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PI-Based Automated Diagnosis: The Blood Supply Chain Perspective

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Presentation abstract

The blood supply chain is sensitive because of the product diversity, the traceability requirements and the storage conditions. Improving continuously the performance of such a supply chain is therefore of prime importance. The usual way to do such a thing consists in establishing a diagnosis based on interviews and/or manual IT systems retrievals. In this research work, we suggest an approach that is coupling Physical Internet (PI) and Process Mining (PM) principles to automatically diagnose the processes of a supply chain. Basically, PI-containers are used to generate in real-time specific log files that can be interpreted by a PM software in order to model automatically the situation and diagnose the processes followed with accuracy and representativeness. An application case of an indoor subset of the French blood supply chain is developed to illustrate the potential benefits of this proposal. By using aggregation treatments and combined indoor/outdoor technologies, future research works would permit to diagnose and improve the whole blood supply chain.

Keywords: *Diagnosis, Identification, Tracking, Physical Internet, Process Mining, Blood Supply Chain*

Introduction

The French Blood Organization (EFS) is the only one able and allowed to deal with blood supply chain from the donor to the receiver in France. This organization has to take from donors the most important diversity of blood products (platelets, red blood cells, plasma), validate their innocuousness, and store them before distributing them to patients. Because of storage conditions and traceability requirements, it is necessary to follow precisely each pouch during its lifecycle to ensure the traceability and be aware of the temperature chain respect. Therefore, the transportation of each blood product between the donors and the receivers requires: to follow the location and the temperature of each product in real time in order to detect unsafe products and optimize the transportation.

Based on this observation, a Physical Internet (PI) approach could be helpful to achieve this objective. As explained by (Crainic and Montreuil, 2016), the PI initiative is developing concrete means able to transform the fragmented freight transportation, logistics and distribution industries into an industry based on hyperconnected logistics. Goods will be encapsulated in designed-for-logistics standard, modular, smart and reusable PI-containers, from the size of small cases up to that of cargo containers (Crainic and Montreuil, 2016). These PI-containers should be routed across open logistics centers by exploiting real-time and worldwide identification and tracking systems. These containers can carry a number of data or information needed during the various operations related to transportation and handling (Charpentier et al., 2015).

In this research work, we are investigating the opportunities that these new capabilities should offer to diagnose and improve supply chains. Actually, a majority of existing research works on PI are focusing on how to transport, handle or store the goods accordingly to the PI philosophy. Our objective is to complete this by using the new identification and tracking capabilities to automatically diagnose and improve a supply chain. Regarding to the number of blood products containers transported every day in France (several thousands), at any hour between dozens of EFS sites, the PI approach just for this organization, would generate a huge quantity of data. These data about different events the containers pass through have to be treated automatically to permit us to extract and understand the processes states.

Actually Process Mining (PM) is a method enabling to automatically model the process thanks to a log file (Van der Aalst, 2011). PM has advantages such as numerous (and fast) input data treatment, automatic process modeling and output data enabling an accurate diagnosis. In order to use this link between PI approach and PM, it is necessary to study the way of collecting these data dynamically, using sensors able to send event and state data about PI-containers on appropriate networks.

This article aims to demonstrate the interest of such integrated approach to automatically diagnose and improve the blood Supply chain. The paper is split up into three sections. Firstly, a rapid background on PI and PM principles is proposed. Secondly, the problem statement is described and a proposal is developed. Thirdly, an illustrative application to a subpart of the French blood supply chain is proposed.

Background

The Physical Internet initiative

Physical Internet (PI) is a relatively new concept for freight transportation and logistics aiming to improve the economic, environmental and societal efficiency and sustainability of the way physical objects are moved, stored, realized, supplied and used all across the world (Montreuil, 2011; Physical Internet Initiative, 2012). This concept is born to face against current and growing freight transportation economic, social and environmental issues. In fact, because of an end-to-end dominating relationship between the supplier and the user, even if the transportation must be optimized by each company, globally freight transport could be much more efficient. Montreuil (2011) develops the problems actual freight transportation is facing with:

- Shipping air and packaging, vehicles are often not full.
- Incompatibility between users needs and products stored nearby.
- Intermodal transport and efficient facilities to go into and out cities does not exist.
- Lorry drivers used to drive for several days and the products usually do not reach people who need them the most.

The idea of PI is directly linked with the digital Internet models. In fact, everyday, information on this network is shared through the world thanks to multi layers protocols, data encapsulation, routing standardization with hub and switch, etc. These models could be used to improve the freight transportation. Different ways of improvements have been proposed ever since to create a hyperconnected world (Crainic and Montreuil, 2016) in which logisticians exchange goods and distribute/collect them through a multi layer approach to the users.

The PI-container

Among all the improvement ideas, like multi tier layer conceptual framework or distributed multi-segment intermodal transport, Montreuil (2011) explains that the main idea is the encapsulation of goods in PI-containers. These containers can hold any product, like a traditional box but are active because they transport a component that owns several data linked with this shipment. In order to standardize and optimize the modularity, these PI-containers are world-standard, smart, green and modular. Moreover, Sallez et al. (2015) distinguishes 3 types of PI-container:

- The T-container, like the actual one, it is directly transported by trucks, trains, boats, etc. In our case, the trolleys loaded in trucks are T-containers.
- The H-container, dedicated to be handled. It measures one of the several standard sizes, like the containers used currently at the EFS for fresh blood pouches or samples for instance.
- The P-container, it constitutes the packaging of each product, in our case this is the pouch.

The P-container sizes are adapted to the H-container dimensions, and that the same between H and T containers. To sum up, gathering several PI-containers of different dimensions in a particular way would permit to create a big one whom the dimensions are among the standards.

On-going research projects like MODULUSHCA and LIBCHIP (Sallez et al., 2016) are developing some concrete solutions to allow PI-containers being active. Even if the final technical solutions are not established yet, PI-containers should use existing technologies such as: indoor tracking systems like RFID (Radio-Frequency Identification) or RTLS (Real-Time Location System), outdoor tracking systems like GPS (Global Positioning System), or indoor/outdoor tracking systems like WSN (Wireless Sensor Networks) and IoT (Internet of Things). These systems are already developed and can be used concretely to track goods all along the supply chain (everywhere and every time) (Dittmer et al., 2012; Charpentier et al., 2015; Sallez et al., 2016). To be really accurate, the PI-containers' identification systems would include a mix of all these technologies to allow good tracking during transportation but also during the indoor operations (in a warehouse or manufacturing plant for instance).

The Process Mining Opportunity

In order to diagnose and improve a supply chain, in its whole complexity, PI-containers can be really relevant if their use produces a log file able to be used through a PM approach. PM is an automated process, represented on Figure 1. It consists in collecting data as a log file, event data in our case, and in creating automatically a process model. More information on the PM step is available in (Van der Aalst, 2011).

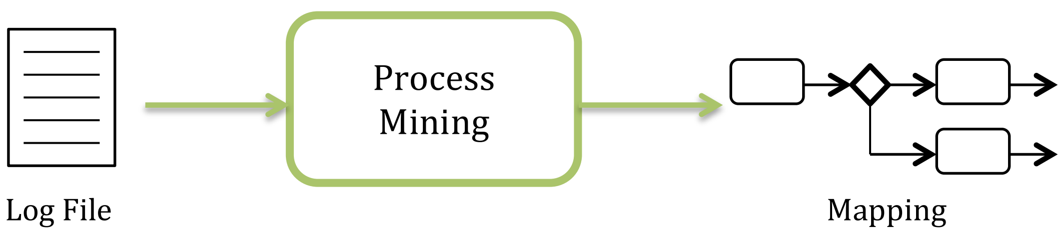

Figure 1: Process Mining concept

However PM required an specific log file: that is to say having enough representative events collected. Consequently, the question is how to constitute such a representative file? In a huge number of companies, IT systems (like ERP, APS, WMS, etc.) are now enough mature to produce log files that could feed adequately a PM system. The problem is to track processes and flows between the companies and plants because in a great majority, only few steps are tracking (often limited to the shipment event and the final arrival event). As a consequence, because of this lack of information, the processes and/or log files are established manually thanks to observations and interviews. However, it is really complicated and time consuming to manually build such a file.

Therefore, the goal is precisely not to limit the tracking to plants or logistic centers but follow, thanks to a PI approach, the PI-containers in real time and all along the supply chain processes.

Problem Statement and Proposal

Even in the PI world, supply chains should need to improve their performance continuously if they want to be sustainable. It imposes reengineering step to understand forces and weaknesses of the system and to suggest appropriate enhancements. As explained by Vernadat (2003), such reengineering process must start with a solid and accurate diagnosis phase (see Figure 2). This usually consists in describing qualitatively and quantitatively the considered processes and material flows. In the current world, such a description may be laborious with hundreds hours of manual observations and stakeholders interviews. And, unfortunately, these efforts are not automatically synonymous of completeness (representativeness), reliability and usability.

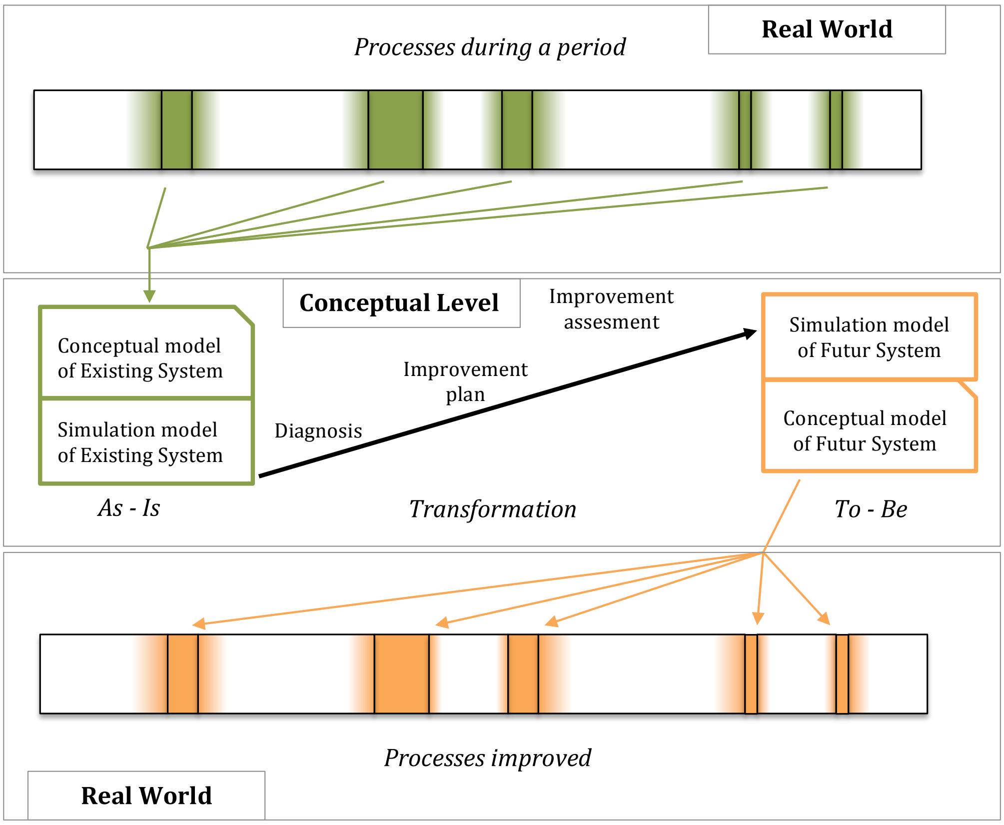

Figure 1 - As-Is To-Be analysis with traditional means

To solve this limitation, we suggest using PM to automatically support the supply chain diagnosis (see Figure 3).

Figure 2 – Proposal Principle

If we would like to use all the PM advantages, as we said before, we must obtain a log file. Getting such a file manually is time consuming and there are several interpretations possible. If we want to get "automatically" a log file (with an analysis step), we can extract data from the IT system. There are more and more data available, but too rarely used. Prodel et al. (2015) for instance used such an approach for revealing, modeling and optimizing the clinical pathways in a hospital. Such an approach could also be used for the blood supply chain. However, there are several issues that compromise this idea:

- Healthcare in France and blood organization particularly, still uses a lot of paper documents to insure traceability. The most sensitive data like patient data is protected in databases, blood pouches are scanned, and warehouses are registered in IT systems. However, the current location and state of each product, which has to be shift from a place A to a place B, are not registered in databases. Thanks to warehouse management system and traceability papers we can track them subsequently but it is not enough and usable to design the entire processes. As an end, there is a lack of computerized and exploitable information.

- Even if the necessary data to build the processes are collected in the IT system, it occurs very often that the syntax is inappropriate and confusing (Miclo et al., 2015). In addition, people in charge of adding information do not standardize their vocabulary (semantic issue). Thus for the same activity it exists a lot of different expressions. If we want the process mining system to understand it, we need to correct one by one these information, which is time consuming.

- A lot of problems also occur with the timestamp (Miclo et al., 2015). In fact, in many cases we miss timestamp for an activity or the gap is automatically filled in with an hazardous date: 01/01/1900. In both cases, when this information is registered in the process mining system, some activities will last a very long time… A last example is an activity that begins today at 11:00 pm and finishes tomorrow at 00:20 am. Because it crosses two days, some systems read into it a 1-day activity, which is absolutely not the case. To avoid misunderstanding and wrong results we need to delete all these activities, which is time consuming and reduces accuracy.

As a consequence, gathering log file from IT systems like ERP, WMS, TMS and so on is not fully satisfactory and presents a lot of limitations. That is why we propose to develop and use PI-containers to automatically collect event data and create log files rather than using a combination of existing data sources and manually entered status updates. Coupling PI-containers and PM appears as an interesting solution to automatically support the diagnosis step of a supply chain. Such an approach should allow automatically registering data events and modeling processes with accuracy and reliability..

In order to focus on the capabilities to automatically diagnose and improve a supply chain thanks to PM linked with a PI approach, we concentrated in this first step of our research project our experiments on indoor analyses. Thus, our proposal suggests using Real-Time Location Systems (RTLS) as main technology to connect PI-container for indoor diagnosis purpose. RTLS is a technology based on active tags that send a signal to 3 antennas at least (like GPS technology) oriented to the center of the area we study. It is limited indoor because the beacons can detect a tag located at 20-200m maximum around them, depending on the configuration of the area (lot of walls, water, etc.) and the signal: RFID, UHF, UWB, Bluetooth (BLE), Zigbee, Wi-Fi, etc. The main objective, as for the GPS, is to locate a tag, which moved in an area with a person or an object, thanks to signal triangulation algorithms. The parameters collected are the Time Of Arrival (TOA), the Time Difference Of Arrival (TDOA), the Received Signal Strength (RSS) and the Roundtrip Time Of Flight (RTOF). This system can usually detect a movement of 15 centimeters in an XY or XYZ map. The software used with these tags and beacons have 3 modules: the first one calculates the position, the second one is used to define areas on a "map", and the third one is used to define events caused by a transfer of a tag from an area to another. In practice, we have chosen to use the PM software Disco®.

Illustrative Application

The blood Supply Chain

The blood supply chain is very sensitive because of:

- *Product diversity:* There are several dozens of blood products types (groups and phenotypes), which are often not compatible one to another. Consequently, it is necessary to take blood from different donors and store the most important diversity of blood products.

- *Traceability:* An inappropriate product may be lethal to a patient, and consequently it is essential to own and find in the blood products stock the appropriate one. Thus, each pouch can follow a unique way between a collection center and the distribution center where the product will be used.

- *Storage conditions:* The blood products needs to be stored in appropriate temperature environments (platelets 22°C, red blood cells 4°C, plasma -25°C) and their lifespan ranges from 5 days (platelets) to 42 days (red blood cells) and 1 year (plasma) between the donation and the transfusion. Blood products are critical and have to be treated carefully all their "life" along.

These three elements and the patients needs obligate EFS to collect every day around 9500 pouches of blood (or directly one of its components). In order to do so, around 40 000 blood collections are organized everywhere in France each year. In fact, a donor is allowed to donate his blood at the most 6 times per year for a man and 4 times for a woman. Therefore, the EFS can not set up all its collections in the same places but has to come as close as possible from the potential donors, even in medium and small cities.

The blood supply chain is divided in several steps: First, pouches of blood are collected in a collection center before to be sent to a Processing Center in order to be transformed in three end products. These end products are then transferred to Distribution Center. Simultaneously with these blood donations, EFS takes off just one of the three blood components from some regular donors by apheresis. The pouches follow the same supply chain even if the operations in the processing center are quite different. Moreover, this organization has to deal with some samples taken off at the beginning of each donation, which need to be analyzed in less than 24 hours in one of the four Screening Center in France. ,Thus, these samples are used to cross several regions, as well as some rare products or plasma pouches that need to be transported to specific centers.

We represent the complexity of this supply chain in Figure 4 just for one of the 14 metropolitan regions and its collection and donation centers. Each region is responsible for the supply chain of its area and respects the global strategy. Thus, there is more or less the same way of working in each region, with several centers "around" a hub that receives blood donations and ships validate end products. However the processes followed are not exactly the same. It is quite obvious considering that it exists more than 140 donation and/or distribution centers in France.

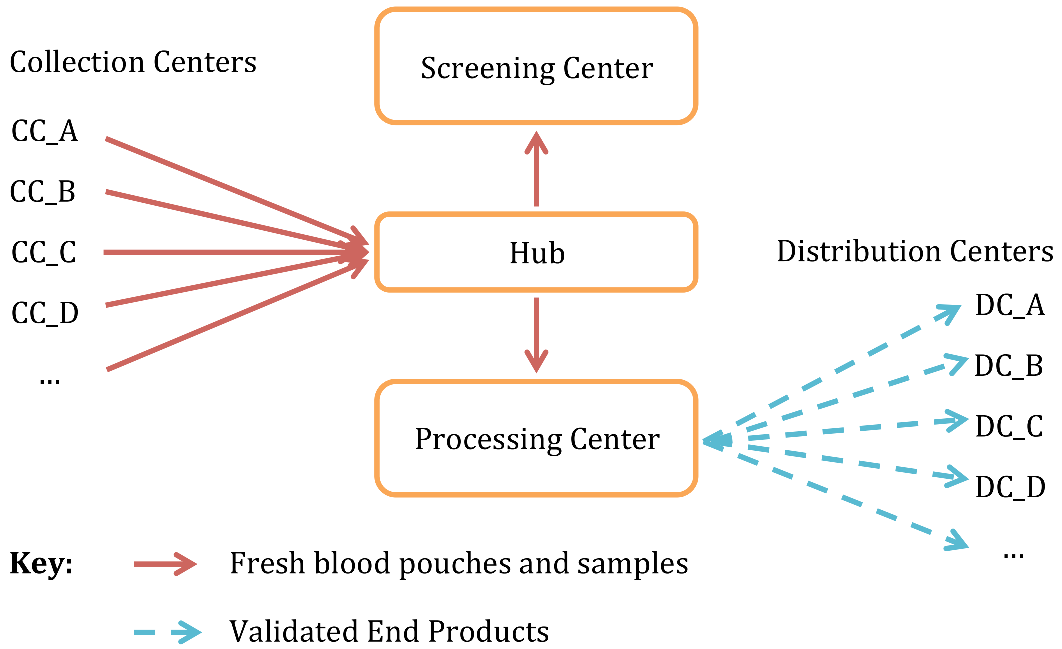

Figure 3: Scheme of the blood supply chain

We began to model the supply chain processes in a pilot region, focusing on transport between the collection centers, the hub, and the donation centers. Finally we collected few data comparatively to the flow of products and the high number of stakeholders. The study required one engineer during five months and finally we recorded and measured processes in one place at the same time and did not work continuously, whereas the activity never stops. Moreover, we studied the supply chain in just one region and not fourteen…

The transportation Rounds

In order to pick up every donation and distribute every validated blood bag to each center everyday, EFS regions have commonly organized rounds. Trucks leave from the regional hub, where blood components are separated, with containers holding end products for each city of the round, following a repartition decided by the Wholesaler Managing System. Dropping them off along the round in each city, the truck picks up at the same time containers fresh blood pouches collected by each center during the day. We represent a round among the others on Figure 5. A round lasts around 4 to 6 hours and the truck crosses around 100 to 400 kilometers.

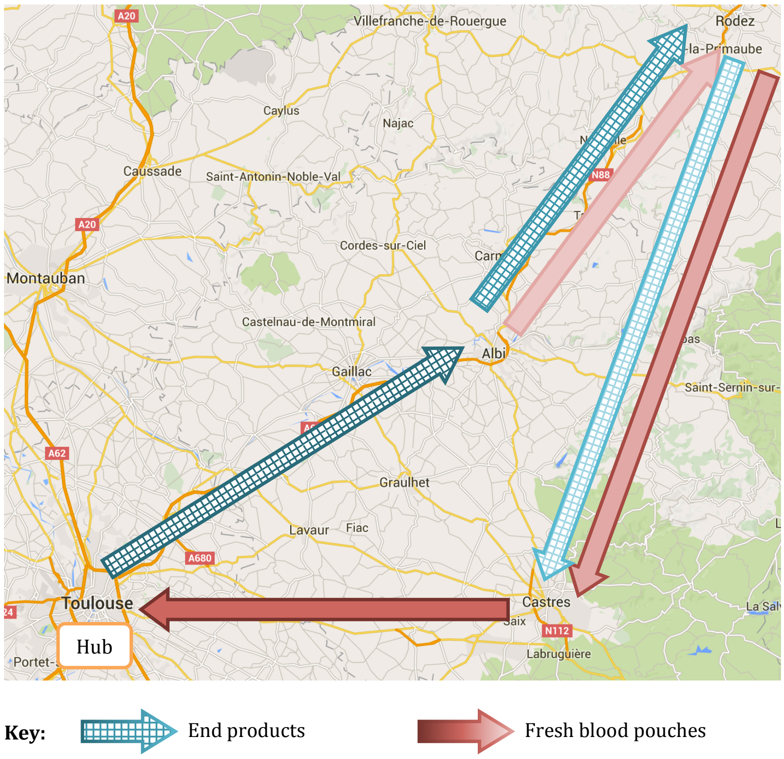

Figure 4 - Example of round with mixed flows of fresh and end products

This case is the most common. In fact, some blood products, or samples, can be carried from an EFS center to another without coming to the hub. Not to destroy products because of their lifespan, some of them that have been distributed to small centers come back to the hub. From there, they are distributed to larger donation centers where they will be used quickly, before the end of their lifespan. As consequences, we observe clearly how fragmented is the transportation for a large part of blood products. They can easily be carried in different containers, and stored in different places more than 3 times between the donor and the receiver.

Experiment

In these conditions, to improve traceability of blood products we propose to use H-containers. Integrating a sensor able to communicate with the network in a container, like RTLS sensor, makes it a H-container able to exchange data about its location. In addition, we define in the warehouses several locations dedicated to different H-containers status. When a H-container is putting in one of these places, we register it. In the future, if we register the link between a set of pouches (P-containers) and the H-container (with an ID) in which they are packed, tracing by RTLS the H-container will permit to trace every single pouch.

Thanks to this last idea we are able to establish an accurate and real time link between: pouch – P-container – place – status. Then, this improves the traceability and allows feeding PM step to detect problems, diagnose and improve the whole blood product supply chain.

In the following, we describe an indoor experiment we have led in collaboration with one of EFS region. Because our study was temporary we installed 3 beacons in strategic places. Indeed, we needed to be sure that the beacon would be able to detect every RTLS sensors in every testing box (H-container) during the whole process. We represent this area (around 12*12m) on the Figure 6 below.

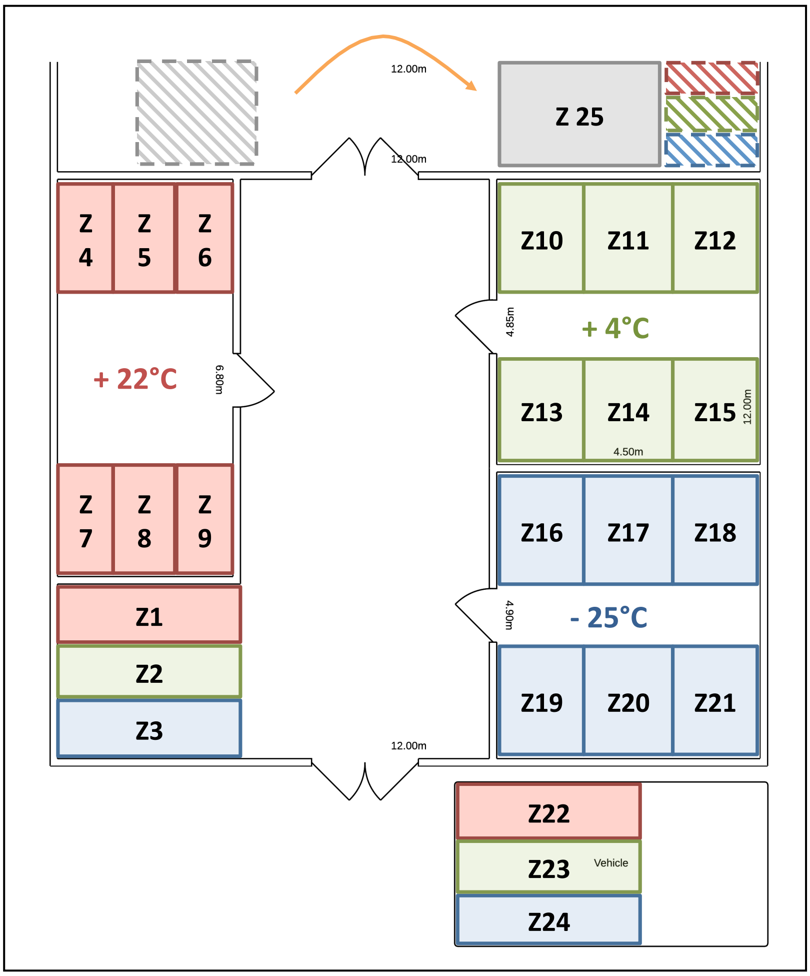

Figure 5 - Map of the logistic area with experimental areas identified

We consider during this use case the three most common end products named with their acronym: platelets (CPA), red blood cells (CGR), plasma (PFC). The table 1 indicates for each area the status of PI-containers stored into them:

Table 1 - Listing of identified areas

ID	Description	Event
Z 1	Empty containers for +22°C products	EmptyContainers_Area.Buffers_Empty_Cont_CPA(1)
Z 2	Empty containers for +4°C products	EmptyContainers_Area.Buffers_Empty_Cont_CGR(1)

Z 3	Empty containers for -25°C products	EmptyContainers_Area.Buffers_Empty_Cont_ PFC(1)
Z 4	Full +22°C containers ready to go to site A	Ready2Go_CPA.Buffers_CPA(1)
Z 5	Full +22°C containers ready to go to site B	Ready2Go_CPA.Buffers_CPA(2)
Z 6	Full +22°C containers ready to go to site C	Ready2Go_CPA.Buffers_CPA(3)
Z 7	Full +22°C containers ready to go to site D	Ready2Go_CPA.Buffers_CPA(4)
Z 8	Full +22°C containers ready to go to site E	Ready2Go_CPA.Buffers_CPA(5)
Z 9	Full +22°C containers ready to go to site F	Ready2Go_CPA.Buffers_CPA(6)
Z 10	Full +4°C containers ready to go to site A	Ready2Go_CGR.Buffers_CGR(1)
Z 11	Full +4°C containers ready to go to site B	Ready2Go_CGR.Buffers_CGR(2)
Z 12	Full +4°C containers ready to go to site C	Ready2Go_CGR.Buffers_CGR(3)
Z 13	Full +4°C containers ready to go to site D	Ready2Go_CGR.Buffers_CGR(4)
Z 14	Full +4°C containers ready to go to site E	Ready2Go_CGR.Buffers_CGR(5)
Z 15	Full +4°C containers ready to go to site F	Ready2Go_CGR.Buffers_CGR(6)
Z 16	Full -25°C containers ready to go to site A	Ready2Go_PFC.Buffers_PFC(1)
Z 17	Full -25°C containers ready to go to site B	Ready2Go_PFC.Buffers_PFC(2)
Z 18	Full -25°C containers ready to go to site C	Ready2Go_PFC.Buffers_PFC(3)
Z 19	Full -25°C containers ready to go to site D	Ready2Go_PFC.Buffers_PFC(4)
Z 20	Full -25°C containers ready to go to site E	Ready2Go_PFC.Buffers_PFC(5)
Z 21	Full -25°C containers ready to go to site F	Ready2Go_PFC.Buffers_PFC(6)
Z 22	+22°C area in the vehicle	CPA area in the vehicle(+22°C)
Z 23	+4°C area in the vehicle	CGR area in the vehicle (+4°C)
Z 24	-25°C area in the vehicle	PFC area in the vehicle (-25°C)
Z 25	Packaging area of each pouch in containers	PickAndPack_Area.Picking(1)

The 6 areas in each cold room match with the 6 rounds that leave from this hub (A … F). The process followed by every PI-container is normally:

1. It leaves from Z1, Z2 or Z3 empty.
2. It is filled with end products from one of the wholesalers (the three rectangles shaded on the top right hand side).
3. It is stored in the correct area matching with its destination.
4. When the vehicle arrives, the driver takes in each cold room the PI-containers of it is round and stores them in the appropriate cold room of its vehicle (Z22 – Z23 – Z24).
5. When the vehicle leaves we loose the RTLS signal.

To define in the RTLS software these 25 areas, we calibrate the beacons with a tag located step by step on each anchorage (the corners of each area). Registering the TOA, TDOA, RSS and RTOF of each point, we were able to draw each area and attribute them a status. During the experiment, the empty H-container was equipped with RTLS tags. Then, the technicians who fill them following the needs of each site of each round, created new status in the log file. Thanks to Disco® (PM software) we model the processes, as we would have tried to do in a traditional way (As-Is Business Process Model). The event data collected permit to check the different places of the H-container and analyze if there are differences between what it is and what it should be. For instance, a container which needs to be stored quickly in a 4°C place must not wait in a 20°C place. Table 2 below is an extract of our log file with a filter on some H-containers. We clearly observe their way in the hub and understand how the technician works.

Table 2 - Extract of our log file

Event	Container ID	Activity	Timestamp start	Timestamp end
8	2004	EmptyContainers_Area.Buffers_Empty_Cont_CGR(1)		26/10/2015 8:12
31	2004	PickAndPack_Area.Picking(1)	26/10/2015 8:16	26/10/2015 8:48
49	3007	EmptyContainers_Area.Buffers_Empty_Cont_PFC(1)		26/10/2015 9:09
62	3007	PickAndPack_Area.Picking(1)	26/10/2015 9:14	26/10/2015 9:20
191	2004	Ready2Go_CGR.Buffers_CGR(1)	26/10/2015 8:53	26/10/2015 12:06
214	2004	CGR area in the vehicle (+4°C)	26/10/2015 12:12	26/10/2015 12:21
231	3007	Ready2Go_PFC.Buffers_PFC(2)	26/10/2015 9:24	26/10/2015 12:36
244	3007	PFC area in the vehicle (-25°C)	26/10/2015 12:43	26/10/2015 12:46
1395	2191	EmptyContainers_Area.Buffers_Empty_Cont_CGR(1)		27/10/2015 15:47
1413	2191	PickAndPack_Area.Picking(1)	27/10/2015 15:51	27/10/2015 16:39
1493	1077	EmptyContainers_Area.Buffers_Empty_Cont_CPA(1)		27/10/2015 18:16
1518	1077	PickAndPack_Area.Picking(1)	27/10/2015 18:20	27/10/2015 19:03
1602	2191	Ready2Go_CGR.Buffers_CGR(3)	27/10/2015 16:43	27/10/2015 19:55
1625	2191	CGR area in the vehicle (+4°C)	27/10/2015 20:00	27/10/2015 20:12
1703	1077	Ready2Go_CPA.Buffers_CPA(6)	27/10/2015 19:07	27/10/2015 20:58
1727	1077	CPA area in the vehicle(+22°C)	27/10/2015 21:04	27/10/2015 21:23
4278	3339	EmptyContainers_Area.Buffers_Empty_Cont_PFC(1)		30/10/2015 19:45
4366	3339	PickAndPack_Area.Picking(1)	30/10/2015	30/10/2015

			19:50	20:12
4471	3339	Ready2Go_PFC.Buffers_PFC(6)	30/10/2015 21:17	30/10/2015 21:11
4498	3339	PFC area in the vehicle (-25°C)	30/10/2015 21:16	30/10/2015 21:22

Exploitation

As we said before, with this amount of event data the software Disco® is able to automatically model the processes and give indications about the average and maximum time for each activity. Figure 7 is an example of this ability we have to filter the processes on the number of occurrence. It represents in a synthetic view the most common processes. As we could have expected it observing the flows, the most important one, whom the number of H-containers carried is the higher, is the one with CGR for the round (4).

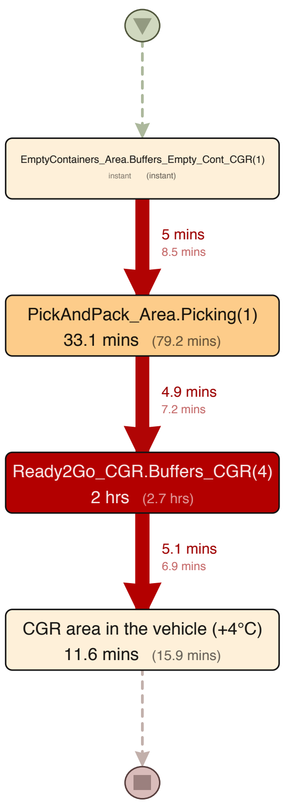

Figure 6: Model of the most common process

Then Figure 8 shows a view with more details, filtering less i.e. representing not just the most common activities. As we see on the middle of this model, other common activities after “Ready2Go_CGR.Buffers_CGR(4)” are the same but for other rounds. The waiting activities of other containers empty appear too, as well as the activities of PFC and CPA containers loaded in the truck.

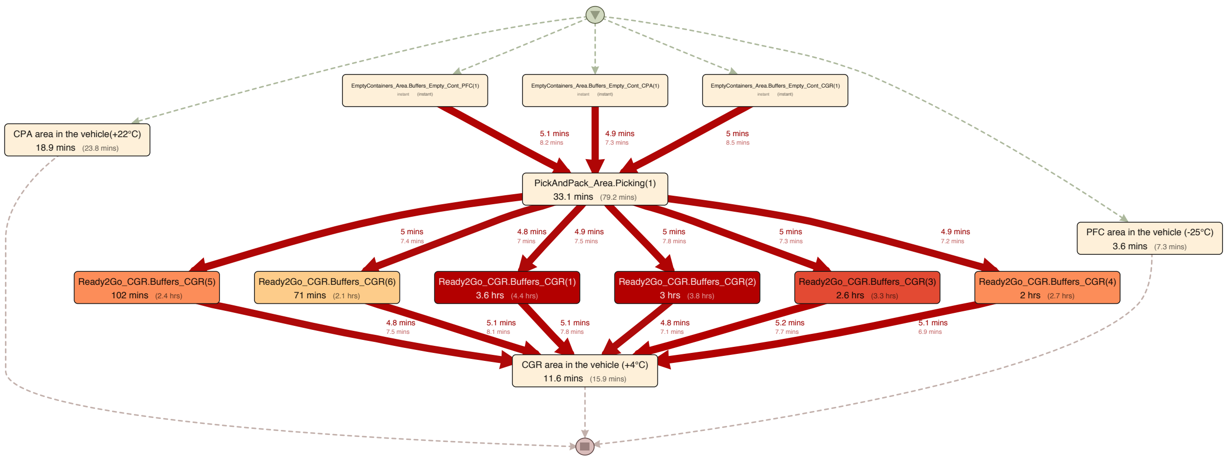

Figure 7: Model of some of the most common processes

Focusing less, with no filter, the software draws a process model with all the activities, linked by the "PickAndPack" activity on the top and "container loaded" activities on the bottom. This ability to draw the processes, focusing more or less on the number of occurrences, permits to concentrate our strength on the most regular activities to improve the process. Thanks to that, an improvement can be directly implemented on the activity where it will be the most visible. However, it is difficult to gather activities. For instance, to make the distinction between the products, we would like to gather in the same macroscopic activity like "Ready2Go_CGR_anyRound" six of them we defined. This type of analysis could be interesting round by round for all the products, or gathering just some rounds, etc.

Another result in these charts is the ability we have to see the mistakes and identify which are the most common ones in order to diagnose and improve the process on particular elements. For instance, the system detects that a H-container has been moved from Z1 to Z25. A technician will attribute to this H-container a location. In our experiment we define it before, we do not computerize it yet. Then, some minutes later, we notice on the table that this H-container is located in the place Z5. Thus it is the right temperature because each place has a dedicated temperature. If the technician makes a mistake (location here) then we can easily imagine the system detects it immediately thanks to the log file, understanding the status: "This PI-container is waiting for the round B whereas he leaves with round C". This real status is different from the one it should be and the system alerts the technician. This example can also be valid for temperature problem or driver mistake for instance.

Conclusion and future work

To conclude, we presented in this paper a first attempt to automatically diagnose supply chain processes by coupling PI principles and PM mechanisms. This proposal is experimented on the French blood supply chain. Because of the characteristics of its products, improving the performance of the whole supply chain is critical. Thanks to RTLS we succeed in concretizing, at least partially, for an indoor analysis, the principle of PI-container and in using it to automatically produce a log file able to model the related supply chain processes. The obtained results are quite easy to follow and the analysis is so much accurate and reliable than a regular manually study. This step encourages further researches with an outdoor technology. We can imagine that with technologies like WIFI, GPRS, WSN it will be possible to track a PI-container not just in an expedition area but also during transportation phases. With the same PM approach, we could automatically collect event data and create log files in order to make a dynamic and accurate diagnosis to improve the supply chain and adapt the carrier behaviour to random events.

In fact, in the future, collecting all these event data we can imagine two different objectives:

- We should improve the blood supply chain by deploying a RTLS system for some days or weeks, recording event data in a log file (PM) and analyzing the diagnosis. This way of doing will allow a temporary improvement of the processes, the accuracy of the study depending on the quantity and diversity of event data collected. It is a direct extension of what we have done.

- We should improve continuously the blood supply chain by installing a permanent RTLS (or another technology) system in the places where PI-containers will be stored. Every PI-container would own its chip permanently. Registering event data and creating log files continuously the system will make a dynamic and accurate diagnosis of the process real state through PM approach.

In any case, deducing automatically the process model with a log file recording event data is useful but not sufficient to be usable for further analysis. In fact, as we describe it at the end of our proposal, we miss a knowledge base to gather some activities and obtain new KPI representative of the same process but on another level. This ability to adapt the granularity of the study depending on the level of accuracy we need is essential to make decisions and establish the objectives of the whole process. Some future work would need to be done on these perspectives to create useful PI-Based automated diagnosis.

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