Scalable Logistic Cell RFID Witness Model

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Abstract: This paper describes a scalable logistic cell Radio Frequency IDentification (RFID) Witness Model. First, a scalable logistic cell analysis is done which can be applied to the logistics of any size-scale and application. This model is then implemented into Witness and simulated, for different cases. To show practicability, the model is mirrored in a physical Internet of Things (IoT) device in form of an Arduino micro-controller board which is attached to an RFID-Reader, together with a model-warehouse / forklift truck unit. The specific challenge of this work is to design a universal logistic model, for demonstration of all possible logistic applications with one simple cell, together with a single step IoT connection, that can be easily built as well as a physical, as a computer simulation model.

1 INTRODUCTION

Nowadays production, logistics, and general process simulation is increasingly important in industry and is applied to different fields like e.g. Business Process Management (García-García et al., 2020). There is a trend in the last years of using distributed Software, which may be important for collaboration, as well as cloud-based solutions, increasing simulation velocity (Lunesu et al., 2018). This can also be subsumed to the efforts to decrease the effects of the nowadays increasing endangerment of actual pandemic developments, making remote collaboration more feasible and even necessary. Furthermore, there can be seen a trend in process simulation towards agent-based simulations (Ali et al., 2014), which shows the necessity of increasing Artificial Intelligence (AI) models, for simulation of decision processes, that depict increasing complexity and needed flexibility in industrial production as well as logistic processes. There exists now also a wide variety of process simulation software (Leporis and Králová, 2010), which is important to implement a virtual twin of industrial production, logistics, and many other processes.

The goal of this work is to implement a simple and powerful scalable model for a universal logistic process, that is hence useful in a wide variety of logistic applications. To give an immediate insight together with a process simulation a simplified logistic process is implemented as an educational demonstration tool with a micro-controller application. For this the Arduino Platform is used, where an excellent summary for the Arduino can be found with the "Arduino in A Nutshell Book" which is quite practically useful, as there is also given a description of the electronics needed for the periphery of this Microcontroller Platform (Borchers, 2013). The challenge of this work is to implement a simple model for an educational purpose, that depicts some essential universal and scalable aspects of an IoT-system in the context of an industrial applicable logistic network, as a physical-IoT-model and as a digital twin simulation. In this work, first in section two, the position of this paper is given. In section three a scalable logistic cell is developed, which has the property of being scalable and widely applicable. Section four gives then a practical application of a virtual twin of this model. Section five shows then the results of an IoT application of this simulation model in a real-world model, implemented with the Arduino platform in connection with a Radio Frequency IDentification (RFID)-Reader. Finally in section six the summary and a short outlook are given.

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2 POSITION

The position of this paper is, that a simple logistic cell model with one exemplary IoT-sensor application, is adequate for implementing a scalable logistic process and that this process can be hence demonstrated by a simple physical model as well as a simulation model. It is further suggested, that such a model can be easily scaled up and interconnected to depict an industrial real-world logistic process. This process is admissable because it can be interpreted as an orgiton (Heiden et al., 2019) or a fractal program (Mandelbrot, 1991) that is based on a core element (cell, orgiton, fractal generator) that is multiplied and interconnected.

3 A SCALABLE LOGISTIC CELL

The term "logistic cell" can be derived from cybernetics and namely from the concept of cybernetic systems, which are informational open and functional closed (compare also (Weber, 2010), (Luhmann, 1997)). The system is defined as open if it has an energetic and matter exchange with the external world. The term "external world" is taken in this context from the theory of systems of George Spencer-Brown, where the system appears from the separation as a marked state (system) from the unmarked state (external world) (Spencer-Brown, 2008) (q.v. Figure 1). An informational open system means that the exchange of information between this system and the external world also exists. Functional closed means, on the other hand, that the system can define a method of communication with the external world independently, using its functional organization.

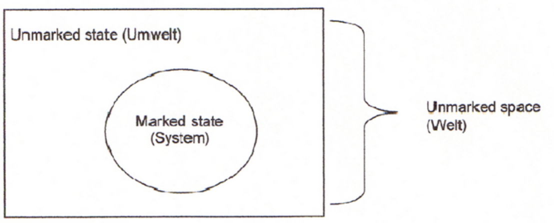

Figure 1: Appearance of a system in the theory of George Spencer-Brown (Spencer-Brown, 2008).

This term of a cybernetic system can be also applied in the logistical context. For the definition of a *logistic cell*, the cybernetic system has to be modified in that way, that it is defined as open for matter and information because it always has an exchange in the matter (material, transport and people flow) and information (external communication) levels. For that these flows are flowing, they have to be powered by energy. The unity of these natural components can be determined through the Orgiton-Theory of Bernhard Heiden et al. (Heiden et al., 2019), where it is called "Orgiton". If a system is defined as matter-open it has also to be answered, which can be designated as a border of this system. Concerning the logistic cell, the boarders have to be so defined that they are pulled or pushed by the observer. So, the system has to be considered by an observer, where a concrete object has to be *marked* (marked state) as a cell. To specify it as a technical model, functional interaction of the "cell" has to be considered. The main feature of this interaction is *functional autonomy*, which means that it is operationally closed. It means, that the system can work without external input requirements because it has sufficient own functionality. On the other hand, this system is determined as matter open, because it e.g. pulls the information from the external world and can communicate with other cells through matter, energy and information exchange. From that two main features for the determination of logistic cell can be taken:

(1) The autonomous self-sufficiency and the

(2) potential interaction with similar cells in their respective matter, energy and information levels.

This second property of the here defined logistic cell can be denoted as *scalability*. Scalability can be understood as the property of a logistic cell that allows for applying volume and / or size changes in the system. At the same time it has to be noticed, that the borders of logistic cells are strongly connected with the borders of flows, respectively, the bigger is the Material-Energy-Information (MEI)-flow, the bigger is the "input surface" and with it tendentiously the cell (q.v. Figure 2). Mathematically this can be described by Equation (1), where G_2 and G_1 are respectively the borders of flow and cell systems.

$$G_2 = f(G_1) \tag{1}$$

This means that the size of the connection of the cells changes with the material flow e.g. Imagine a pipeline, that has to be bigger when more material is passing between two cells. This has a manifold of applications in nature, es e.g. in trees, blood vessels, or lung branches (compare e.g. (Mandelbrot, 1991)). The scalability of a cell is hence closely connected to these to borders, border of the border in the projection, and the border of the cell. This is then a self-referential structure, an orgiton of a higher order, or according to Benoît Mandelbrot a fractal self-referential structure.

To sum up the definition of the scalable logistic cell: The scalable logistic cell is a material and func-

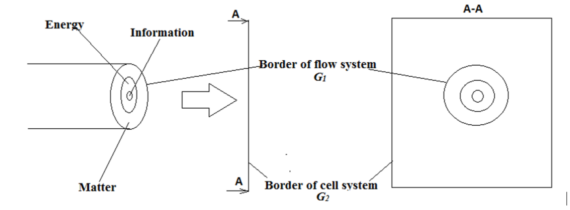

Figure 2: Dependence Between Borders of Flow System and Cell System.

tional open system, which on the one hand is autonomic and has, on the other hand, potential interaction with other logistic cells on material, informational and energetic levels.

4 WITNESS-MODEL

This simple logistic cell model has then been simulated in the simulation software Witness 2014 together with a storage option. The choice of this simulation software was based on many of Witness, advantages, which sets it apart from other process simulation software in the industrial environment. These advantages are:

- Powerful construction principle
- Unlimited number of intelligent objects, modular structure
- Seamless integration with ERP, BDE, MES, etc.
- Automated mass experiments with the integrated WITNESS Experimenter
- Automatic 3D visualization with WITNESS Quick 3D (LannerGroupLimited, 2020)

The whole logistic cell simulation model is shown in Figure 3.

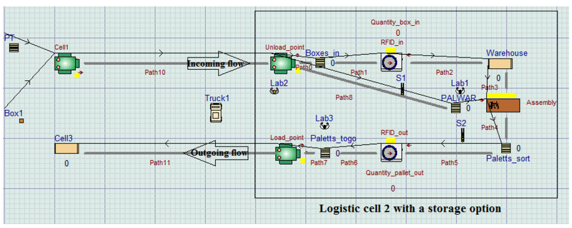

Figure 3: Logistic Cell with a Storage Option in the Witness Model.

The model consists of the considered logistic cell with a storage option (cell 2) and schematically depicts cell 1 and cell 2, which play the role of e.g. the supplier and the customer respectively. The main idea of this model is to show the specific functions of a logistic cell with a storage option as well as the interaction between different cells on the matter, information, and energetic levels. As an application, this can be e.g. a production facility, that gets material from other companies and delivers products to customers by truck. So the logstic cell in Witness depicts the internal and the external logistic process in the model. The extension to a network can then be done easily by copying and connecting the cells accordingly.

4.1 RFID as IoT Application

To demonstrate an industrial logistics identification procedure, of incoming goods the technology of Radio-Frequency Identification (RFID) was used as an application example in the model explained in the next section, where the Witness model is the digital twin. Compared to the second most popular identification technology – the barcode technology, whose work is based on optical (laser) contact, the working principle of the RFID-technology is based on radio waves transmission between RFID-Reader and chip and has many advantages. The most important advantages are

- an opportunity to scan up to 1000 items per second,
- to overcome distances up to 100 meters (in special cases) between RFID-Reader and chip,
- that sight contact is not needed and
- the possibility to store up to 64 Kb as information in a chip in comparison to 3000 bytes as information with barcode technology.

That is why the RFID-technology was chosen for the model used here.

4.2 Logistic Process

A simulation process of the logistic model looks as follows:

Step 1: Cell 1 obtains pallets (PT) and boxes (Box1), assembles them to the one unit and sends them to the cell 2 by truck (Truck1). Cell 1 plays in such a model the role of the supplier, whose main task is to provide a considered element with necessary sub-elements. Through the movement of goods, there arises a flow (material flow).

Step 2: The goods arrive at the unload point and are unloaded and separated by labor (Lab2) to boxes and pallets. The boxes are transported in the direction of the interim storage (Boxes_in), the empty pallets are transported to the pallets storage (PALLWAR) and are waiting for the boxes for assembly.

Step 3: The boxes are transported in the direction of the main storage (Warehouse) by a forklift truck (G_1) through the RFID-system ($G_2 = f(G_1)$, compare Figure 1, ”RFID_in” in Figure 3). This is one of the key elements of this cell, which shows the most important advantage of RFID namely:

- The possibility to identify many goods per second, and that there is
- no necessity to direct sight contact and that the
- distance between the RFID-Reader and good can be much larger, than with the barcode technology.

For the demonstration of the identification procedure a variable was added in the ”output actions” of the RFID-system and shows in the model the number of boxes, which have already gone through the RFID-system.

Step 4: After the RFID-identification process the goods are coming to the storage part. Here they are stored in the main storage (Warehouse), assembled in pallets on the assemble station (Assembly) by labor (Lab1) and are going to the interim storage (Pallets sort) to be prepared for the departure.

Step 5: After assembling the pallets are coming to the interim storage, where they are sent to the last interim storage (Pallets_Togo) by a forklift truck (G_1') through the outgoing RFID-system ($G_2' = f(G_1')$). This system has the same functions as an incoming system, as well as a similar variable, to show, how many pallets are going out.

Step 6: Load procedure. When goods are coming to the last interim storage, they have to be assembled in the shipment by labor (Lab3) and prepared for the departure.

Step 7: In the last steps, the shipment has to be taken away by the truck and sent to the cell 3. This step shows, where the flow is leaving a cell 2 and going to the next cell, which plays in this model a role of a potential customer or the next member of the logistic chain.

4.3 Bottleneck Analysis

The simulation can help the companies and parties in the logistics supply chain to identify, understand and prevent a potential inconvenience already in the step of planning and modeling, as the Witness model can be regarded as a virtual twin. An important possibility is the identification of a bottleneck in the factory through simulation. The term ”bottleneck” is used to describe a point of congestion in any system from computer networks to a factory assembly line. In such a system, there is always some process, task, machine, etc. that is the limiting factor preventing a greater throughput and thus determines the capacity of the entire system. Knowing the bottleneck allows us to increase the flow by improving just one process in the system rather than all its remaining parts. Vice versa, if there is a bottleneck, nothing done elsewhere in the value stream can improve the throughput (Leporis and Králová, 2010). With the statistical instrument in Witness, it is possible to show, how the work progress is going in the different steps. Figure 4 shows a diagram, which compares the different ”active” points of logistic cell 2. Under ”active” points in Witness those points are understood, where there is active work done on or with the goods. In this diagram the pink color designates a time when an element is blocked, the yellow color means, that the element is inactive, the green color means that the element (machine) is productive. The dark blue color means that the element is waiting for labor and the light blue means that there is a preparing time slot. From this, it can be concluded, that the Assembly point and the Unload point are potential bottlenecks because in these points the biggest processing time is calculated for the simulation case.

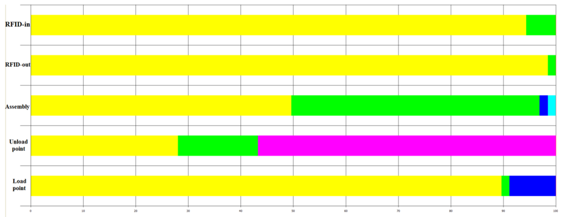

Figure 4: Statistics of Active Elements of Cell 2.

5 RFID-ARDUINO-APPLICATION

To show the practicability of such a logistic cell, the model is mirrored in a physical Internet of Things (IoT) device in form of an Arduino micro-controller board which is attached to an RFID-Reader, together with a model-warehouse / forklift truck unit. Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards can ”read” inputs and turn it into an output (Arduino, 2020) as they consist of an Input / Output (IO) system together with a calculation unit, which can be also regarded as a basic cybernetics system.

5.1 Model

For the demonstration and for educational purposes a practical model has been implemented. The model of the here described logistic cell consists of a board, made from a plywood sheet, a forklift truck, an Arduino microcontroller board, an end-stop-switch, and an RFID-Reader (q.v. Figure 5).

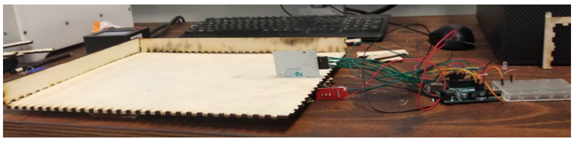

Figure 5: Set Up of the Model; The End-Stop-Switch is Situated Under the Plywood Plate, on the Left Side of the Entrance. The Entrance Ramp is not Mounted in this Picture yet as in Figure 6.

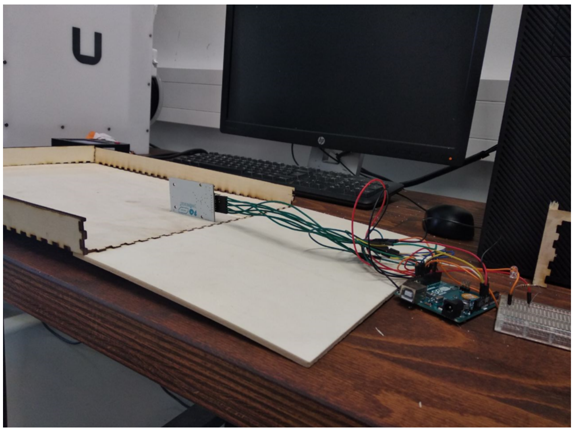

Figure 6: Model of the Logistic Cell.

The plywood board has the function of a cell, where goods are coming in or going out. It consists of a few plywood sheets, which were cut out by a laser cutter and connected. A forklift truck is a transporter, which delivers goods in and out of the cell. For this model, a toy forklift truck was used (q.v. Figures 8 and 9). For this model, it was chosen an Arduino-Uno as the most popular, cheap, and easy-to-use micro-controller-board, the RFID-Reader model MAKEVMA405 and a (simple) mechanical end-stop switch to register, together with the Arduino-Uno, whether a forklift truck is coming in or going out.

5.2 Arduino-hardware Set-up

The scheme, how the RFID-Reader was connected to the Arduino-board is shown in Figure 7.

The Light Emitting Diode (LED) was connected to the Arduino-board using a breadboard. To determine, whether the forklift is going in or out of the

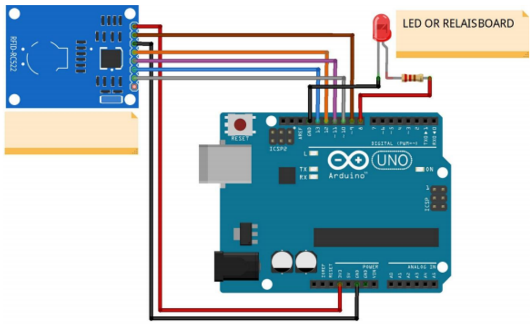

Figure 7: Scheme of the Connection of the RFID-Reader MakeVMA405 to the Arduino Uno.

cell, a ramp was separated into two equal parts, one of them can move up and down and the second is strongly connected. Under the first part the end-stop switch was installed (q.v. Figures 5 and 6).

The forklift is loaded with a pallet and a package of goods, which have an RFID-chip inside. When it is entering a warehouse, it is pushing an end-stop switch and going near the RFID-Reader. It reads then information from the chip and shows it on the computer-screen, as well as the message ”Incoming” in the Arduino IDE monitor port, which means, that the forklift is going in. When a forklift is going out, it is going near the backside of the RFID-Reader and through the strongly connected part of the ramp. In this case, the end-stop switch will not be pushed, so, the message on the screen will be ”outgoing”. The process of ”ingoing” and ”outgoing” of a forklift as well as screen-shots from the monitor screen are shown in Figure 8 and Figure 9. For a demonstration of warehouse work, the LED was added. According to the program code, given in the APPENDIX, it is on during the forklift is in the warehouse and is out, when it leaves.

6 CONCLUSIONS, SUMMARY, AND OUTLOOK

This work tries to bridge the gap of modeling a complex industrial large scale logistic process, with a basic cell, that can be combined to simulate this network. Additionally, an essential upgrade to yield a basic IoT-system is done, as this is an inner closing from material logistic processes to informational computer systems. In this work, only a basic logistic cell is shown with a basic IoT-system.

First, a general logistic cell was developed, that is applicable for a variety of applications. It shows the properties of being autonomous and scalable. The simulation was done with Witness, and the first results were shown, for this basic process, as well as for the model, that can be used in educational environments, for immediately showing the functionality of the logistic cell, and its IoT application connected with the RFID-Reading process, associated with the material, energetic and informational transport process.

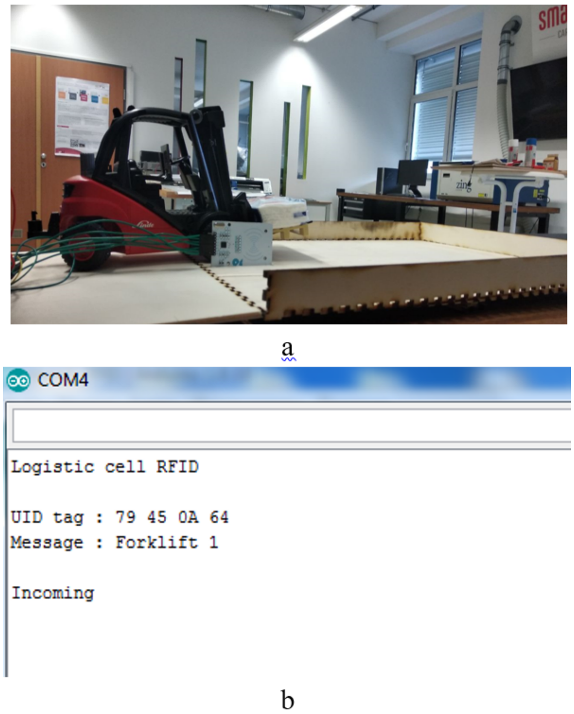

Figure 8: Incoming of a Forklift: Model (a) and Arduino Monitor Screenshot (b).

Future work has also to investigate, what does it mean to scale up the model in times of computation time, and also overall realistic predictions of the logistic process. Another point is that the model shall be used in an educational context to make sensible for the increasing necessity of IoT-applications as well as interconnected computer simulations. This offers a wide variety of possibilities in the educational as well as the industrial context.

Future research applications shall also implement decision processes, that shall be done e.g. by the Artificial Intelligence (AI) - language PROLOG (q.v. (Sterling and Shapiro, 1994)), in combination with Witness. Utilizing this approach real-time decision models shall be simulated conveniently. This would account for the increasing necessity of agent-based decisions (García-García et al., 2020) that could be implemented with this method. Another branch of investigations is aiming at large scale networks, and their applicability concerning modeling accuracy, optimization, and program performance. Finally, the

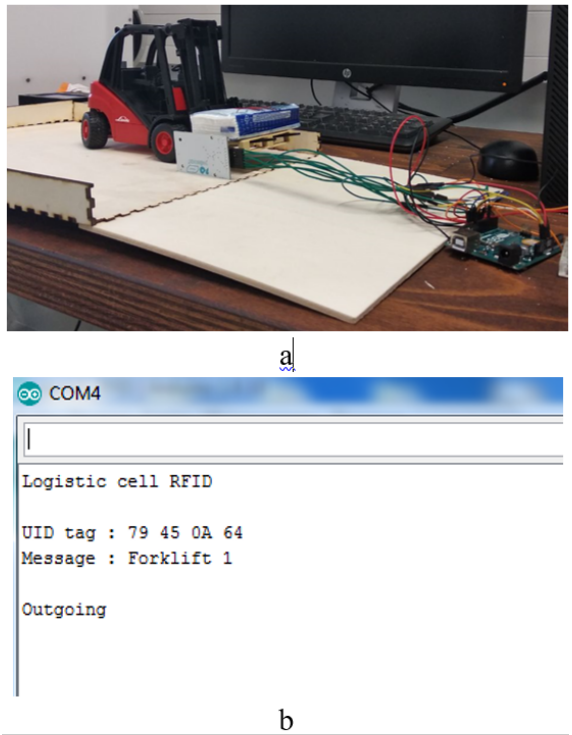

Figure 9: Outgoing of a Forklift: Model (a) and Arduino Monitor Screenshot (b).

research question is open, in which IoT-systems can enhance the systems adequately to yield higher order systems, leading e.g. to better performance, reliability and prediction accuracy.

INDEX

Symbol / Name	*Description*
AI	. . . Artificial Intelligence
Arduino	. . . Micro-Controller
BDE	. . . Operational Data Retrieval
ERP	. . . Enterprise Resource Planning
IO	. . . Input / Output System
IoT	. . . Internet of Things
LED	. . . Light Emitting Diode
MEI	. . . Material, Energy, Information
MES	. . . Management Execution Systems
PROLOG	. . . AI Computer Language
RFID	. . . Radio Frequency Identification
Witness	. . . Production Process Simulation Software

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APPENDIX - ARDUINO PROGRAM CODE

```
#include <SPI.h>
#include <MFRC522.h>
#define SS_PIN 10
#define RST_PIN 9
int endstop_x = 4;
int led = 8;
MFRC522 mfrc522(SS_PIN, RST_PIN);
  void setup()
    {
    Serial.begin(9600);
    SPI.begin();
    mfrc522.PCD_Init();
    Serial.println("Approximate your card to the reader...");
    Serial.println();
      pinMode(led, OUTPUT);
    }
  void loop()
    {
       if ( ! mfrc522.PICC_IsNewCardPresent())
      {
        return;
      }
       if ( ! mfrc522.PICC_ReadCardSerial())
      {
        return;
      }
    Serial.print("UID tag :");
        //  "UID TeTa: "
      String content= "";
      byte letter;
      for (byte i = 0; i < mfrc522.uid.size; i++)
      {
         Serial.print(mfrc522.uid.uidByte[i] < 0x10 ? " 0" : " ");
         Serial.print(mfrc522.uid.uidByte[i], HEX);
```

```
        content.concat(String(mfrc522.uid.uidByte[i] < 0x10 ? " 0" : " "));
        content.concat(String(mfrc522.uid.uidByte[i], HEX));
    }
    Serial.println();
    Serial.print("Message : ");
    content.toUpperCase();
   if (content.substring(1) == "79 45 0A 64")
    {
      Serial.println("Gabelstapler 1");
      Serial.println();
      delay(3000);
    }
   else   {
      Serial.println(" Access denied");
      delay(3000);
    }
   if (digitalRead(endstop_x)==0){
        Serial.print("Incoming");
        digitalWrite(led, HIGH);
        // delay(10);
      }
    else{
         Serial.print("Outgoing");
         digitalWrite(led, LOW);
         //delay(10);
      }
  }
```