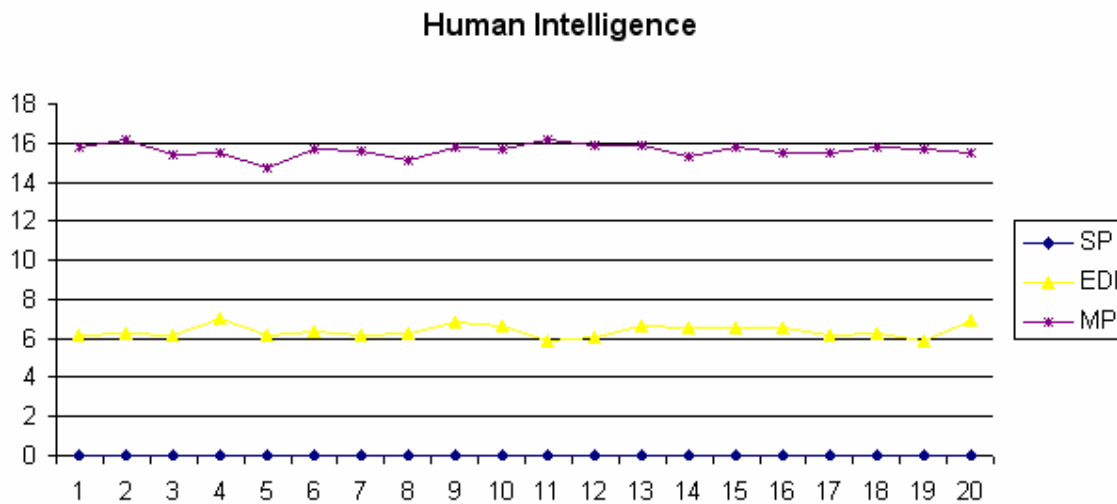


Fig. 4. Human intelligence required for 5 subprocesses

TABLE 4

ANOVA TEST FOR HUMAN INTELLIGENCE FOR 5 SUBPROCESSES IN BASIC SCENARIO

Human Intelligence: All

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
SP	20	0	0	0
EDI	20	127.5141	6.375705	0.102618236
MP	20	312.382	15.6191	0.111301779

ANOVA

Source of Vari	SS	df	MS	F	P-value	F crit
Between G	2466.975001	2	1233.488	17298.34629	4.57E-80	3.158846
Within Gro	4.06448029	57	0.071307			
Total	2471.039482	59				

TABLE 5
FISCHER'S LEAST SIGNIFICANT DIFFERENCE METHOD

LSD =	0.168886556		
EDI vs. SP			
=	6.375705	>	0.168887
MP vs. EDI			
=	9.243395	>	0.168887
MP vs. SP =	15.6191	>	0.168887
From this analysis, we can see that all pairs of means are significantly different.			

Let's consider machine intelligence. This time SP has the highest level, EDI next and MP last. Again ANOVA test and Fischer's LSD method are done to ensure the significance of difference.

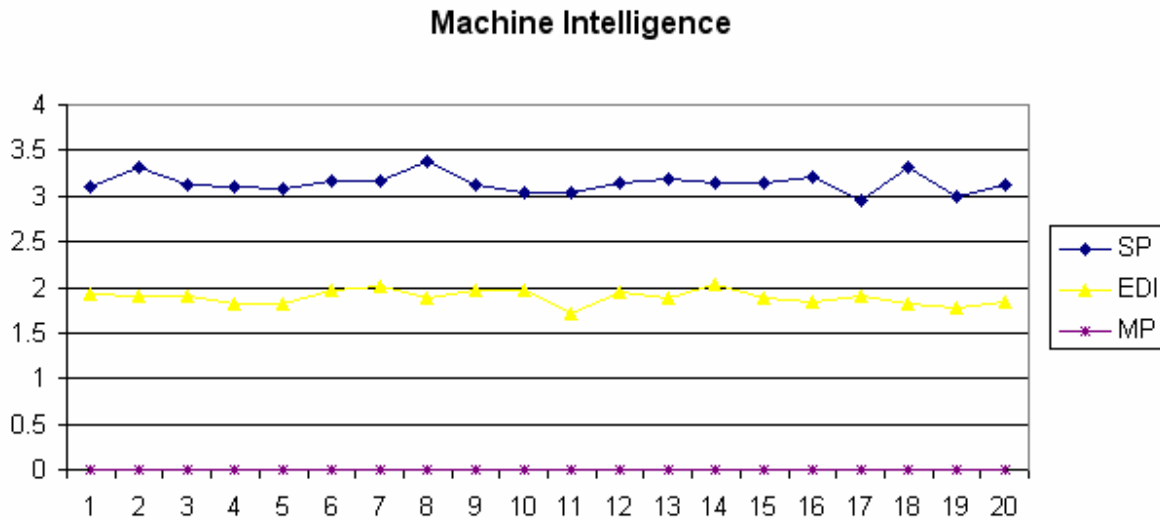


Fig. 5. Machine intelligence required for 5 subprocesses in basic scenario

Lastly, we compare system intelligence. This is the intelligence we are most interested in. MP has the highest level of intelligence, and EDI second, and SP last as we expected. We can see the same order in human intelligence. Also, we can say human intelligence has more influence than machine intelligence in deciding system intelligence.

Again, ANOVA test and Fischer's LSD method are done to ensure the significance of difference.

System Intelligence

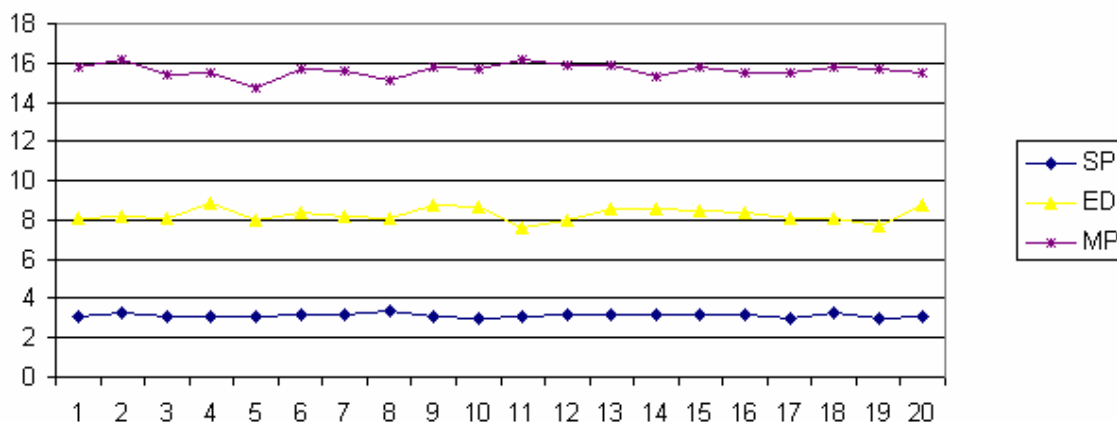


Fig. 6. System intelligence required for 5 subprocesses in basic scenario

2) For 10 and 15 subprocesses

There are no significant difference in comparison of human, machine, and system intelligence from 5 subprocesses cases. We will consider the pattern at 3).

3) Comparison between 5, 10, 15 subprocesses

From Table 6, we can see the average value for each intelligence in basic scenario.

TABLE 6
AVERAGES OF VALUES FOR EACH INTELLIGENCE IN BASIC SCENARIO

Intelligence and cases		no. of sub-processes		
		5	10	15
Human	SP	0	0	0
	EDI	6.375705	12.9401	19.2992
	MP	15.6191	31.33615	47.1867
Machine	SP	3.143075	6.35365	9.41577
	EDI	1.8898	3.796735	5.705205
	MP	0	0	0
Interface	SP	0	0	0
	EDI	0.121345	0.421957	0.657548
	MP	0	0	0
System	SP	3.143075	6.35365	9.41577
	EDI	8.2655	16.73675	25.0044
	MP	15.6191	31.33615	47.1867

Let us take a look at p -value to assess the significance of the differences in values for each intelligence between SP, EDI and MP. Refer to Table 7. As the number of subprocesses increases, p -value tends to become smaller with some exceptions. However, if we look at the ANOVA test in Table 8, we can see that they are not significantly different as the number of subprocesses increases. We believe it is so, because p -value becomes very small in 5 subprocesses. As we incorporate more criteria in our future simulation, we expect that the number of subprocesses may have more impact on the value of intelligences. Also, the rate of decrease slows down between 10 and 15.

TABLE 7
P-VALUE FOR BASIC SCENARIO

no. of subprocesses \ Intelligences	5	10	15
Human Intelligence	4.56638E-80	8.20858E-91	6.3066E-89
Machine Intelligence	3.13093E-71	8.17354E-85	3.89423E-89
Interface Intelligence	9.64232E-53	5.34709E-62	2.90998E-69
System Intelligence	7.2636E-73	2.96391E-84	1.17497E-82

Table 8
ANOVA TEST FOR P-VALUES

ANOVA test for p -value

one factor

No. of subprocesses factor

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
5	4	9.64232E-53	2.41E-53	2.3E-105
10	4	5.34709E-62	1.34E-62	7.1E-124
15	4	2.90998E-69	7.27E-70	2.1E-138

ANOVA

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	1.5496E-105	2	7.7E-106	1	0.405344	4.256492
Within Groups	6.9731E-105	9	7.7E-106			
Total	8.5227E-105	11				

From the simulation result for basic scenario, we verified the following result.

$$\begin{aligned}
 I_{SYS}: MP > EDI > SP \\
 I_H: MP > EDI > SP \\
 I_M: MP < EDI < SP
 \end{aligned}
 \tag{15}$$

4) *Case study in basic scenario*

Let us suppose we would like to answer the following question:

- What will be the lowest mean time of human process for EDI to be comparable with SP in the 5 subprocesses case?

Let's reconsider processing time distribution just for SP and EDI as in the following Table 9.

TABLE 9
PROCESSING TIME DISTRIBUTION FOR SP AND EDI IN BASIC SCENARIO

	Process A (Human)			Process B (Machine)			Interface		
	distribution	mean	variance	Distribution	mean	Variance	distribution	mean	Variance
SP	0 (2.6,3.4)+	0	0	(0.54,0.66)+ (0,0.06)	0.6	0.06	0	0	0
EDI	(0,0.3)	3	0.4	(0.54,0.66)+ (0,0.06)	0.6	0.06	(0.04,0.08)	0.06	0.02

From Table 10, we can see the procedure to search down the solution.

TABLE 10
A SOLUTION SEARCH PROCEDURE IN BASIC SCENARIO

Case	Mean human subprocess time for EDI	ANOVA result	Conclusion
1 st (Original case)	3	Significant!	
2 nd case	0.6	Insignificant!	Now we know that the solution lies between 0.6 and 3.
3 rd case	1	Significant	Now we know that the solution lies between 0.6 and 1.
4 th case	0.7	Significant!	Now we know that the solution lies between 0.6 and 0.7.

We may continue to narrow down the interval which the solution lies in after 4th case. Furthermore, we can do similar case study for 10 and 15 subprocesses

B. ADVANCED SCENARIO

In Table 11, we showed processing time for SP, Web EDI, EDI, MP+ and MP. Based on the basic scenario, we constructed parameters in the advanced scenario. Web EDI represents EDI with web user interface and MP+ represents manual processing with more guidelines. Please note that they have different distribution from each other both for human and machine except machine for SP and machine for EDI. If we compare the distribution of EDI and Web EDI, Web EDI has less time for human process and a little more time for machine. This is because Web EDI users don't need to worry about background transactions but machine need more job. By employing Web EDI we can achieve an overall time save, because the magnitude of time saving by reduction in human is bigger than the increase in machine.

TABLE 11
PROCESSING TIME DISTRIBUTION FOR SIMULATION IN ADVANCED SCENARIO

	Process A (Human)			Process B (Machine)			Interface		
	distribution	Mean	variance	Distribution	mean	variance	distribution	mean	variance
SP	0	0	0	(0.54,0.66)+ (0,0.06)	0.6	0.06	0	0	0
Web EDI	(2.3,2.7) + (0,0.25)	2.5	0.2	(0.63,0.77)+ (0,0.07)	0.7	0.07	(0.04,0.06)	0.05	0.01
EDI	(2.6,3.4)+ (0,0.3)	3	0.4	(0.54,0.66)+ (0,0.06)	0.6	0.06	(0.04,0.08)	0.06	0.02
MP+	(2.3,3.7)+ (0,0.6)	3	0.7	0	0	0	0	0	0
MP	(2.8,4.4)+ (0,0.72)	3.6	0.8	0	0	0	0	0	0

1) For 5 subprocesses

Like as in the basic scenario, let's consider the one for 5 subprocesses. We are going to compare human intelligence, machine intelligence and system intelligence for Web EDI, and MP+ as well as SP, EDI and MP.

Let us begin with human intelligence. In the following Fig. 7, for the MP, EDI and SP, they maintain the same order as in the basic scenario. Let's focus on Web EDI and MP+. They both have less human intelligence level compared to EDI and MP each. It makes sense because Web EDI requires less human intelligence because users don't need to worry about the interface. Also, MP+ requires less human intelligence because they have some guidelines. Again, the significance of difference was confirmed by ANOVA test and Fischer's LSD method.

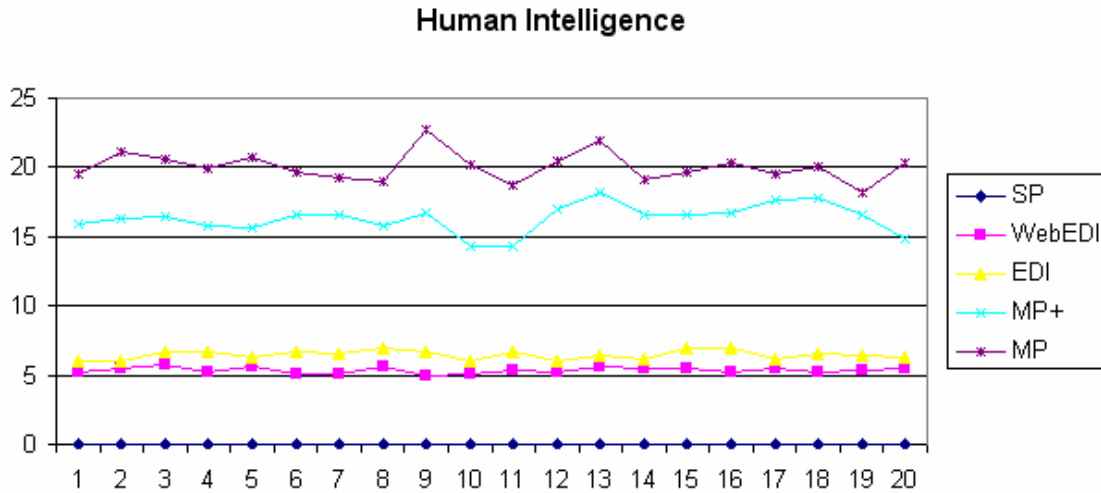


Fig. 7. Human intelligence required for 5 subprocesses in advanced scenario

Let's consider machine intelligence. Look at Fig. 8 below. SP has the highest level like in the basic scenario. (ANOVA test and Fischer's LSD method are done to ensure the significance of difference.)

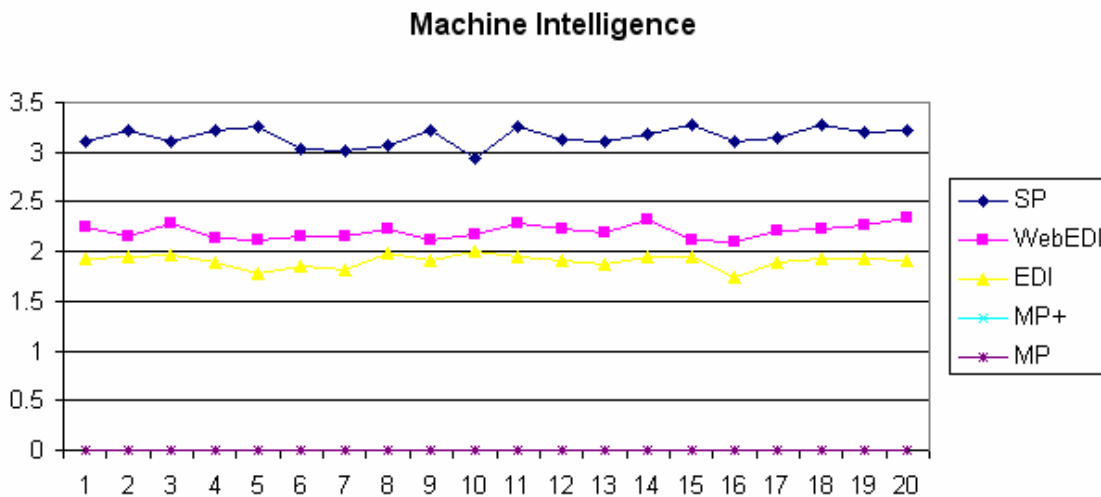


Fig. 8. Machine intelligence required for 5 subprocesses in advanced scenario>

Let's take a look at interface intelligence. This time we have two interface intelligences to compare. Web EDI has a lower magnitude of interface intelligence than EDI as expected. (ANOVA test and Fischer's LSD method are done to ensure the significance of difference.)

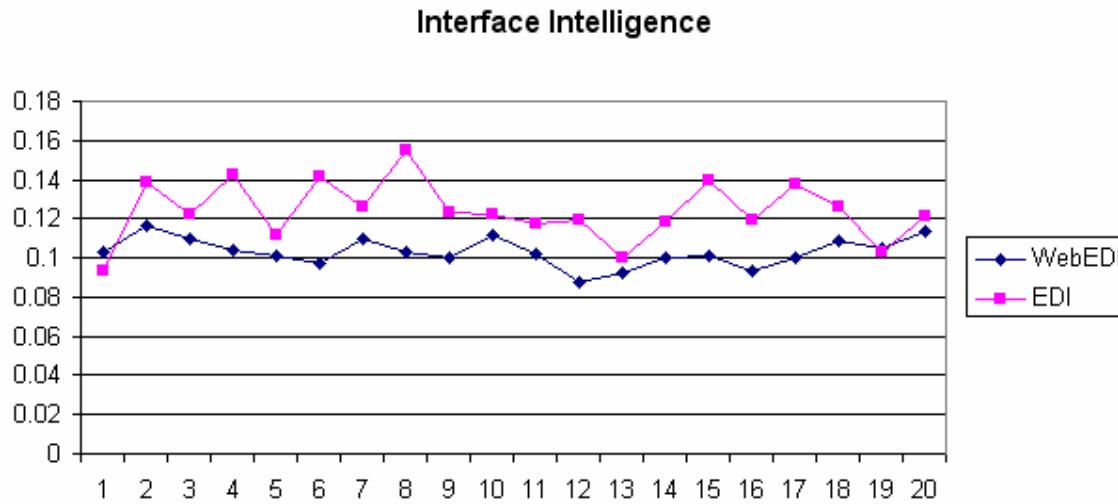


Fig. 9. Interface intelligence required for 5 subprocesses in advanced scenario

Lastly, let us compare system intelligence in which we are most interested in. The order of MP, EDI, and SP is not changed. Web EDI has lower level than EDI and MP+ has lower level than MP. In the advanced scenario, the order of system intelligence is the same as the one in human intelligence. We can conclude that human intelligence has more impact on system intelligence than machine intelligence. (ANOVA test and Fischer's LSD method are done to ensure the significance of difference.)

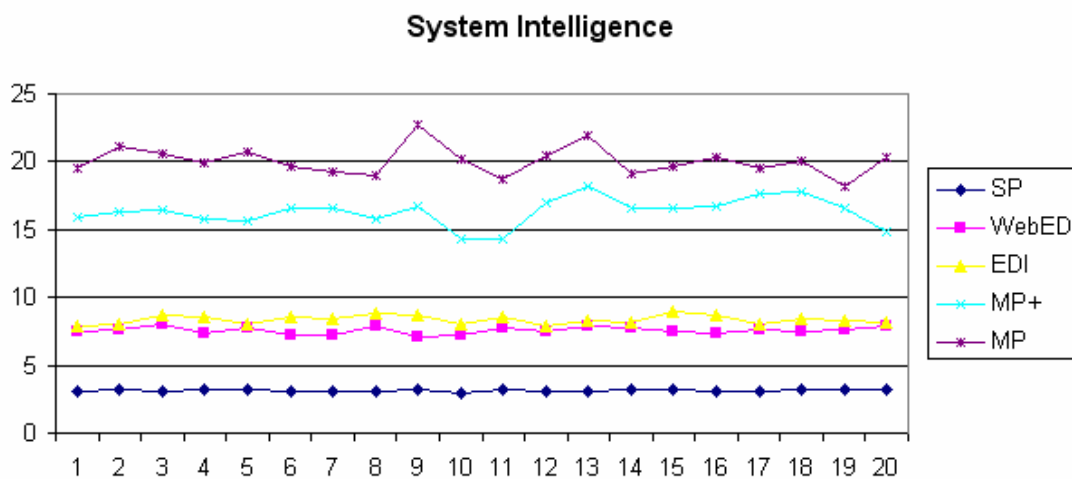


Fig. 10. System intelligence required for 5 subprocesses in advanced scenario

2) For 10 and 15 subprocesses

Like in the basic scenario, there is no significant difference in comparison of human, machine, and system intelligence from 5 subprocesses cases. We will consider the pattern at 3).

3) Comparison between 5, 10, 15 subprocesses

From Table 12 we can see the average values for each intelligence in advanced scenario.

TABLE 12
AVERAGES OF VALUES FOR EACH INTELLIGENCE IN ADVANCED SCENARIO

processes case		number of sub- intelligence /	5	10	15
			Human	SP	0
Web EDI	5.355965	10.95625		16.3286	
EDI	6.454885	13.10055		19.6345	
MP+	16.3063	33.26795		49.17035	
MP	20.024	39.4621		59.5911	
Machine	SP	3.15189	6.328415	9.464105	
	Web EDI	2.20166	4.376135	6.62504	
	EDI	1.90464	3.794445	5.66539	
	MP+	0	0	0	
	MP	0	0	0	
Interface	SP	0	0	0	
	Web EDI	0.103047	0.348545	0.543856	
	EDI	0.123919	0.427063	0.666942	
	MP+	0	0	0	
	MP	0	0	0	
System	SP	3.15189	6.328415	9.464105	
	Web EDI	7.557645	15.33235	22.95355	
	EDI	8.35952	16.89495	25.2999	
	MP+	16.3063	33.26795	49.17035	
	MP	20.024	39.4621	59.5911	

The analysis for p -values is very similar to the one in the basic scenario. As the number of subprocesses increases, p -value tends to become smaller with one exception. Refer to Table 13. However, like in basic scenario, they are not significantly different depending on the number of subprocesses. (Refer to Table 14.) We would like to make the same conjecture as in the basic scenario that it is so because p -value becomes very small in 5 subprocesses. As we incorporate more criteria in our future simulation, we expect that the number of subprocesses may have more impact on the value of intelligences. Also the rate of decrease slows down between 10 and 15.

TABLE 13
P-VALUE FOR ADVANCED SCENARIO

No. of subprocesses Intelligences	5	10	15
Human Intelligence	2.01254E-98	1.0565E-109	3.8192E-126
Machine Intelligence	4.8781E-125	4.6077E-140	2.9839E-150
Interface Intelligence	6.26298E-83	1.1718E-111	3.1467E-109
System Intelligence	8.77962E-91	5.4098E-102	3.7907E-118

Table 14
ANOVA TEST FOR P-VALUES

ANOVA test for p -value

one factor
no. of subprocesses factor

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
5	4	6.26298E-83	1.57E-83	9.8E-166
10	4	5.4098E-102	1.4E-102	7.3E-204
15	4	3.1467E-109	7.9E-110	2.5E-218

ANOVA

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	6.5375E-166	2	3.3E-166	1	0.405344	4.256492048
Within Groups	2.9419E-165	9	3.3E-166			
Total	3.5956E-165	11				

From the simulation result for advanced scenario, we verified the following result.

I_{sys}: MP > EDI > SP

$$I_H: MP > EDI > SP \quad (16)$$

$$I_M: MP < EDI < SP$$

This scenario has Web EDI and MP+ as well as SP, EDI and MP to better represent real world situations. Please note that we included the Web EDI case in one of our simulation scenarios because the web services become critical in business integration and its architecture (Abaas 2005) and worth considering web version of EDI. Since web services have a natural loose coupling (Abaas 2005), we place Web EDI at the left side of EDI in Fig. 1. For Web EDI, users don't need to worry about the background EDI format other than just key-in whatever web interface requires.

Likewise we include MP+ case as a variation of MP case. MP+ case represents manual processing with more guidelines provided, which we can easily expect in practice.

We verified the results of the mathematical analysis by an experimental case study and obtained the same result as in (7), which was our expectation. The graphical presentation of the simulation results for three scenarios is provided. We can see the consistent patterns of values in total system intelligence (I_{SYS}), human intelligence (I_H), machine intelligence (I_M) and interface intelligence (I_f).

4) Case study in advanced scenario

This time let us suppose we want to answer the following question: *What will be the lowest mean of human processing time for EDI to be comparable with SP in the 5 subprocesses case?* Let's reconsider processing time distribution just for SP and EDI as in Table 15.

TABLE 15
PROCESSING TIME DISTRIBUTION FOR SP AND EDI IN ADVANCED SCENARIO

	Process A (Human)			Process B (Machine)			Interface		
	distribution	mean	variance	Distribution	mean	variance	distribution	mean	variance
SP	0	0	0	(0.54,0.66)+ (0,0.06)	0.6	0.06	0	0	0
EDI	(2.6,3.4)+ (0,0.3)	3	0.4	(0.54,0.66)+ (0,0.06)	0.6	0.06	(0.04,0.08)	0.06	0.02

Also, from Table 16 we can see the procedure to search down the solution.

TABLE 16
A SOLUTION SEARCH PROCEDURE IN ADVANCED SCENARIO

Case	Mean human sub-processing time for EDI	ANOVA RESULT	Conclusion

1 st (Original case)	3	Significant	Should be less than 3.
2 nd case	0.6	Significant	Even though we lower the human processing time up to the level of machine processing time, we cannot make EDI and SP comparable. It is evident that it is because of interface time in EDI. Thus we need to lower the interface time to make EDI and SP comparable.

One may continue to find out the value of interface time to make EDI and SP comparable. Also as in basic scenario, we can do similar case study for 10 and 15 subprocesses.

5. Conclusions

In this paper we provided a guideline for information system design in terms of how much intelligence we need, depending on the amount of information, or the degree of human involvement in collaboration between two parties. We believe this research can provide a foundation towards a comprehensive model to represent real world situations better when it comes to collaboration between human and information system.

The proposed mathematical model helps us determine the trade-off between intelligence levels of collaboration schemes. Collaboration through SP with PFC was proven the best approach among the three cases.

On the other hand, the simulation analysis showed that we attained the same result as in the mathematical model for various cases. Also through case study in the simulation, we explained how to attain a threshold value to compare the case SP and EDI in terms of performance. We can expand the case study for our comparisons easily. If we include the financial aspect in the analysis, this would be a useful tool for our decision making.

We may use a different measure for intelligences as we mentioned earlier. In our simulation, we employed “time required” as a measure for the intelligences. We may use a different measure other than “time required” in a simulation. Possible different measures may include complexity to finish, and the amount of resources needed, such as manpower, money, error rate, etc. Also we may want to consider that time required itself could be reduced for higher intelligence, which is quite opposite to our simulation. As we can find more comprehensive measures for intelligence, we have more explaining power in our model or simulation.

Also, we claim there is a close relationship between cyber trust and the level of intelligence or the quality of information. For example, if we have higher trust, we may require less amount of information from as well as provide a favorable treatment to our partner in our transaction. Possible trust measures can be history data such as failure rate, amount of transaction and partner’s characteristic such as financial structure, its reputation, CEO’s credibility etc.

On the other hand remembering we made three cases based on the degree of human involvement and we were trying to minimize human intervention, we will consider adopting “intelligent agent” in our future research.

In addition, we can also consider managerial implications associated with this research. Managers can take advantage of the guideline on how much they need to invest to install/ design more intelligent information system.

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