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# An Extended Pi-calculus for Distributed Communication and Its Abstract Machine

Hiroyuki Fukuda (010098)

School of Information Science,
Japan Advanced Institute of Science and Technology

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## 1 Introduction

These days,the pi-caluclus attracts attention as a computing model of a concurrent programming language. The pi-calculus was presented by Milner,Parrow,and Walker in 1990.This computing model formalizes communication along the channel between the concurrent processes,and allowing channels to be passed as data along other channels introduces an element of mobility,enabling the specification and verification of concurrent systems with dynamically evolving communication topologies.Moreover,channel mobility leads to a surprising increase in expressive power,yielding a calculus capable of discribing a wide variety of high-level concurrent features while retaining a simple semantics and tractable algebraic theory.

On the other hand,a similar combination of simplicity and expressiveness has made the $\lambda$-calculus both a popular object of theoritical investigation and an attractive basis for sequential and functional programming language design.By analogy,then,one may wonder what kind of high-level programming language can be constructed from the pi-calculus.By such motivation,there is Pict as a programming language designed experimentally to explore the state of the programming language based on the pi-calculus.

Pict was developed by Pierce and Turner from 1992.Pict uses communication as an only mechanism of computation,and can be called a programming language based on the pi-calculus purely.A number of programming language designs have combined pi-calculus-like communication with a functional core language,and Pict differ greatly at the point from them.Pict adopts the abstract machine which Turner proposed,and implements efficiently communication along the channel which is a foundamental computing mechanism in the pi-calculus.However,the abstract machine of Turner realizes communication in only local environment,implementation to distributed environment is future research subject.

Then,in this research,the operational semantics of the pi-calculus is considered,it shows clearly what problem arises when implemented to distributed environment,and the solution method is explored.And I propose the computing model which can be implemented to distributed environment by extending the pi-calculus,and try to implement the computing model by extending the abstract machine of Turner.

The effect of this reserch will enable us to verify correctness and safety of distributed applications which grow up to be large and complex these days.Because a design for programming language based on a computing model can give mathamatical basis for meaning of programs described in the programming language.By this,we can prove the characteristic of behavior of a program,and it improves reliability of programs.Therefore,the reserch to the basic theory of a program will increase the importance increasingly from now on. Especially,the basic theory of distributed and concurrent programming languages are not enough yet,and it is a future important research subject.

## 2 Extention for Distributed Communication

The important thing for implementation of the pi-calculus is how to implement communication which is the fundamental computing mechanism efficiently.In the pi-calculus, communication is defined as follows.

$$x!a.P|x?(y).Q \to P|\{a/y\}Q$$

In this reduction,when the input process and output process for the same channel appear,it means that sending and receiving a value or a channel are performed.Here,I supporse to implement this reduction to distributed environment.This reduction depends on two states of input process and output process as it is seen. When these two processes exist in the different site,in order to communicate,it is necessary to grasp the state of two sites.There were an unspecified number of sites on distributed environment ,and the sites are dynamically runed and stoped,including temporary sites,it is difficult to grasp all these states. That is,it can be said that it is impossible to implement the above reduction to distributed environment efficiently. Then,I introduce the mechanism of synchronous communication,and four reductions (RCOM1,RCOM2,RCOM3,RETURN) independent of the state of other sites realize distributed communication. By this,the communication along the channel can be limited in a certain site,and the characteristic of the pi-calculus is left as it is.

## 3 Conclusion

The conclusion of this research is as follows.

- I could propose the computing model which can be implemented to distributed environment and has the characteristic of the pi-calculus as it is by introducing the mechanism of synchronous communication.
- Distributed communication can be clearly formalized now by the extended Pi-calculus.
- Implementation of the extended pi-calculus was given by extending the abstract machine of Turner.

- I could implement the programming language system based on the extended pi-calculus which we can describe distributed communication easily and flexiblibly.
- I could give the base of experiments after this research by actually implementing the programming language system based on the extended pi-calculus to distributed environment.