On Mobility and Communication

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Abstract

By imposing three semantic constraints on the -calculus equipped with delayed input, we obtain a variant of the -calculus. We prove that Hennessy and Riely's distributed -calculus can be encoded into this new model, satisfying a full abstraction theorem, which means that one-dimensional mobility can be characterized by communication. We also discuss the di culties of expressing two-dimensional mobility, the mechanism used by ambient calculi.

Key words: mobility, communication, distributed -calculus, delayed input

1 Introduction

In the community of process algebra, there exist di erent kinds of strategies for controlling resource access, which entail di erent models for describing concurrency and mobility. For example, in the standard -calculus [8], the restriction operator can be considered as a tool of limiting names for local use. In distributed -calculus (D) [6], location is introduced to realize this function, since processes in di erent locations are not able to interact with each other directly. In mobile ambients [4], every ambient has a boundary which distinguishes interior processes from exterior ones.

But all those controlled resources are not isolated. To describe mobile systems, i.e., systems with a dynamically changing linkage topology, each model must provide a mechanism to allow resources to extrude their original scope so as to be used by processes outside the scope. For instance, in the -calculus, the following reduction relation holds.

(1) $(b)(ab:P|Q)|a(x):R \longrightarrow (b)(P|Q|R\{b=x\})$

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The private name b, which is previously shared by $a\langle b\rangle:P$ and Q, is transmitted along a. As a consequence, the scope of b is extended to $R\{b=x\}$. Consider the following example from D :

(2) $l[\mathtt{go}\ k:a\langle b\rangle:P|Q]|k[a(x):R] \longrightarrow l[Q]|k[a\langle b\rangle:P]|k[a(x):R]$
(3) $\longrightarrow l[Q]|k[P|R\{b=x\}]$

After the first step of reduction, the agent $a\langle b\rangle:P$ moves from one location to another, say from l to k. Then it can communicate with $a(x):R$ which stays in location k. In mobile ambients, mobility paves the way for one ambient to enter the range of another. A typical example is given below:

(4) $n[\mathtt{in}\ m:\langle b\rangle:P|Q]|m[\mathtt{open}\ n:(x):R] \longrightarrow m[n[\langle b\rangle:P|Q]|\mathtt{open}\ n:(x):R]$
(5) $\longrightarrow m[\langle b\rangle:P|Q|(x):R]$
(6) $\longrightarrow m[P|Q|R\{b=x\}]$

To send the name b to process R, ambient n has to enter the domain of m, be opened and then communicate with $x()$:R.

In example (1), only communication happens. In the next two examples, both mobility and communication take place. A careful observation reveals that (2) and (4) use different sorts of mobility, which we call one-dimensional mobility and two-dimensional mobility respectively. In (2), all locations are always located on the same level, no location nesting being permitted, while in (4), ambient n becomes a subambient of m after its movement.

In this paper, we will show that one-dimensional mobility can be characterized by communication if we use the semantics of delayed input [10,7]. Such a delayed input prefix, written $a(x) : P$, allows the continuation P to evolve underneath the input guard, except for observable actions related to x. Hence, it allows more parallelism in processes. However, the sequentialization forced by the ordinary prefix is useful for expressing the behaviors of many concurrent systems. So in this paper, instead of replacing one with the other, we keep both operators, with the requirement that the delayed input only possesses a part of its functions under the ordinary meaning. First, we give a restricted form of the π-calculus with delayed input ($_{\mathrm{DI}}$), called $_{\mathrm{rdi}}$. It is obtained by allowing only a portion of the legal operations in ordinary semantics of delayed input. In other words, if we use $\mathcal{S}_1$ and $\mathcal{S}_2$ to stand respectively for all legal operations in $_{\mathrm{rdi}}$ and $_{\mathrm{DI}}$, then $\mathcal{S}_1$ is actually a subset of $\mathcal{S}_2$. Then we give an encoding of D into $_{\mathrm{rdi}}$. So the reductions in example (2) will be simulated as follows:

(7) $l : l:k : ab\langle k\rangle:\langle\!\langle P\rangle\!\rangle^k|\langle\!\langle Q\rangle\!\rangle^l|k : a(x):k:\langle\!\langle R\rangle\!\rangle^k$
(8) $\longrightarrow k : ab\langle k\rangle:\langle\!\langle P\rangle\!\rangle^k|\langle\!\langle Q\rangle\!\rangle^l|k : a(x):k:\langle\!\langle R\rangle\!\rangle^k$
(9) $\longrightarrow k : k:\langle\!\langle P\rangle\!\rangle^k|\langle\!\langle Q\rangle\!\rangle^l|k : k:\langle\!\langle R\rangle\!\rangle^k\{b=x\}$
(10) $\longrightarrow^2 \langle\!\langle P\rangle\!\rangle^k|\langle\!\langle Q\rangle\!\rangle^l|\langle\!\langle R\rangle\!\rangle^k\{b=x\}$
(11) $\equiv \langle\!\langle Q\rangle\!\rangle^l|\langle\!\langle P|R\{b=x\}\rangle\!\rangle^k$

where l and k are abbreviations of $l(y)$ and $k(z)$ respectively, for some y and