

**istgame:**

## **Drawing Extensive Game Trees with TikZ**

2016 한국텍학회 학술대회

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# Introduction

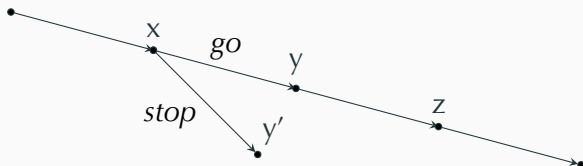
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# 전개형 게임

- 전개형 게임 (extensive games)
  - 순차진행게임 (sequential move games)
  - directed graph
    - ↪ game tree
- 구성 요소
  - players
  - whose turn it is to move
  - possible actions
  - information structures
  - payoffs

# 게임 트리

- 게임 트리: **마디**와 **가지**로 구성
  - 마디 (node, vertex, point): 의사결정 시점
    - decision nodes (initial node 또는 root 포함)
    - terminal nodes에 payoffs 표시
  - 가지 (branch, edge): 선택 가능 행동

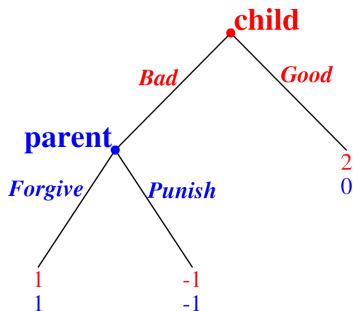


# Motivation

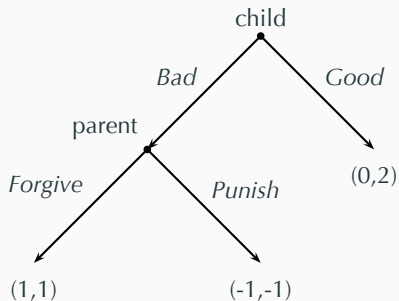
- 게임 트리 그리기: 직관적으로 쉽게
  - '그림' 그리기와 무엇이 다른가
  - **생각의 흐름**과 같은가
- **재활용**은 쉬운가
  - copy and paste  $\rightsquigarrow$  읽기는 쉬운가
  - 변형은 쉬운가
- **컴파일** 문제
  - pstricks와 xelatex
- **how often**
  - 소수의 게임 트리 그리기
  - 반복하여 다수의 게임 트리 그리기

# 게임 트리 그리기: 몇 가지 대안

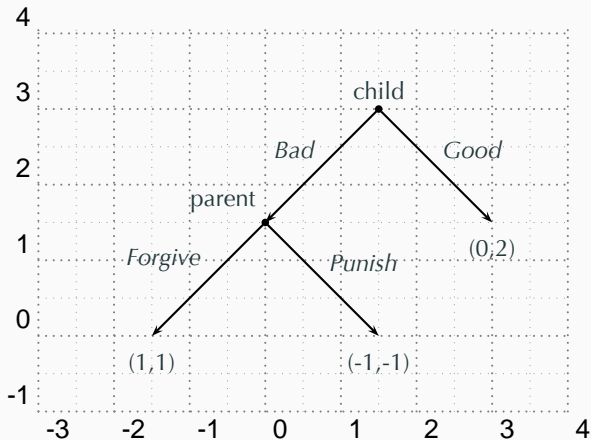
- 외부 그래픽 툴로 그려서  
`\includegraphics`로 불러들이기  
 예: Game Theory Explorer  
 (<http://gte.csc.liv.ac.uk/gte/builder/>)
- egameps 패키지. pstricks 기반  
 Osborne(2004b)
- tikz 패키지/tikzpicture 환경  
 Chen(2013)



# 간단한 게임: parent-child game



## egameps 패키지 / egame 환경

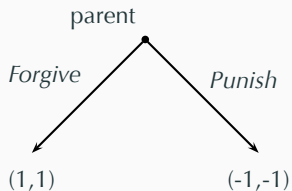




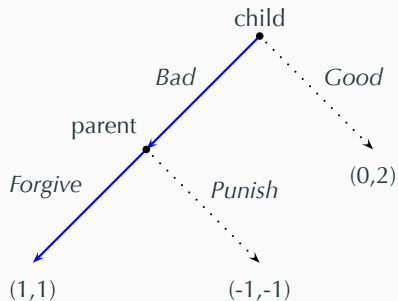
# 간단한 게임: egameps 패키지

```
% \usepackage{pstricks, egameps}
\begin{e game}(-150,0) (300,350)
\footnotesize
\renewcommand{\egarrowstyle}{e}
\initialfalse
%\putbranch(150,300) (1,1){150}
%\iib{child}{$Bad$}{$Good$} [] [(0,2)]
\putbranch(0,150) (1,1){150}
\iib{parent}[1]{$Forgive$}{$Punish$} [(1,1)] [(-1,-1)]
\end{e game}
```

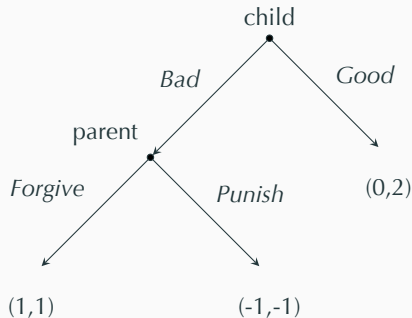
# 간단한 게임: 변형



# 간단한 게임: 변형



# 간단한 게임: tikzpicture



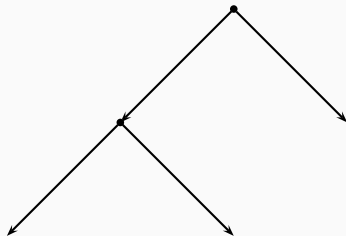
# 간단한 게임: tikzpicture

```

\begin{tikzpicture}[>=stealth,font=\footnotesize]
\tikzstyle{level 1}
  =[level distance=15mm,sibling distance=30mm]
\node(0)[solid node,label=above:{child}]{}
child{ node[solid node,label=above left:{parent}]{}
  child{node[label=below:{{(1,1)}}]{} edge from
    parent [->] node[above left]{$Forgive$}}
  child{node[label=below:{{(-1,-1)}}]{} edge from
    parent [->] node[above right]{$Punish$}}
  edge from parent [->] node[above left]{$Bad$}
}
child{ node[label=below:{{(0,2)}}]{}
  edge from parent [->] node[above right]{$Good$}
};
\end{tikzpicture}

```

# 트리 구조 비교



## 트리 구조: egameps 패키지

```
%\usepackage{egameps} %% 간단한 게임
\begin{egame}(-150,0)(300,350)
\renewcommand{\egarrowstyle}{e}
\initialfalse
\putbranch(150,300)(1,1){150}
  \iib{}{}{}
\putbranch(0,150)(1,1){150}
  \iib{}{}{}
\end{egame}\hspace*{\fill}
```

# 트리 구조: tikz 패키지

```
%\usepackage{tikz} %% 간단한 게임
\begin{tikzpicture}[->,>=stealth]
\tikzstyle{level 1}
    =[level distance=15mm,sibling distance=30mm]
\node(0)[solid node]{}
child{ node[solid node]{}
    child
    child
    }
child
;
\end{tikzpicture}
```



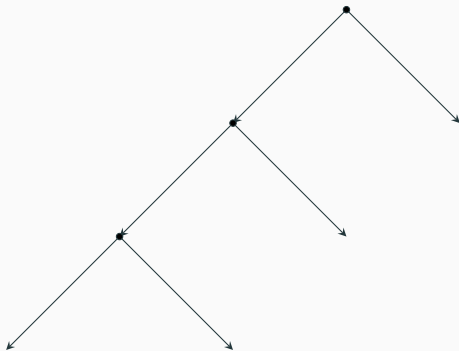
# 트리 구조: istgame 패키지

```
%\usepackage{istgame} %% 간단한 게임
\begin{istgame}[->,>=stealth]
\xdistance{15mm}{30mm}
\istroot(0)
  \istb
  \istb
\endist
\istroot(1)(0-1)
  \istb
  \istb
\endist
\end{istgame}
```

# egameps → tikz → istgame

- 게임 분석자에게 `egameps`가 `tikzpicture` 보다 편리하다.
  - `tikzpicture`의 트리 기능의 **생각의 흐름** 때문이다.
  - 당연한 결과: `pstricks`를 기반으로 한 `egameps`
- 문제는, `pstricks`의 `xelatex` **컴파일 시간**
- 이제 `tikz` 만을 고려하기로 하자.
- 왜 `istgame`인가?
  - `pstricks`  $\rightsquigarrow$  `egameps`
  - `tikz`  $\rightsquigarrow$  `istgame`
  - 조금 더 복잡한 게임을 보자.

# 조금 더 복잡한 게임



## 조금 더 복잡한 게임: istgame

```
\begin{istgame}[->,>=stealth]
\xdistance{15mm}{30mm}
\istroot(0)
  \istb
  \istb
\endist
\istroot(1)(0-1)
  \istb
  \istb
\endist
\istroot(2)(1-1)
  \istb
  \istb
\endist
\end{istgame}
```

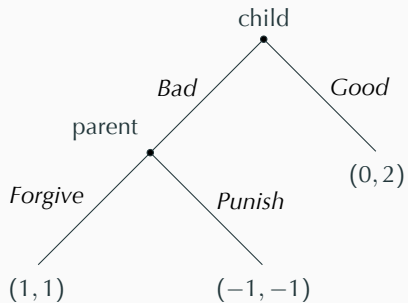
## 조금 더 복잡한 게임: tikzpicture

```
\begin{tikzpicture}[->,>=stealth]
\begin{tikzstyle}{level 1}
    =[level distance=15mm,sibling distance=30mm]
\node(0)[solid node]{}
child{
  child{
    child
    child
  }
  child
}
child
;
\end{tikzpicture}
```

# From tikzpicture to istgame

- 자연스러운 생각의 흐름을 따라 그릴 수 있다.
- 재활용 및 분석도 간단하게
  - subgames
  - 분석을 위한 장식(style, 색깔 등)
  - 변형(방향 등)
- label 붙이기도 간단하게
  - owners, action labels, payoffs
  - information sets

# istgame 패키지



# istgame: structure only

```
\begin{istgame}  
\xdistance{15mm}{30mm}  
\istroot(0)  
  \istb  
  \istb  
  \endist  
\istroot(1)(0-1)  
  \istb  
  \istb  
  \endist  
\end{istgame}
```



# istgame: full code

```
\begin{istgame}[font=\footnotesize]
\xdistance{15mm}{30mm}
\istroot(0){child}
  \istb{Bad}[al]
  \istb{Good}[ar]{(0,2)}
\endist
\istroot(1)(0-1)<135>{parent}
  \istb{Forgive}[al]{(1,1)}
  \istb{Punish}[ar]{(-1,-1)}
\endist
\end{istgame}
```

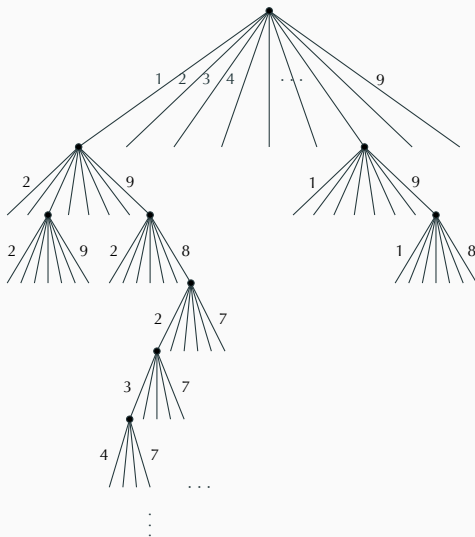
## tikzpicture 환경

```

\begin{tikzpicture}[font=\footnotesize]
\tikzstyle{level 1}
  =[level distance=15mm,sibling distance=30mm]
\node(0)[solid node,label=above:{child}]{}
child{ node[solid node,label=above left:{parent}]{}
  child{node[label=below:{{(1,1)}}}{}
    edge from parent  node[above left]{$Forgive$}}
  child{node[label=below:{{(-1,-1)}}}{}
    edge from parent  node[above right]{$Punish$}}
  edge from parent  node[above left]{$Bad$}
}
child{ node[label=below:{{(0,2)}}}{}
  edge from parent  node[above right]{$Good$}
};
\end{tikzpicture}

```

# 조금 더 복잡한 게임...



```

\begin{istgame}[font=\tiny]
\xdistance{20mm}{7mm}
\istroot(0) \istb \istb \istb \istb \istb
  \istb{\dots} \istb \istb \istb{9}[r] \endist
\foreach \x in {1,...,4}
{\xActionLabel(0)(0-\x){\x}[1]}
\xdistance{10mm}{3mm}
\istroot(a1)(0-1) \istb{2}[1] \istb \istb \istb
  \istb \istb \istb \istb{9}[r] \endist
\istroot(a7)(0-7) \istb{1}[1] \istb \istb \istb
  \istb \istb \istb \istb{9}[r] \endist
\xdistance{10mm}{2mm}
\istroot(A)(a1-3) \istb{2}[1] \istb \istb \istb
  \istb \istb \istb{9}[r] \endist
\istroot(B)(a1-8) \istb{2}[1] \istb \istb \istb
  \istb \istb \istb{8}[r] \endist
\istroot(C)(a7-8) \istb{1}[1] \istb \istb \istb
  \istb \istb \istb{8}[r] \endist
\istroot(Bx)(B-7) \istb{2}[1] \istb \istb \istb
  \istb \istb{7}[r] \endist
\istroot(By)(Bx-1) \istb{3}[1] \istb \istb \istb
  \istb{7}[r] \endist
\istroot(Bz)(By-1) \istb{4}[1] \istb \istb
  \istb{7}[r] \endist
\xPayoff(Bz-4){\vdots}
\xPayoff(Bz-4){\cdots}[xshift=10pt,right]
\end{istgame}

```

**istgame**

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# istgame 패키지

- `\usepackage{istgame}`
  - `expl3`, `xparse`, `tikz`를 불러들임
  - `\usetikzlibrary{calc,shapes}`
- 간단한 **기본 구조**를 반복하여 트리 완성

`\begin{istgame}`

- `xdistance`
- `istroot - istb - endist`
- `istroot - istb - endist`
- ...

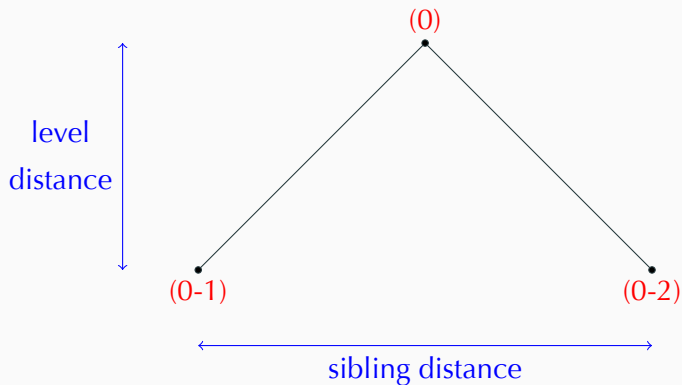
`\end{istgame}`

# istgame 환경

```
%% \usepackage{istgame}  
\begin{istgame}  
\xdistance{15mm}{30mm}  
\istroot(0)  
  \istb  
  \istb  
  \endist  
\end{istgame}
```

# \xdistance

```
\xdistance[<level>]{<level dist>}{<sibling dist>}
```





# \istroot

Syntax:

```
\istroot[grow](coor)(coor)[node style]<angle>{owner}
      +level distance..sibling distance+
```

Options:

```
[grow]           % 방향 <default: south>
(coor)           % 노드 이름: mandatory
(coor)           % 노드 위치 <default: (0,0)>
[node style]    % 노드 모양 <default: decision node>
<angle>          % owner 이름 위치 <default: above>
{owner}         % owner 이름
+level dist..sibling dist+ % <defaults: 15mm,15mm>
```

# \istb

Syntax:

```
\istb<grow,dist>[line style]{action}[pos]{payoff}[pos]
```

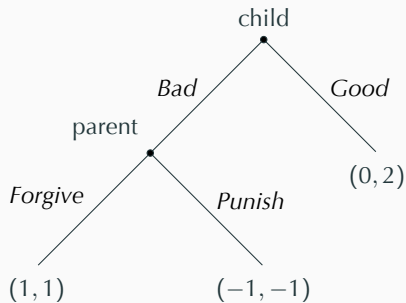
Options:

```

<grow,dist> % grow=south(default), 개별 branch 방향
             % level distance=15mm, sibling distance=15mm
             % missing (branch 안보이게, child 좌표 부여 안됨)
[line style] % ->, thick, red, dotted...
{action}     % action 이름 (math mode)
[pos]        % 위치
{payoff}     % 보수 (payoffs) (math mode)
[pos]        % 위치

```

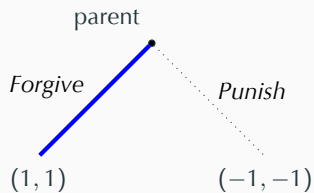
# 간단한 게임: Again



Next: 재활용과 분석

- subgame
- 게임의 분석을 위한 line style

# subgame and line styles



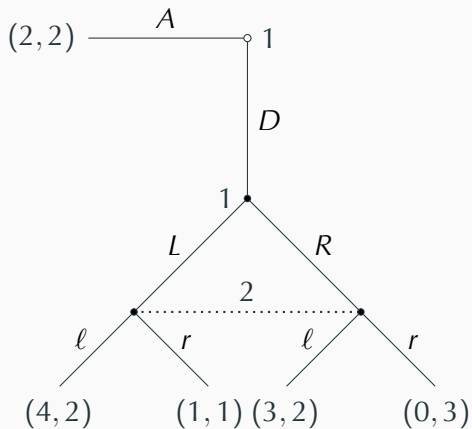
# subgame and line styles

```

\begin{istgame}[font=\footnotesize]
\xdistance{15mm}{30mm}
%\istroot(0){child}
% \istb{Bad}[al]
% \istb{Good}[ar]{(0,2)}
% \endist
\istroot(1)(0,0)<135>{parent} % subgame at (0,0)
%\istroot(1)(0-1)<135>{parent} % original
  \istb[ultra thick,blue]{Forgive}[al]{(1,1)} % line
  \istb[dotted]{Punish}[ar]{(-1,-1)} % line
\endist
\end{istgame}

```

## information sets



## information sets: \xInfoSet

```

\begin{istgame}
\xdistance{15mm}{30mm}
\istroot[-135](0)[initial node]<0>{1} % grow
  \istb{A}[a]{(2,2)}[1]  \istb{D}[r]          \endist
\istroot(1)(0-2)<left>{1}
  \istb{L}[al]          \istb{R}[ar]          \endist
\xInfoSet(1-1)(1-2){2}          % information set
\xdistance{10mm}{20mm}          % distances changed
\istroot(2)(1-1)
  \istb{\ell}[al]{(4,2)} \istb{r}[ar]{(1,1)} \endist
\istroot(3)(1-2)
  \istb{\ell}[al]{(3,2)} \istb{r}[ar]{(0,3)} \endist
\end{istgame}

```

## supplement macros: basics

```

\XInfoSet[line style](from)(to){owner}[pos,opt]
% \XInfoSet[dashed,red](0-1)(0-2){p2}[above,blue]
\XInfoSetOwner(from-coor)(to-coor){owner}[pos,opt]
% \XInfoSetOwner(0-1)(0-2){p2}[ar]
\XActionLabel(from-coor)(to-coor){action}[pos,opt]
% \XActionLabel(0)(0-1){\ell}[below,red] % math
\XOwner(coor){owner}[pos,node opt]
% \XActionLabel(0)(0-1){p1}[al]
\XPayoff(coor){payoff}[pos,node opt]
% \XPayoff(0-1){\pi,\xi}[al] % math mode
\XDot(coor)[node style,node opt]{owner}
% \XActionLabel(0)[box node,red]{child}

```

abbreviations for [pos]: [a] [b] [l] [r] [al] [ar] [bl] [br]



# node styles

`% predefined`

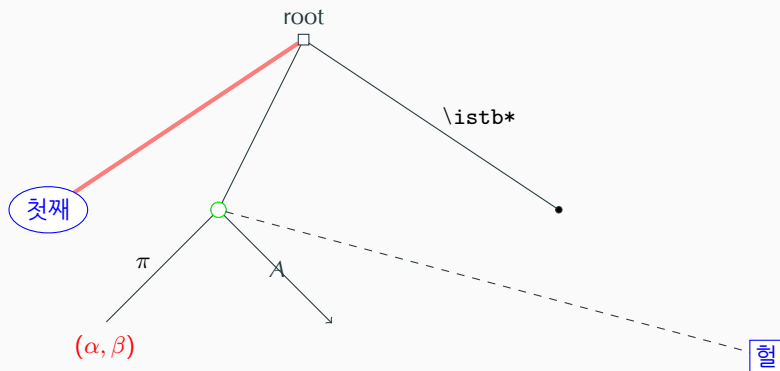
```
\tikzstyle{null node}=[white,  
    fill=white,inner sep=0pt,outer sep=0pt]  
\tikzstyle{hollow node}=[circle,  
    draw,fill=white,inner sep=.95,outer sep=0pt]  
\tikzstyle{solid node}=[circle,  
    draw,fill=black,inner sep=.85,outer sep=0pt]  
\tikzstyle{rectangle node}=[rectangle,  
    draw,fill=white,inner sep=2,outer sep=0pt]  
\tikzstyle{ellipse node}=[ellipse,  
    draw,fill=white,inner sep=2,outer sep=0pt]
```

# node styles

```
\tikzstyle{initial node}=[hollow node] % initial
\tikzstyle{decision node}=[solid node] % decision
\tikzstyle{terminal node}=[solid node] % terminal
\tikzstyle{chance node}=[hollow node] % chance node
\tikzstyle{square node}=[rectangle node]
\tikzstyle{box node}=[rectangle node]
\tikzstyle{oval node}=[ellipse node]
```

필요하면, 새로운 node style을 만들면 된다.

## variations



```
\istroot(1a)(0-2)[oval node,green]
```

```
\istb<grow=-15,level distance=50mm>[dashed]
```

```
\endist
```

# variations

```

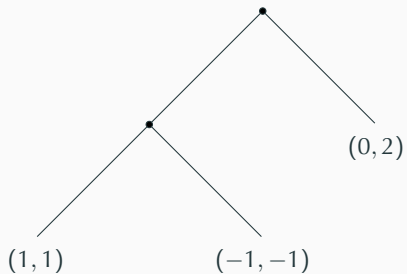
\begin{istgame}[scale=1.5,font=\footnotesize]
\xdistance{15mm}{15mm}
\istroot(0)[box node]{root} % box node
  \istb[ultra thick,opacity=.5,red] % opacity
  \istb
  \istb<missing> % missing
  \istb*{\text{\cmd{istb*}}}[ar] \endist % \istb*
\istroot(1)(0-2)[oval node]+10mm..20mm+ % dist
  \istb{\pi}[al]{(\alpha,\beta)}[below,red]
  \istb[->]{A} \endist
\istroot(1a)(0-2)[oval node,green] % 임의로 뺀 가지
  \istb<grow=-15,level distance=50mm>[dashed]\endist
\xDot(0-1)[oval node,blue]{첫째} % \xDot
\xDot(1a-1)[box node,blue]{헐} % \xDot
\end{istgame}

```

## **istgame: extended issues**

---

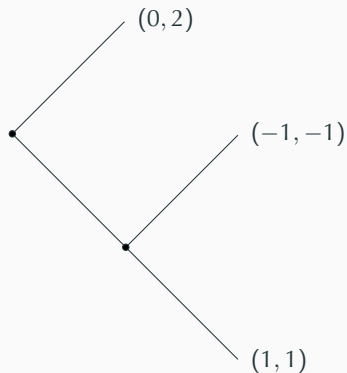
# 간단한 게임: `\istgrowdirection{south} : default`



## 간단한 게임: \setistgrowdirection

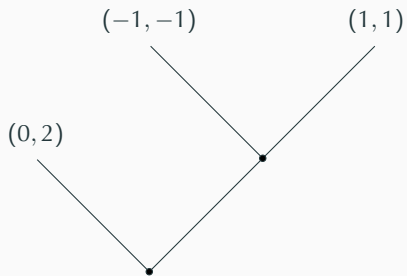
```
\begin{istgame}[font=\footnotesize]
%\setistgrowdirection{east} %% default: south
\xdistance{15mm}{30mm}
\istroot(0)
  \istb
  \istb{}{(0,2)}
\endist
\istroot(1)(0-1)
  \istb{}{(1,1)}
  \istb{}{(-1,-1)}
\endist
\end{istgame}
```

# 간단한 게임: `\setistgrowdirection{east}`

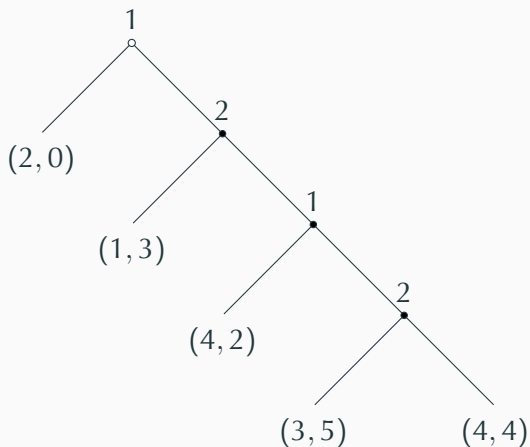




# 간단한 게임: `\setistgrowdirection{90}`



# centipede game: growing down

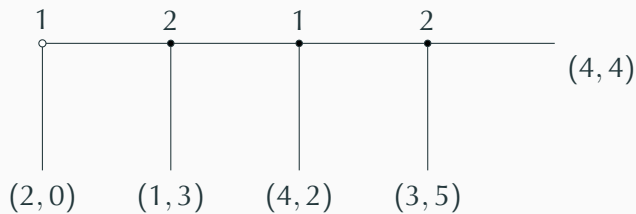


## centipede game: growing down

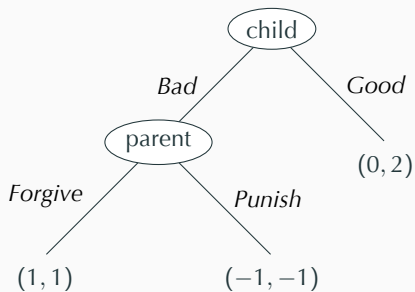
```

\begin{istgame}[scale=1.2]
%\setistgrowdirection{south east} % default: south
\xdistance{10mm}{20mm}
\istroot(0)[initial node]{1} % initial node
  \istb{}{(2,0)}[b] \istb{}[a] \endist
\istroot(1)(0-2){2}
  \istb{}{(1,3)}[b] \istb{}[a] \endist
\istroot(2)(1-2){1}
  \istb{}{(4,2)}[b] \istb{}[a] \endist
\istroot(3)(2-2){2}
  \istb{}{(3,5)}[b] \istb{}[a]{(4,4)} \endist
\end{istgame}

```

centipede game: `\setistgrowdirection{south east}`

```
\istroot*
```

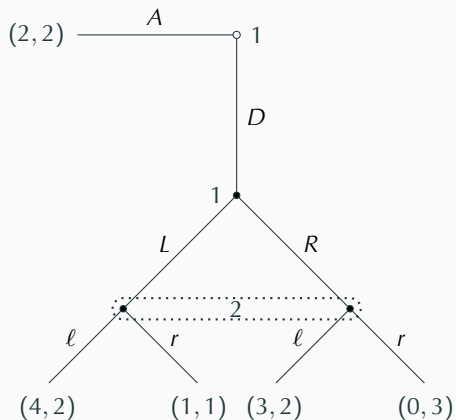


default node style: oval node

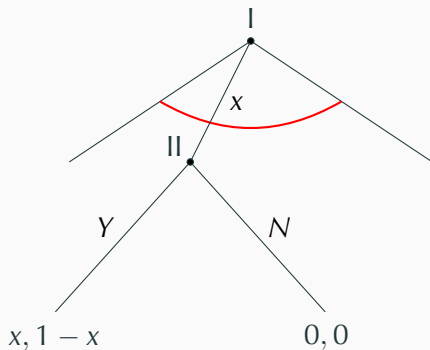
## \istroot\*

```
\begin{istgame}[font=\footnotesize]
\xdistance{15mm}{30mm}
\istroot*(0){child}           % starred version
  \istb{Bad}[al]
  \istb{Good}[ar]{(0,2)}
\endist
\istroot*(1)(0-1)<135>{parent} % starred version
  \istb{Forgive}[al]{(1,1)}
  \istb{Punish}[ar]{(-1,-1)}
\endist
\end{istgame}
```

## information sets: \xInfoSet\*



## ultimatum bargaining: \istcntm\*





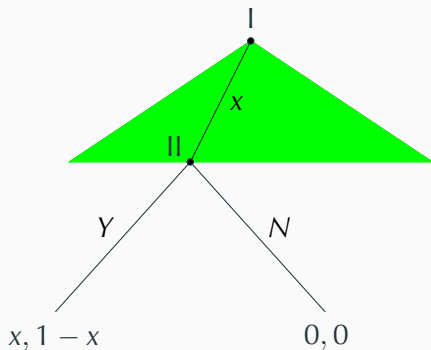
## ultimatum bargaining: \istcntm

```

\begin{istgame}[scale=2]
%\istcntm*(ctm)[thick,red]{.5}+8mm..24mm+    % (.5)
\istcntm(ctm)[green]+8mm..24mm+            % (black!25)
\istroot(0)(ctm){I}+8mm..8mm+
  \istb{x}[r]
  \istb<missing>
\endist
\xdistance{10mm}{18mm}
\istroot(1)(0-1)<[label distance=-3pt]120>{II}
  \istb{Y}[al]{x,1-x}
  \istb{N}[ar]{0,0}
\endist
\end{istgame}

```

## ultimatum bargaining: \istcntm



# miscellaneous macros: experimental

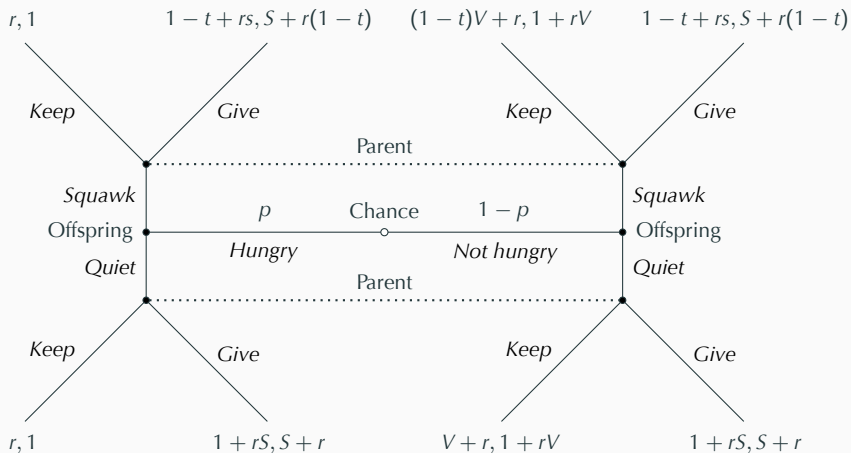
- `\ShowTerminalNodes`[node style]
  - `\ShowTerminalNodes` ... default: solid node
  - 예: `\ShowTerminalNodes`[box node]
- `\HideTerminalNodes`
- `\setistactionlabelshift`{x-shift}{y-shift}
  - for abbreviations [a], [b], [l], and [r]
- `\setistactionlabelposition`{x-shift}{y-shift}
  - for abbreviations [al], [ar], [bl], and [br]

For more details, `texdoc istgame`.

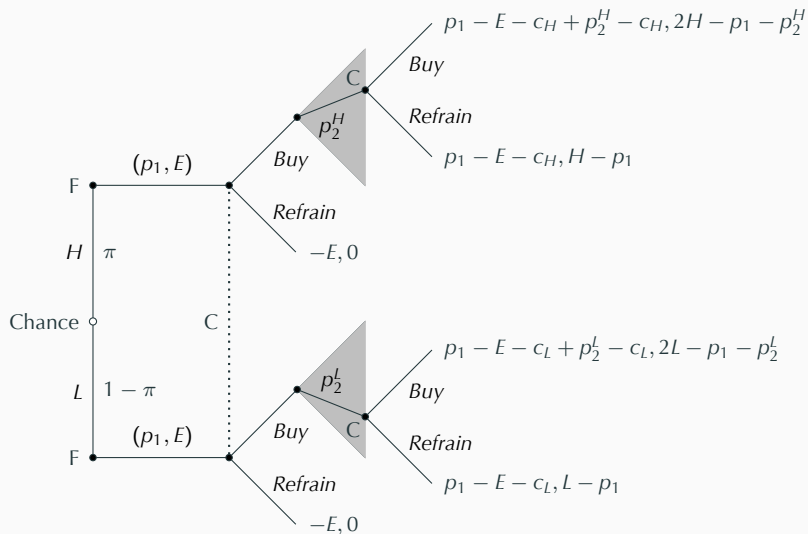
## Some examples

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## Osborne, IGT 336.1



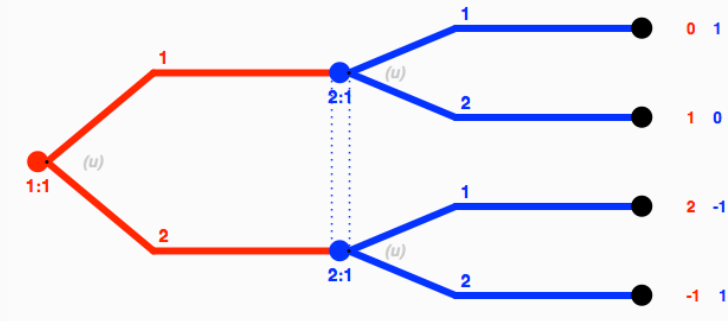
## Osborne, IGT 337.1



## Further Issues

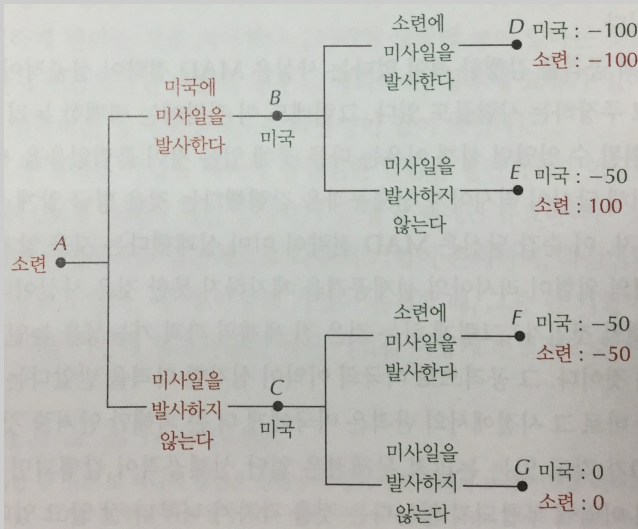
---

## branches: GAMBIT

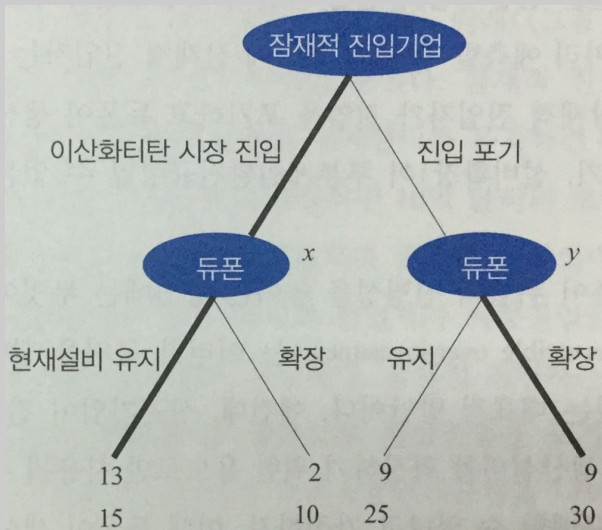




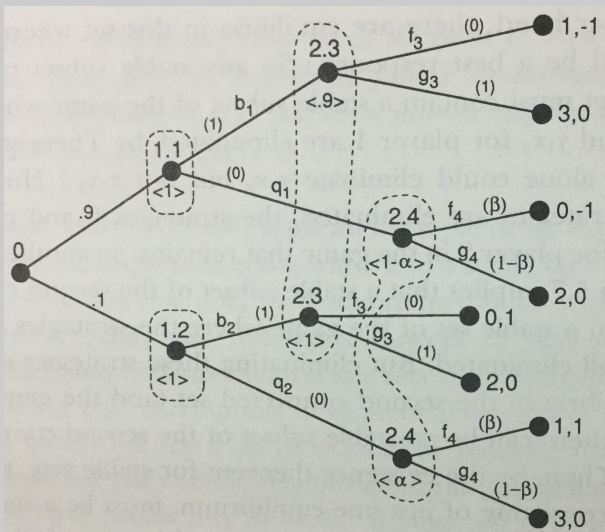
## branches: 홍인기 · 박창수 (2016), Frank



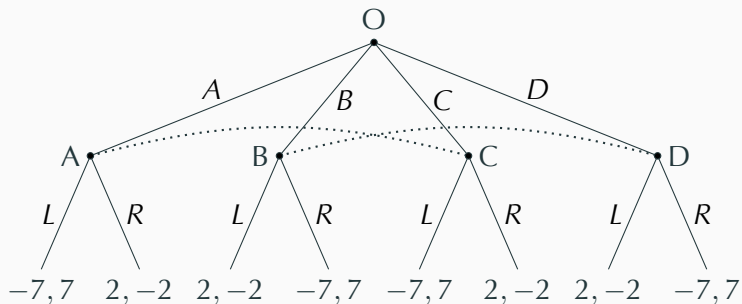
## \istroot\*: 김영세 (2016)



## \xInfoSet\*: Myerson (1991)



# \xInfoSet with options



```
\xInfoSet [out=10,in=170] (0-1) (0-3)
```

```
\xInfoSet [out=10,in=170] (0-2) (0-4)
```



`\istroot*`

`\xInfoSet*`

감사합니다

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